CHAPTER 4

RESULTS

The study of diversity of benthic diatoms during 2011-2012 for water quality index establishment of Wang River were investigated in October 2011 to September 2012. Samples were collected from 12 sampling sites in the Wang River and were taken from both running and standing water. The results were as follows.

4.1 Diversity of benthic diatoms

A total of two hundred and twenty species of benthic diatoms were collected from the Wang River of Thailand. These were classified into 3 classes, 5 subclasses, 12 orders, 25 families and 53 genera. The species list was classified systematically into categories and is shown in Table 11 and Figures 10-71. *Navicula* spp. was found to be present in the highest number (30 species), followed by *Nitzschia* spp. (29 species), *Gomphonema* spp. (15 species), *Sellaphora* spp. (11 species), *Achnanthidium* spp. (11 species), *Surirella* spp. (11 species) and *Cymbella* spp. (10 species), respectively.

4.1.1 Benthic diatom diversity in running water

A total of two hundred and thirteen species of benthic diatoms were recorded in the 10 sampling sites of the main river. The sampling sites were numbered 1, 2, 4, 5, 7, 8, 9, 10, 11 and 12. The most abundant species found in the running water were *Nitzschia palea* (Kützing) W. Smith, *Achnanthidium minutissimum* (Kützing) Czarnecki, *Seminavis strigosa* (Hustedt) Danieledis & Economou-Amilli in D.B. Danielidis & D.G. Mann, *Achnanthidium exile* (Kützing) Heiberg, *Cocconeis placentula* Ehrenberg, *Cymbella affinis* Kützing, *Cymbella* cf. *bifurcumstigma* Nakkaew, Peerapornpisal and Mayama, sp. nov, *Cymbella parva* (W.Smith) Kirchner, *Cymbella turgidula* Grunow, *Delicata* cf. *sparsistriata* K.Krammer, *Encyonema malaysianum* Krammer, *Encyonopsis leei* K.Krammer, *Encyonopsis microcephala* **(**Grunow) Kramm, *Gomphonema auritum* A.Braun ex Kützing, *Gomphonema parvulum* (Kützing) Kützing, *Gomphonema pumilum* (Grunow) E.Reichardt &Lange-Bertalot, *Planothidium frequentissimum* (Lange-Bertalot) Round &

L.Bukhtiyarova, *Navicula cf. aquaedurae* Lange-Bertalot, *Navicula cf. leistikowii* Lange-Bertalot, *Navicula simulata* Manguin, *Navicula suprinii* Gerd Moser, *Nitzschia gracilis* Hantzsch, *Nitzschia recta* Hantzsch ex Rabenhorst and *Nitzschia ruttneri* Hustedt, and there were 102 species of benthic diatoms recorded from the main river sampling sites, which was found to be significantly different from the number of species that were recorded at the standing water sites (Table 11 and Figure 7).

4.1.2 Benthic diatom diversity in standing water

L.Bukhtiyarova, *Navicula* cf. *aquaedurae* Lange-Bertalot, *Navicula* cf. *leistikowii* Lange-Bertalot, *Navicula simulata* Manguin, *Navicula suprinii* Gerd Moser, *Nitzschia gracilis* Hantzsch, *Nitzschia recta* Hantzsch ex Rabenhorst and *Nitzschia ruttneri* Hustedt, and there were 102 species of benthic diatoms recorded from the main river sampling sites, which was found to be significantly different from the number of species that were recorded at the standing water sites (Table 11 and Figure 8).

4.1.2 Benthic diatom diversity in standing water

Two reservoirs of the Wang River, specifically those formed by the Kiew Lom Dam and the Kiew Kor Ma Dam, were the locations of two of the sampling sites in this study, numbered 3 and 6, respectively. A total of one hundred and nineteen species of benthic diatoms were found in the standing water. The most abundant species recorded in the standing water were *Achnanthidium minutissimum* (Kützing) Czarnecki, *Achnanthidium exile* (Kützing) Heiberg, *Kobayasiella* sp.1, *Aulacoseira granulata* (Ehrenberg) Simonsen, *Encyonopsis microcephala* **(**Grunow) Kramm, *Discostella stelligeroides (*Hustedt) Houk & Klee, *Gomphonema auritum* A.Braun ex Kützing, *Brachysira neoexilis* Lange-Bertalot, *B. microclava* Lange-Bertalot & Gerd Moser, and *Nitzschia frequens* Hustedt. Additionally, there were eight species that were only found at the standing water sites, which included *Placoneis*. *elegans* Metzeltin Lange-Bertalot&García-Rodríguez, *Gomphonema bohemicum* Hustedt, *Achnanthidium* sp.2, *Neidium affine* (Ehrenberg) Pfizer *Sellaphora seminulum* (Grunow) D.G. Mann, *Craticula ambigua* (Ehrenberg) D.G. Mann, *Craticula vixnegligenda* Lange-Bertalot and *Epithemia cistula* (Ehrenberg) Ralfs in Pritch (Table 11, Figure 9)

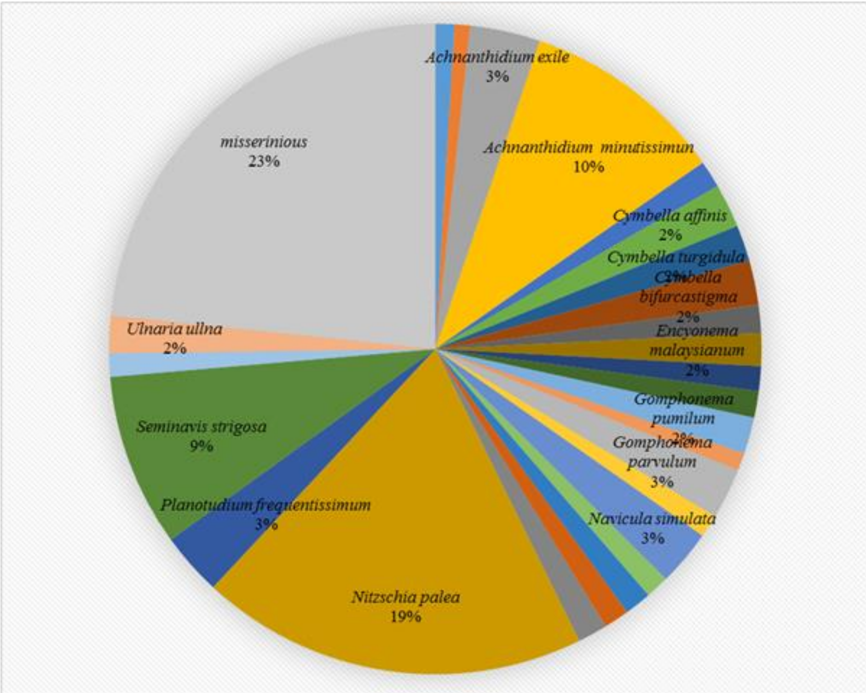


Figure 8 The diatom species proportions found in the running water sampling sites of the Wang River during the period of October 2011 to September 2012

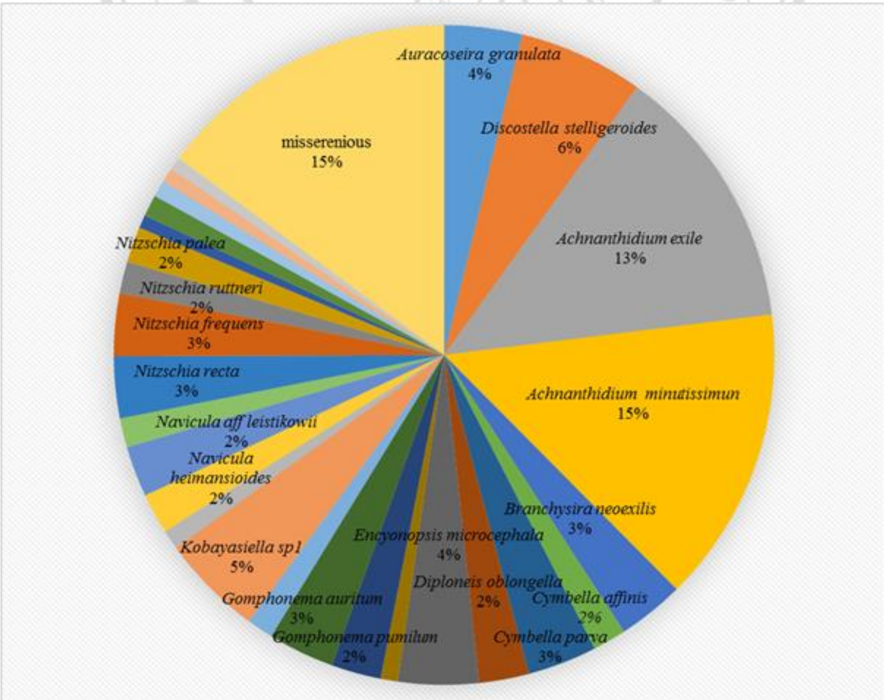


Figure 9 The diatom species proportions found in the standing water sampling sites of the Wang River during the period of October 2011 to September 2012

Table 11 Species list and relative abundance of each taxon of benthic diatoms in the Wang River, Thailand during the period of October 2011 to September 2012

d = dominant (>20%), f = frequent (5-20%), c = common (1-5%) r = rare (<1%) (Kelly and Whitton, 1995)

●= presented in running water, *= presented in standing water, ●* = presented in both running and standing water

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Division Bacillariophyta												
Class Coscinodiscineae												
Subclass Thalassiosirophycidae												
Order Thalassiosirales												
Family Stephanodiscaceae												
Cyclotella meneghiniana Kützing ●*	-	-	r	-	-	r	r	r	r	r	r	r
Puncticulata shanxiensis Xie & Qi ●*	-	-	r	r	-	r	r	r	-	-	-	-
Discostella stelligeroides (Hustedt) Houk & Klee ●*	-	-	c	c	r	f	c	r	r	-	r	r
Order Aulacoseirales												
Family Aulacoseiraceae												
Aulacoseira granulata (Ehrenberg) Simonsen ●*	-	-	r	r	r	f	f	c	c	-	r	r
Class Fragilariophyceae												
Subclass Fragilariophycidae												
Order Fragilariales												
Family Fragilariaceae												
Fragilaria capucina Desmazières ●	-	-	-	r	-	-	r	-	-	-	-	-
Fragilaria vaucheriae (Kützing) J.B.Petersen ●*	-	-	r	-	-	-	r	-	-	-	-	-
Fragilaria rumpens (Kützing) G.W.F.Carlson ●*	-	-	r	r	r	r	-	-	-	-	-	-
Staurosira sp.1 ●	-	-	-	-	-	-	-	r	r	-	r	-
Ulnaria arcus (Kützing) M. Aboal ●*	-	-	r	r	r	r	r	r	r	r	r	r
Ulnaria lanceolata (Kützing) P.Compère ●*	r	-	r	c	c	r	c	-	-	-	c	c
Ulnaria ramesii (Héribaud) T. Ohtsuka in Ohtsuka ●	-	r	-	-	-	-	-	r	-	-	-	-
Ulnaria ulna (Nitzsch) P. Compère ●*	c	c	r	r	r	r	c	r	c	c	c	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Class Bacillariophyceae												
Subclass Eunotiophycidae												
Order Eunotiales												
Family Eunotiaceae												
Eunotia minor (Kützing) Grunow in van Heurck ●	-	r	-	-	-	r	-	r	r	r	-	-
Eunotia curvata (Kützing) Lagerstedt ●	-	-	-	-	-	-	-	-	r	-	-	-
Eunotia bilunaris (Ehrenberg) Schaarschmidt ●*	-	-	r	r	-	-	-	-	-	-	-	-
Subclass Bacillariophycidae												
Order Cymbellales												
Family Cymbellaceae												
Cymbella affinis Kützing ●*	-	c	c	c	f	r	f	-	-	-	f	c
Cymbella bifurcumstigma sp. nov. ●*	f	-	r	-	-	-	-	-	-	-	-	-
Cymbella parva (W.Smith) Kirchner ●*	-	-	c	f	r	c	r	-	-	-	-	-
Cymbella cf. *subleptoceros* Krammer ●*	r	-	-	-	-	-	-	-	r	r	-	-
Cymbella sumatraensis Krammer ●	r	r	-	-	-	-	-	-	-	-	-	-
Cymbella tumida (Brébisson) Van Heurck ●*	r	r	r	-	r	r	r	-	r	r	-	r
Cymbella turgidula Grunow ●*	r	r	-	r	-	-	-	f	c	c	r	-
Cymbella cf. *geddiana* Krammer & Lange- Bertalot in Krammer ●*	r	-	r	-	-	-	-	-	r	-	-	-
Cymbella sp.1 ●*	-	-	r	r	r	-	r	-	r	-	-	-
Cymbella sp.2 ●*	-	-	r	-	-	-	r	-	r	-	-	-
Delicata delicatula (Kützing) Krammer ●	-	-	-	r	-	-	-	-	-	-	-	-
Delicata cf. *sparsistriata* Krammer ●	f	-	-	-	-	r	-	-	-	-	-	-
Encyonema gaeumannii (Meister) Krammer ●	-	-	-	c	-	r	-	-	-	-	-	-
Encyonema hustedtii Krammer ●*	-	-	-	r	-	r	r	r	-	-	-	-
Encyonema malaysianum Krammer ●	f	-	-	-	-	-	-	-	r	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Encyonema minutum (Hilse in Rabenhorst) D.G.Mann ●	-	-	-	-	r	-	r	-	-	-	-	-
Encyonema mesianum (Cholnoky) D.G.Mann ●*	-	r	r	-	-	r	r	r	r	-	-	r
Encyonema prostratum (Berkeley) Kützing ●	r	-	-	-	-	-	-	-	-	-	-	-
Encyonema sp.1 ●	-	-	-	-	-	-	-	-	r	-	-	-
Encyonopsis leei Krammer ●*	f	-	r	-	r	-	-	-	-	-	-	-
Encyonopsis microcephala **(**Grunow) Krammer ●*	f	r	f	c	r	-	-	-	-	-	-	-
Placoneis exigua var. *capitata* Cox ●	-	-	-	-	r	-	-	-	r	-	-	r
Placoneis witkowskii Metzeltin, Lange-Bertalot & García-Rodríguez ●	-	-	-	-	-	-	-	r	-	-	r	-
Placoneis cf. *elegans* Metzeltin, Lange-Bertalot & García-Rodríguez *	-	-	r	-	-	-	-	-	-	-	-	-
Family Gomphonemataceae												
Gomphonema affine Kützing ●*	-	-	r	r	-	-	r	r	r	-	-	-
Gomphonema turris Ehrenberg ●	-	-	-	-	-	-	-	r	-	-	-	r
Gomphonema pseudoaugur Lange-Bertalot ●	-	-	-	-	r	-	-	-	c	r	-	-
Gomphonema gracile Ehrenberg ●*	r	-	r	c	r	r	-	-	r	r	-	-
Gomphonema pumilum (Grunow) E.Reichardt & Lange-Bertalot ●*	r	c	c	f	-	c	-	c	-	-	-	-
Gomphonema auritum A.Braun ex Kützing ●*	c	-	f	f	r	f	f	-	-	r	-	r
Gomphonema productum Hustedt ●	-	r	-	-	-	-	-	-	-	-	-	-
Gomphonema lanceolatum Kützing ●*	-	-	-	-	r	r	r	r	c	r	-	-
Gomphonema lagenula Kützing ●*	-	c	-	r	r	r	c	r	-	-	-	r
Gomphonema bohemicum Hustedt *	-	-	r	-	-	-	-	-	-	-	-	-
Gomphonema javanicum Hustedt ●*	-	-	-	r	r	c	r	-	-	-	-	-
Gomphonema micropus Kützing ●*	-	-	-	-	r	r	-	-	c	-	r	r
Gomphonema pala E.Reichardt ●	r	-	-	-	-	-	-	-	-	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Gomphonema minutum C.Agardh ●	-	-	-	-	-	-	r	r	-	-	-	-
Gomphonema parvulum Kützing ●*	-	c	-	r	f	r	f	f	r	c	c	c
Reimeria uniseriata S.E.Sala, J.M.Guerrero &M.E.Ferrario ●	-	-	-	-	-	-	r	-	-	-	-	-
Family Cocconeidaceae												
Cocconeis placentula Ehrenberg ●	r	r	r	r	r	-	f	c	c	c	r	r
Order Achnanthales												
Family Achnanthaceae												
Achnanthes inflata (Kützing) Grunow ●	-	-	-	-	-	-	r	-	-	-	-	-
Achnanthes oblongella Østrup ●	-	r	-	-	r	-	-	-	r	-	-	r
Achnanthes pusilla Grunow in Cleve &Grunow ●	r	-	-	-	-	-	-	-	-	-	-	-
Achnanthes sp.1 ●	r	-	-	-	r	-	-	-	-	-	-	-
Achnanthidium exile (Kützing) Heiberg ●*	r	-	d	d	r	-	c	r	c	-	r	-
Achnanthidium exiguum (Grunow) D.B.Czarnecki ●*	-	c	r	-	-	r	r	-	-	r	r	r
Achnanthidium jackii Rabenhorst ●	r	-	-	-	-	-	-	-	-	-	-	-
Achnanthidium latecephalum H.Kobayasi ●*	r	-	r	r	c	r	r	-	-	-	-	-
Achnanthidium minutissimum (Kützing) Czarnecki ●*	c	d	c	c	d	d	f	-	c	f	c	c
Achnanthidium straubianum Lange- Bertalot ●	r	-	r	-	-	-	-	-	-	-	-	-
Achnanthidium cf. *subhudsonis* (Hustedt) Kobayashi *et al.* ●	-	-	-	r	-	r	-	-	-	-	-	-
Achnanthidium sp.1 ●	r	-	-	-	-	-	-	-	-	-	-	-
Achnanthidium sp.2 ●	-	-	-	-	-	r	-	-	-	-	-	-
Planotidium frequentissimum (Lange-Bertalot) Round & L.Bukhtiyarova ●*	-	c	r	r	c	r	c	f	c	c	f	c
Planotidium rostratum (Østrup) Lange- Bertalot ●	-	r	-	-	r	-	-	r	r	r	r	-
Planotidium sp.1 ●	-	-	-	-	-	-	-	r	-	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Order Naviculales												
Family Diadesmidaceae												
Diadesmis confervacea Kützing ●	-	-	-	-	-	-	-	-	r	r	r	-
Luticola mitigata (Hustedt) D.G.Mann ●*	-	r	r	-	r	-	-	-	r	-	-	-
Luticola mutica var. *lanceolata* (Frenguelli) M.Aboal ●	-	-	-	-	-	-	-	-	r	-	-	r
Luticola saxophila (Bock ex Hustedt) D.G. Mann ●	r	-	-	-	-	r	r	-	r	-	-	-
Luticola simplex Metzeltin, Lange-Bertalot& García- Rodríguez ●*	r	-	r	r	-	r	r	-	-	-	-	r
Luticola terminata (*tropica*) (Hustedt) J.R.Johansen in Johansen *et al*. ●	-	-	-	-	r	-	-	-	-	-	-	-
Luticola cf. *pseudokotschyi* ● (Lange-Bertalot) Gotoh	-	-	-	-	-	-	-	-	r	-	r	c
Luticola sp.1 ●	-	-	-	-	-	r	-	r	r	r	r	c
Family Brachysiraceae												
Branchysira neoexilis Lange-Bertalot ●*	-	r	f	c	r	-	r	-	r	r	-	r
Branchysira cf. *microclava* Lange-Bertalot&Ger Moser ●*	-	r	r	-	-	r	r	-	-	-	-	-
Family Neidiaceae												
Neidium affine (Ehrenberg) Pfizer *	-	-	r	-	-	-	-	-	-	-	-	-
Neidium affine var. *longiceps.* (W.Gregory) Cleve ●*	r	-	-	-	r	r	-	-	-	-	-	-
Neidium binodeforme Krammer in Krammer Lange-Bertalot ●	r	-	-	r	-	-	r	-	-	-	-	-
Neidium dubium (Ehrenberg) Cleve ●	-	r	-	-	-	-	-	-	-	-	-	-
Neidium gracile Hustedt ●	-	-	-	-	-	-	-	-	r	-	-	-
Family Sellaphoraceae												
Fallacia pygmaea (Kützing) A.J. Stickle & D.G. Mann ●	-	-	-	-	-	-	-	-	r	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Sellaphora bacillum (Ehrenberg) D.G. Mann ●*	r	-	r	r	r	-	-	-	-	-	-	-
Sellaphora blackfordensis D.G.Mann & S.Droop ●*	r	r	r	-	r	r	r	-	-	-	-	-
Sellaphora capitata D.G.Mann & McDonald, S.M. ●	-	-	-	-	r	-	-	-	-	-	-	r
Sellaphora lanceolata D.G.Mann&S.Droo ●*	r	r	r	r	r	-	r	r	c	r	r	-
Sellaphora obesa D.G.Mann & M.M.Bayer ●	-	r	-	-	-	-	-	-	r	r	-	r
Sellaphora papula (Kützing) Mereschkovsky ●	-	-	-	-	-	-	r	-	-	-	-	-
Sellaphora seminulum (Grunow) D.G. Mann ●	-	-	-	-	-	r	-	-	-	-	-	-
Sellaphora stroemii (Hustedt) Mann ●	r	-	-	-	-	-	-	-	-	-	-	-
Sellaphora subbacillum (Hustedt) E. Falasco & L. Ectorin Falasco *et al.* ●*	-	-	c	r	r	r	-	-	-	-	-	-
Sellaphora sp.1 ●	-	-	-	-	-	-	r	-	-	-	-	-
Sellaphora sp.2 ●	-	r	r	-	-	-	-	-	-	-	-	-
Family Pinnulariaceae												
Pinnularia substomatophora Hustedt ●	r	-	-	-	-	r	-	-	-	-	-	-
Pinnularia oominensis H.Kobayasi●	-	r	-	-	-	-	-	-	-	-	-	-
Pinnularia biceps W.Gregory●	-	-	-	-	-	-	-	-	r	-	-	-
Pinnularia acidojaponica Idei&H.Kobayasi●	-	-	-	-	-	r	r	-	r	-	r	c
Pinnularia cf. *interrupta* W.Smith●*	-	r	r	r	-	-	-	r	r	r	-	-
Family Diploneidaceae												
Diploneis oblongella (Nägeli ex Kützing) Cleve-Euler in Cleve-Euler & Osvald●*	c	r	c	r	r	r	r	r	r	r	-	-
Diploneis oculata (Breb) Cleve●	r	-	-	-	-	-	-	-	-	-	-	r
Diploneis smithii Cleve●	r	-	-	-	-	-	-	r	-	-	-	-
Family Naviculaceae												
Adlafia bryophila (J.B.Petersen) Gerd Moser, Lange-Bertalot&D.Metzeltin●*	r	-	r	r	-	-	-	-	-	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Caloneis bacillum (Grunow) Cleve●	r	r	-	r	r	-	r	-	-	-	-	-
Caloneis silicula var. *alpine* Cleve●*	-	-	r	-	-	r	r	-	r	-	-	-
Caloneis silicula var. *peisonis* Hustedt●	-	-	-	r	-	-	-	-	-	-	-	-
Caloneis ventricosa (Ehrenberg) F.Meister●	-	-	-	-	-	r	-	r	-	r	-	-
Caloneis cf. *tenuis* (W.Gregory) Krammer in Krammer & Lange-Bertalot●	-	r	-	-	-	-	-	-	-	-	-	-
Caloneis sp.1●	-	-	-	-	-	r	-	-	-	r	-	-
Caloneis sp.2●	r	c	-	-	r	-	-	-	-	-	-	-
Eolimna minima (Grunow) Lange-Bertalot●*	-	-	-	-	-	r	-	-	r	-	-	c
Geissleria decussis (Østrup) Lange Bertalot & Metzeltin ●*	r	r	-	r	-	r	r	r	r	-	r	r
Geissleria punctiferera (Hustedt) Metzeltin,Lange-Bertalot & Garcia-Rodriguez ●	-	r	-	-	-	-	r	r	r	r	r	r
Geissleria cf. *cummerowi* (L.Kalbe) Lange-Bertalot●	r	r	-	-	-	-	-	-	-	-	-	-
Hippodonta avittata (Cholnoky) Lange-Bertalot●	-	-	-	-	-	-	-	r	r	r	r	-
Hippodonta pseudoacceptata (H.Kobayasi) Lange-Bertalot●	-	c	-	-	-	-	-	r	c	c	c	c
Kobayasiella sp.1●*	-	-	r	r	-	f	r	-	-	-	-	r
Myamaea agrestis (Kützing) H. Lange-Bertalot●*	-	-	-	-	r	r	-	-	-	-	-	-
Navicula amphiceropsis Lange-Bertalot & Rumrich in Rumrich●*	-	-	r	-	c	r	-	c	r	r	-	-
Navicula antonii Lange-Bertalot in Rumrich *et al.* ●*	-	-	-	-	-	-	r	-	c	r	r	-
Navicula capitatoradiata Germain●	c	-	-	-	-	-	r	-	-	-	-	-
Navicula cataracta-rheni Lange-Bertalot●	r	-	-	r	-	-	r	-	-	-	-	-
Navicula caterva Hohn&Hellermann●	-	r	-	-	r	-	-	-	-	-	-	-
Navicula cinctaeformis Hustedt●	-	-	-	-	-	-	-	-	-	-	-	r
Navicula cryptotenella Lange-Bertalot●*	-	c	-	r	-	-	-	-	-	-	-	r

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Navicula erifuga Lange-Bertalot in Krammer & Lange-Bertalot●	-	-	-	-	r	-	r	-	-	-	-	-
Navicula escambia (Patrick) D.Metzeltin & Lange-Bertalot●	-	c	-	-	-	-	r	-	r	-	-	-
Navicula germainii J. H. Wallace●*	-	r	-	r	r	-	r	-	c	c	c	c
Navicula heimansioides Lange-Bertalot●*	c	-	c	r	-	-	r	-	-	-	-	r
Navicula hintzii Lange-Bertalot●	c	-	-	-	-	-	r	-	-	-	-	r
Navicula jacobii Manguin●	-	-	-	-	-	-	r	-	r	-	-	-
Navicula pseudostauropteroides Fritsch●*	r	-	r	-	r	-	-	-	-	-	-	-
Navicula radiosafallax Lange-Bertalot●*	-	-	c	c	-	-	r	r	-	-	-	r
Navicula reichardtiana Lange-Bertalot in Lange-Bertalot&Krammer●	-	r	-	-	-	-	-	-	-	-	-	-
Navicula rostellata Kützing●*	-	c	c	r	r	r	r	r	-	c	c	c
Navicula simulata Manguin●*	-	-	-	c	f	r	c	c	c	c	c	f
Navicula suprinii Gerd Moser●*	f	-	-	-	c	r	c	-	-	-	-	r
Navicula vandamii Schoeman& Archibald●*	r	r	-	r	c	r	r	-	-	-	-	r
Navicula vandamii var. *mertensiae* Lange-Bertalot in Witkowski *et al.*●	-	-	-	-	r	-	r	-	-	c	r	-
Navicula viridula (Kützing) Ehrenberg●*	-	-	r	r	-	-	r	-	-	-	-	-
Navicula viridulacalcis Lange-Bertalot in Rumrich *et al.* ●	r	-	-	-	-	-	-	-	-	-	-	-
Navicula cf. *aquaedurae* Lange-Bertalot●*	-	f	-	r	-	-	r	-	-	-	-	-
Navicula cf. *bella* Hustedt*	-	-	r	-	-	-	-	-	-	-	-	-
Navicula cf. *leistikowii* Lange-Bertalot●*	f	-	-	r	r	c	c	-	-	r	r	-
Navicula cf. *parablis* M.H.Hohn & Hellerman●*	-	c	c	c	-	-	r	c	c	r	r	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Navicula cf. *vekhovii* Lange-Bertalot & Genkal●	r	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.1●	r	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.2●	-	r	-	-	-	-	-	-	-	-	-	-
Naviculadicta nanogomphonema Lange-Bertalot & U.Rumrich●	-	-	-	-	r	-	-	-	r	-	-	-
Seminavis strigosa (Hustedt) Danielidis et D.G.Mann●*	-	f	r	c	f	c	f	c	c	f	d	f
Family Plagiotropidaceae												
Plagiotropis lepidoptera var. *proboscidea* (Cleve) Reimer in Patrick and Reime●	-	-	-	-	r	-	-	-	r	r	-	-
Family Pleurosigmataceae												
Gyrosigma obscurum (W. Smith) J.W. Griffith & Henfrey●	-	-	-	-	-	-	-	-	r	-	-	-
Gyrosigma scalproides (Rabenhorst) Cleve●*	r	r	-	r	r	r	r	r	-	r	r	r
Gyrosigma spencerii (Bailey ex Quekett) Griffith & Henfrey●*	r	c	r	r	r	r	r	r	r	r	r	c
Pleurosigma negoroi T.Gotoh in J.H.Lee, J.Chung & T.Gotoh ●	r	r	-	-	-	-	-	-	r	r	c	r
Family Stauroneidaceae												
Craticula riparia var. *mollenhaueri* Lange-Bertalot●	-	-	-	-	-	-	-	-	r	-	-	-
Craticula molestiformis (Hustedt) Mayama●	r	-	-	-	r	-	-	-	-	-	-	-
Craticula vixnegligenda Lange-Bertalot●*	-	-	r	-	-	-	-	-	-	-	-	r
Craticula ambigua (Ehrenberg) D.G. Mann *	-	-	r	-	-	-	-	-	-	-	-	-
Stauroneis ancep Ehrenberg●	-	-	-	-	r	-	-	-	-	-	r	-
Stauroneis kriegeri Patrick●	r	-	-	r	-	-	-	-	-	-	-	-
Stauroneis smithii Grunow●	r	-	-	-	-	-	-	-	-	-	-	-

Table 11 (continued)

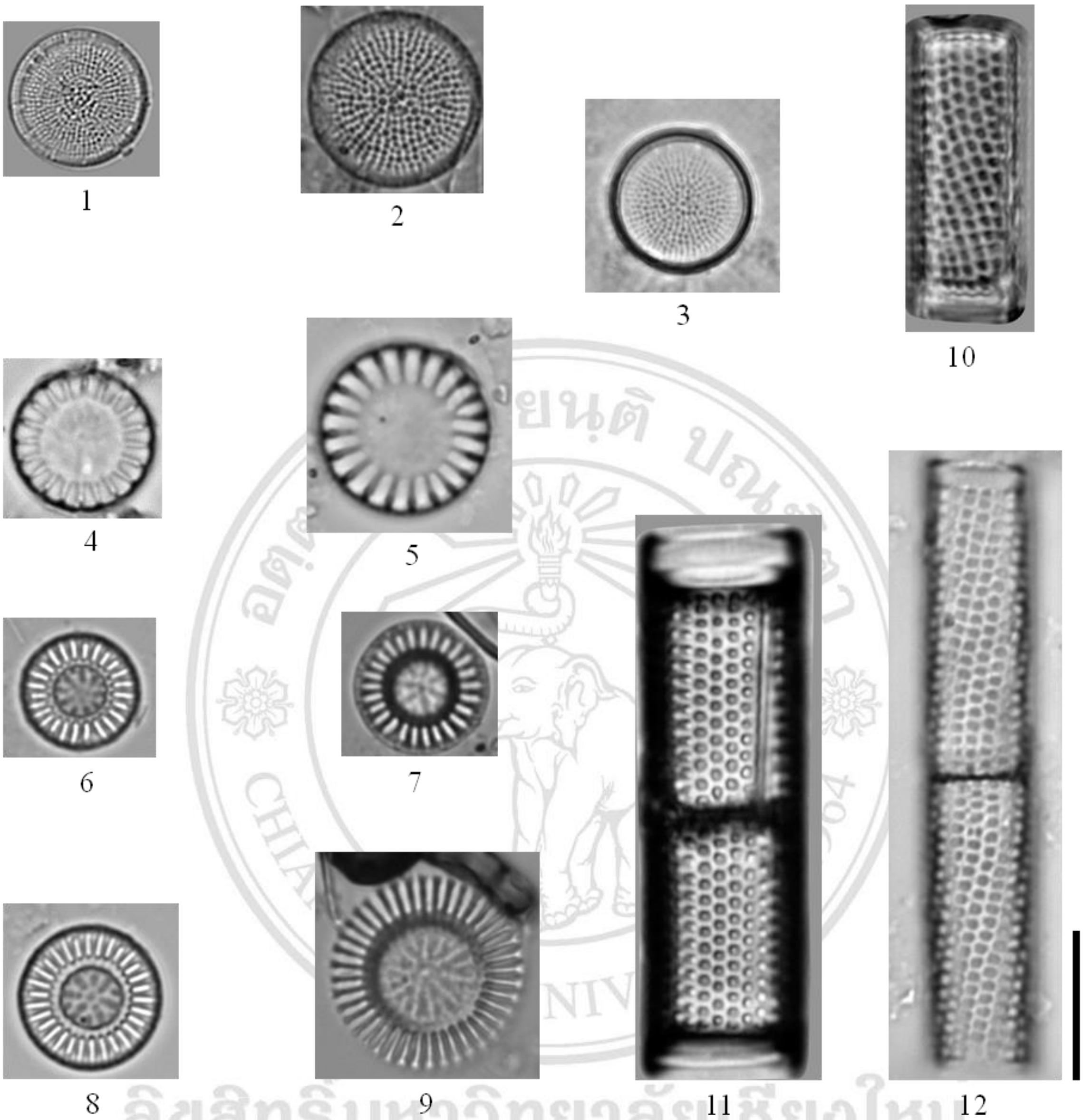
TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Family Amphipleuraceae												
Halamphora bullatoides (Hohn&Hellerman) Levkov●	r	r	-	-	-	-	-	-	-	-	-	-
Halamphora montana (Krasske) Levkov●*	-	r	-	r	r	c	c	r	r	-	r	r
Halamphora veneta (Kützing) Levkov●	-	-	-	-	-	-	-	-	-	-	-	r
Order Thalassiophysales												
Family Catenulaceae												
Amphora liriope Nagumo●*	-	c	r	r	r	-	r	r	c	r	r	r
Order Mastogloiales												
Family Mastogloiaceae												
Aneumastus sp.1●	-	-	-	-	-	-	-	-	-	-	r	-
Order Bacillariales												
Family Bacillariaceae												
Bacillaria paxillifer (O.F.Müller) Hendey●*	r	r	r	r	r	-	r	r	r	r	r	r
Hantzschia amphioxys (Ehrenberg) Grunow●*	-	-	c	-	r	r	-	r	r	-	-	r
Nitzschia amphibia Grunow●*	-	-	r	-	-	-	-	-	-	r	-	-
Nitzschia angustata (W.Smith) Grunow●	-	-	-	r	-	-	-	-	-	-	r	-
Nitzschia clausii Hantzsch●*	-	r	-	r	r	r	r	r	r	r	r	c
Nitzschia commutata Grunow in Cleve &Grunow●	-	r	-	-	-	-	-	-	-	-	-	-
Nitzschia compressa var. *balatonis* (Grunow) Lange-Bertalot in Lange-Bertalot&Krammer●	-	-	-	-	-	-	-	-	-	-	r	-
Nitzschia desertorum Hustedt●*	-	-	-	-	-	r	-	r	-	-	-	-
Nitzschia dissipata (Kützing) Grunow●*	-	c	r	r	r	-	r	r	r	r	r	c
Nitzschia filiformis var. *conferta* ●* (Richt) Lange-Bertalot	-	-	-	-	-	r	-	-	-	-	-	r
Nitzschia frequens Hustedt●*	-	r	r	-	-	f	-	r	-	-	-	-

Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Nitzschia frustulum (Kützing) Grunow in Cleve & Grunow●*	-	r	r	-	-	c	r	-	r	c	c	c
Nitzschia gracilis Hantzsch●*	-	c	-	-	r	r	r	r	r	f	c	c
Nitzschia hantzschiana Rabenhorst ●*	-	-	-	-	-	r	r	-	-	-	-	-
Nitzschia hoehnkii Hustedt●	-	r	-	-	-	-	-	r	-	-	r	c
Nitzschia intermedia Hantzsch●	-	c	r	r	-	-	r	r	-	-	r	-
Nitzschia lanceolata var. *minutula* Grunow●*	-	-	r	-	r	-	-	r	r	-	-	r
Nitzschia lorenziana Grunow in Cleve & Möller●*	-	r	-	r	r	r	-	-	r	r	r	r
Nitzschia palea (Kützing) W. Smith●*	-	f	c	c	f	c	f	d	d	d	d	f
Nitzschia palea var. *deblis* (Kützing) Grunow ●	r	r	-	-	-	-	-	-	-	c	-	-
Nitzschia parvula W.Smith●	-	-	-	r	-	-	-	r	r	-	r	-
Nitzschia persuadens Cholnoky●	-	-	-	-	-	-	r	r	r	r	c	c
Nitzschia pumila Hustedt●*	-	-	r	-	-	r	-	r	r	-	r	-
Nitzschia recta Hantzsch ex Rabenhorst●*	r	-	c	c	c	c	c	-	-	-	c	f
Nitzschia reversa W.Smith●*	-	r	r	-	r	-	-	r	r	r	r	r
Nitzschia salinicola Aleem&Hustedt ●*	-	-	r	-	-	-	-	-	r	r	-	r
Nitzschia sp.1●*	r	-	r	r	-	-	-	-	-	-	-	-
Nitzschia sinuta var. *tabellaria* Grunow●*	r	-	r	r	-	-	-	-	-	-	-	-
Nitzschia scalpelliformis Grunow in Cleve & Grunow●*	-	-	r	-	-	-	-	-	-	-	r	c
Nitzschia solgensis Cleve-Euler●	r	-	-	-	-	-	-	-	-	-	-	-
Nitzschia cf. *ruttneri* Hustedt●*	-	c	-	-	r	c	f	r	-	c	c	c
Tryblionella cf. *salinarum* (Grunow) Pantocsek●*	-	r	r	r	-	r	-	-	-	r	r	r
Order Rhopalodiales												
Family Rhopalodiaceae												
Epithemia cistula (Ehrenberg) Ralfs in Pritch*	-	-	r	-	-	-	-	-	-	-	-	-

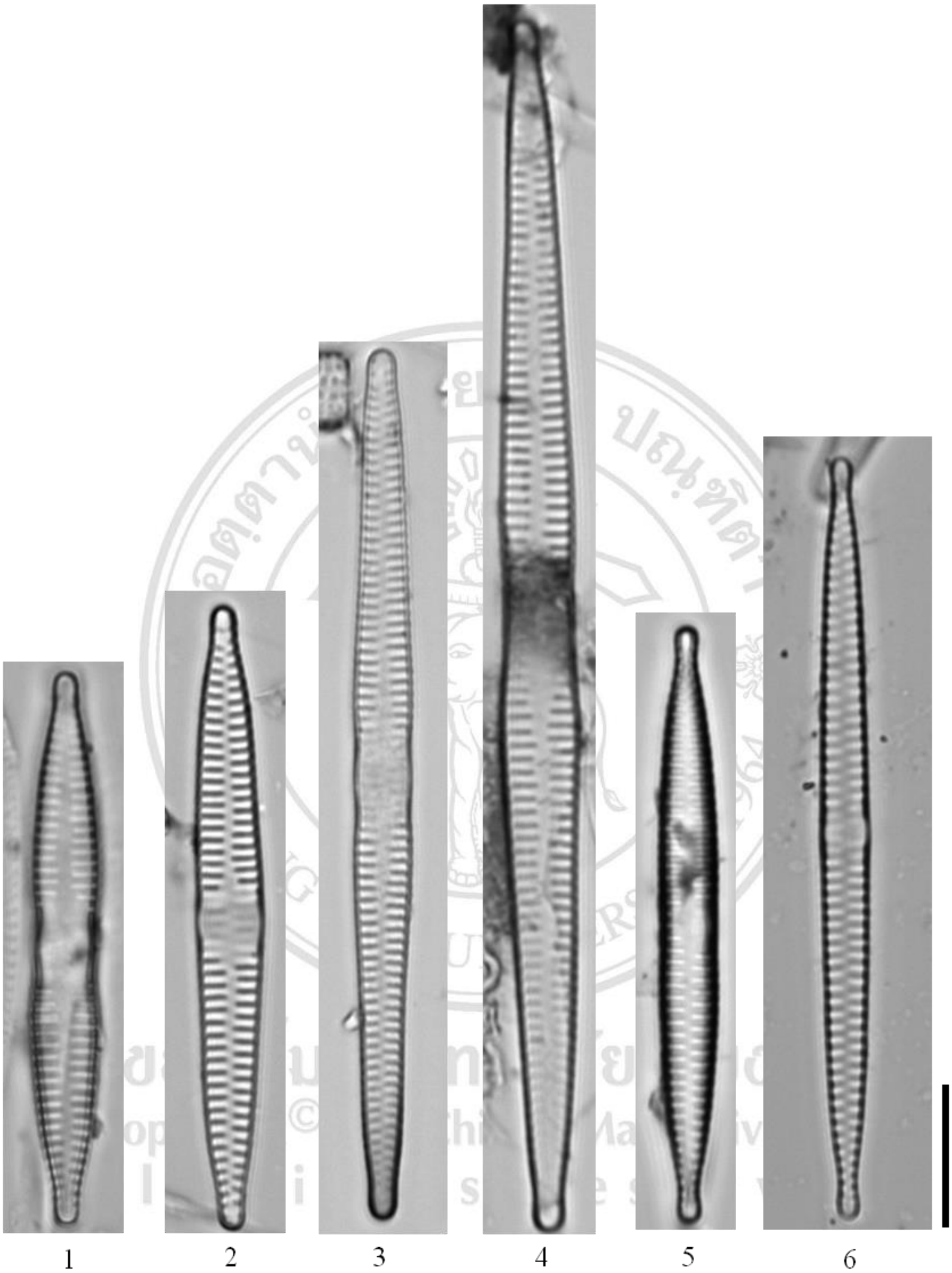
Table 11 (continued)

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Rhopalodia gibba (Ehrenberg) O. Müller●*	-	-	r	r	-	-	-	-	-	-	-	-
Rhopalodia contorta Hustedt ●	-	-	-	-	-	-	-	-	-	-	-	r
Rhopalodia musculus (Kützing) O. Müller●*	-	r	r	r	r	r	-	-	-	-	r	r
Order Surirellales												
Family Surirellaceae												
Surirella ostentata B.J.Cholnoky●*	r	r	-	-	r	r	r	r	r	-	r	r
Surirella angusta Kützing●	-	r	-	-	-	-	-	-	-	-	-	r
Surirella fonticola F.Hustedt●	-	r	-	-	-	-	-	r	-	r	r	-
Surirella linearis W.Smith●	-	r	-	-	r	-	-	r	r	r	-	r
Surirella splendida Kützing●	-	r	-	r	-	-	-	-	-	-	-	-
Surirella tenera W.Gregory●	-	r	-	-	-	-	-	r	r	-	-	-
Surirella tenera var. *nervosa* A.Schmidt in Schmidt *et al*. ●	-	-	-	-	-	-	-	r	r	r	-	-
Surirella sp.1●	r	-	-	-	-	-	-	-	-	-	-	-
Surirella sp.2●	-	-	-	-	-	-	-	-	r	-	-	-
Surirella sp.3●	r	-	-	-	-	-	-	-	-	-	-	-
Surirella sp.4●	-	r	-	-	-	-	-	-	-	-	-	-



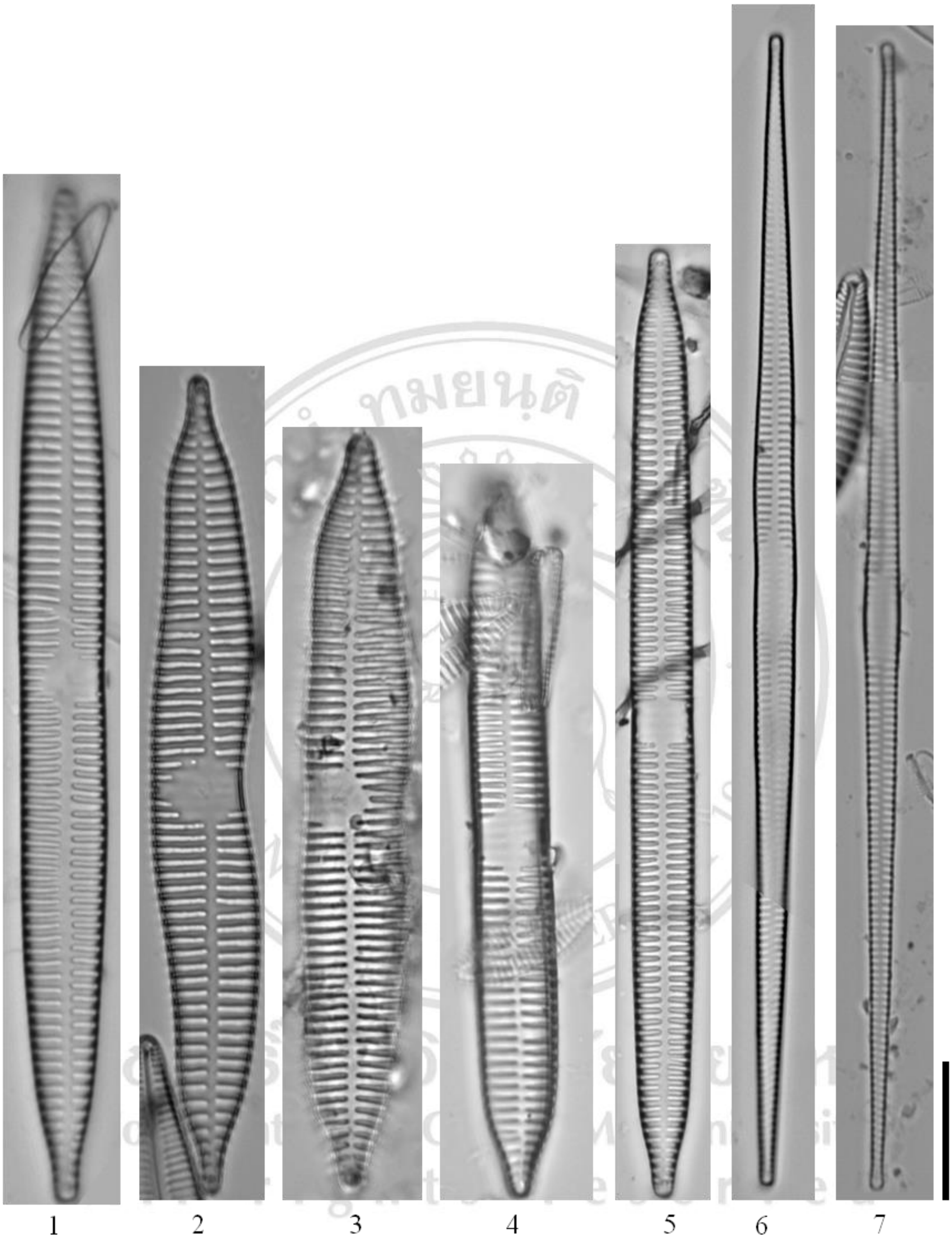
Scale bar = 10 µm.

Figure 10 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Puncticulata shanxiensis* Xie & Qi, (4-5) *Cyclotella meneghiniana* Kützing, (6-9) *Discostella stelligeroides* (Hustedt) Houk & Klee, (10-12) *Aulacoseira granulata* (Ehrenberg) Simonsen



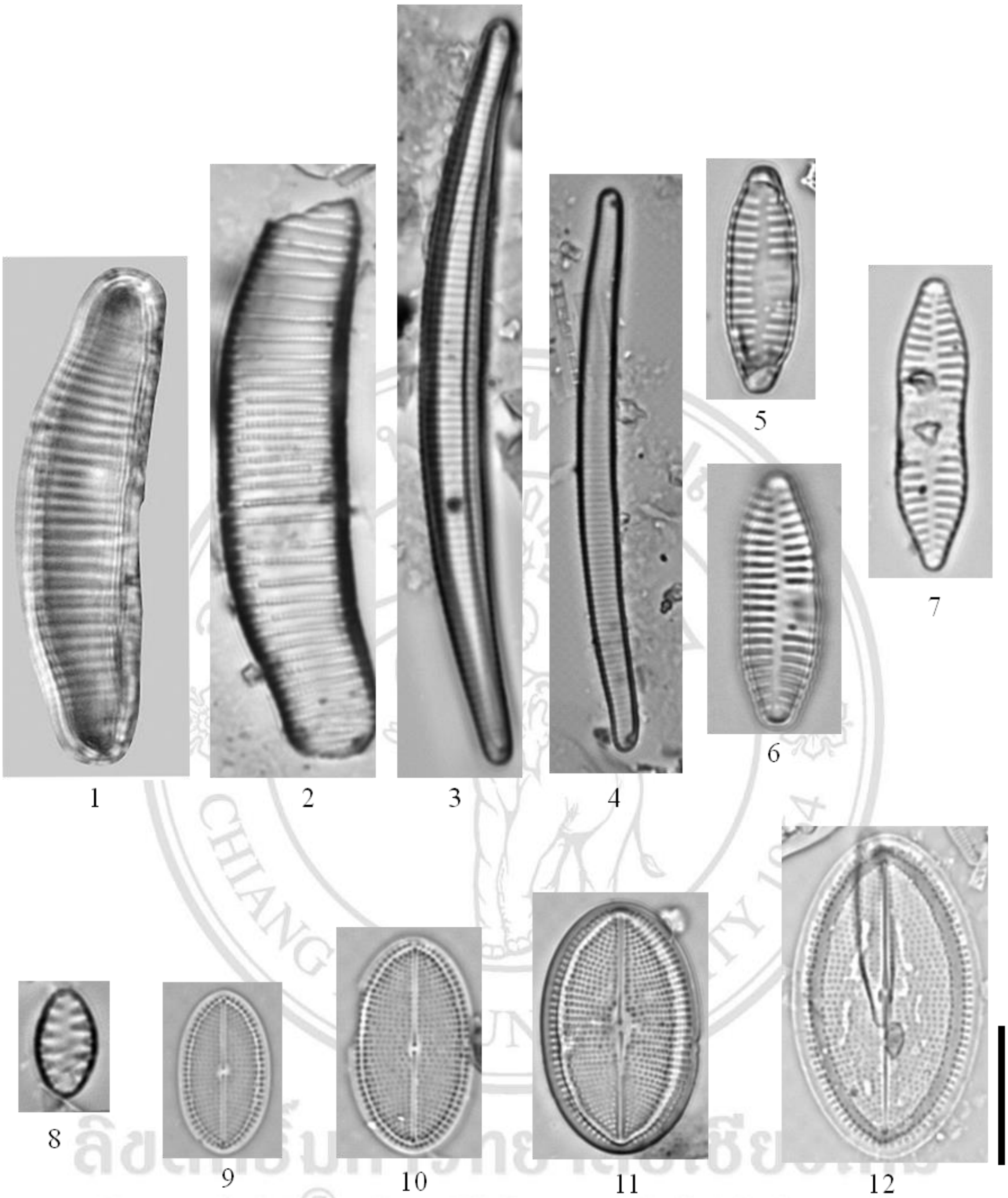
Scale bar = 10 µm.

Figure 11 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Fragilaria capucina* (Desmazières), (5-6) *F. rumpens* (Kützing) G.W.F. Carlson



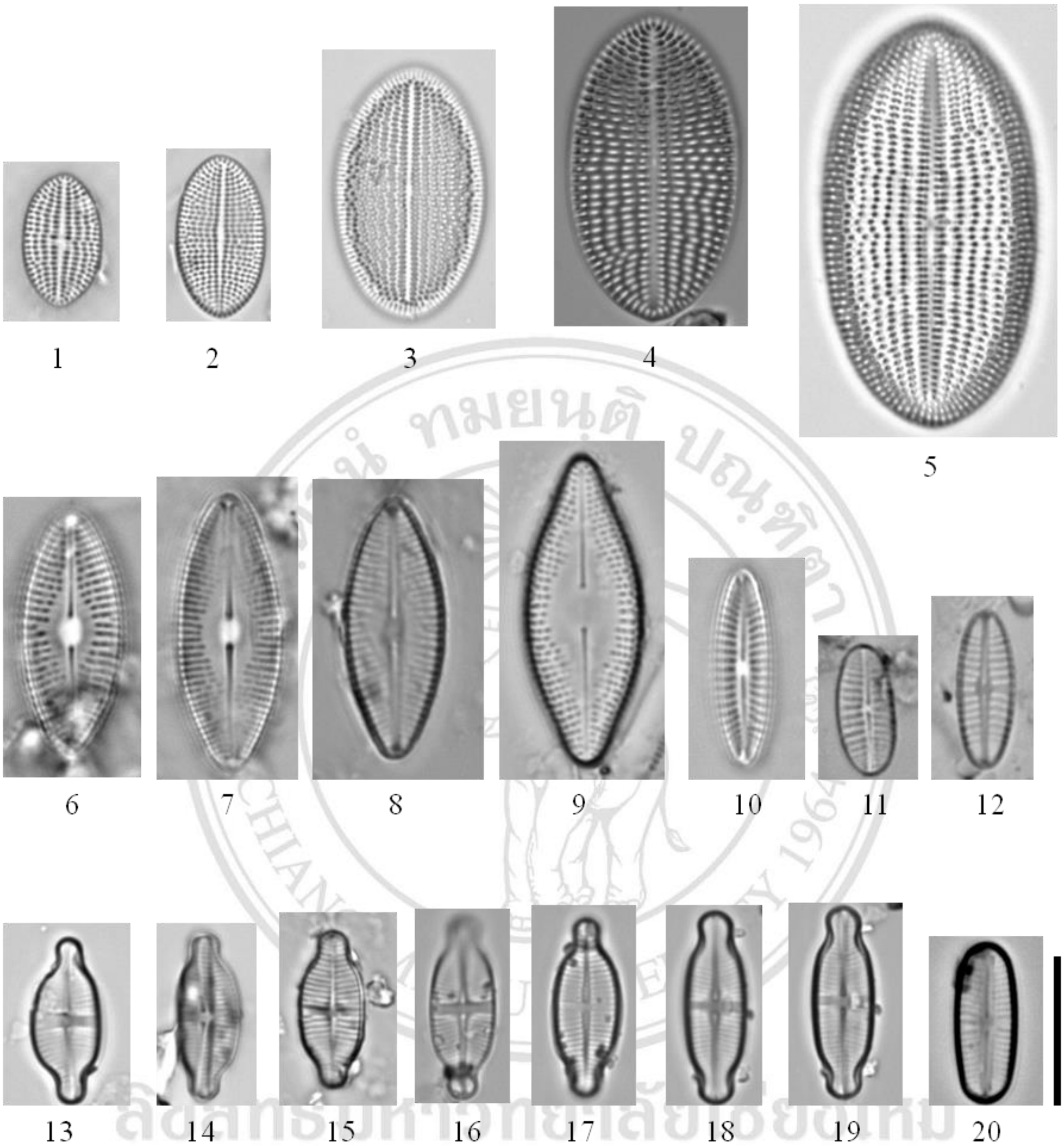
Scale bar = 10 µm.

Figure 12 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Ulnaria lanceolata* (Kützing) P. Compère, (4) *U. ramesii* (Héribaud) T. Ohtsuka in Ohtsuka, (5) *U. ulna* (Nitzsch) P. Compère, (6-7) *U. arcus* (Kützing) M. Aboal



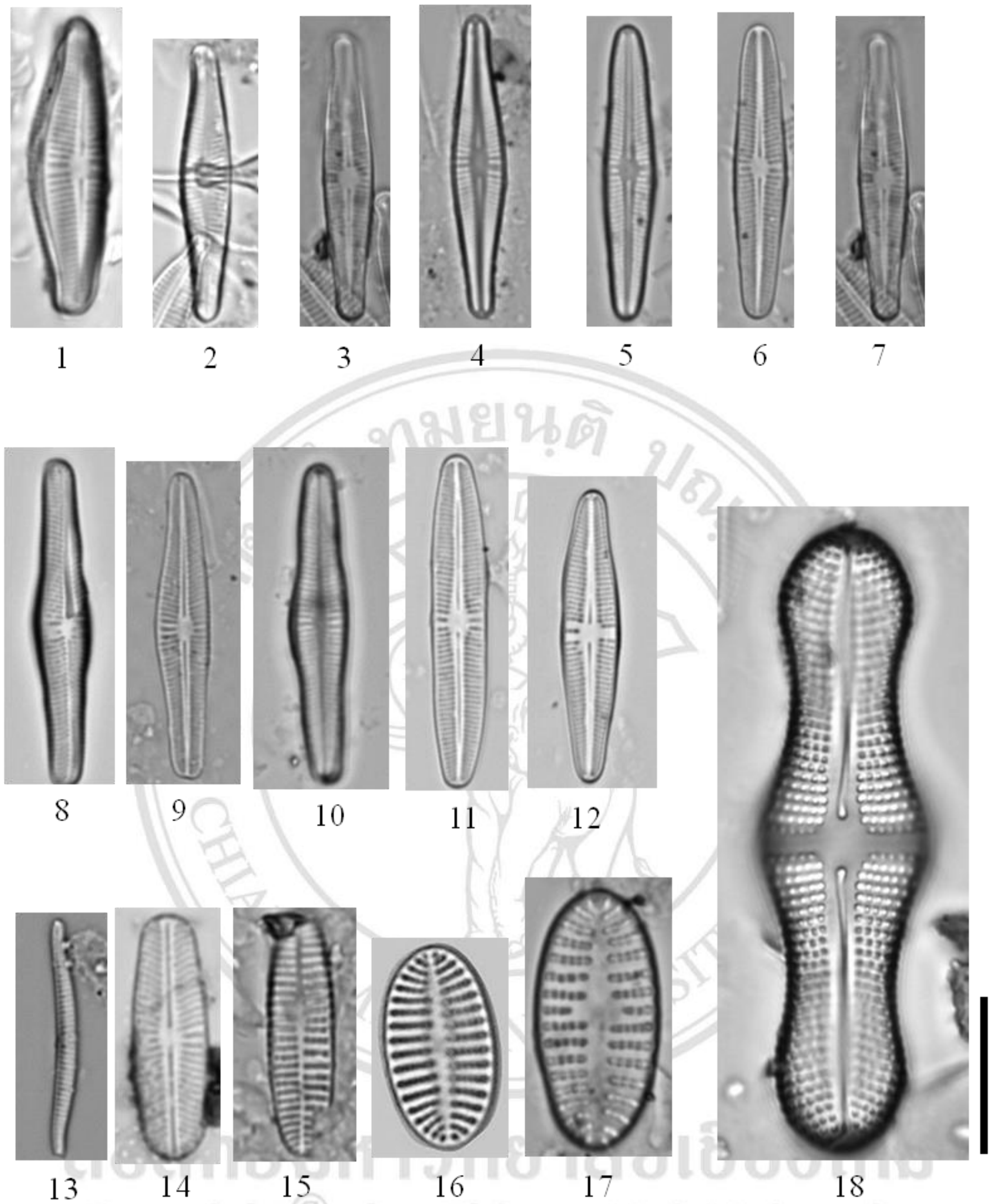
Scale bar = 10 µm.

Figure 13 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Eunotia minor* (Kützing) Grunow in van Heurck, (3) *E. curvata* (Nagamo), (4) *E. Eunotia bilunaris* (Ehrenberg) Schaarschmidt, (5-7) *Fragilaria vaucheriae* (Kützing) J.B. Petersen, (8) *Staurosira* sp.1, (9-12) *Cocconeis placentula* Ehrenberg



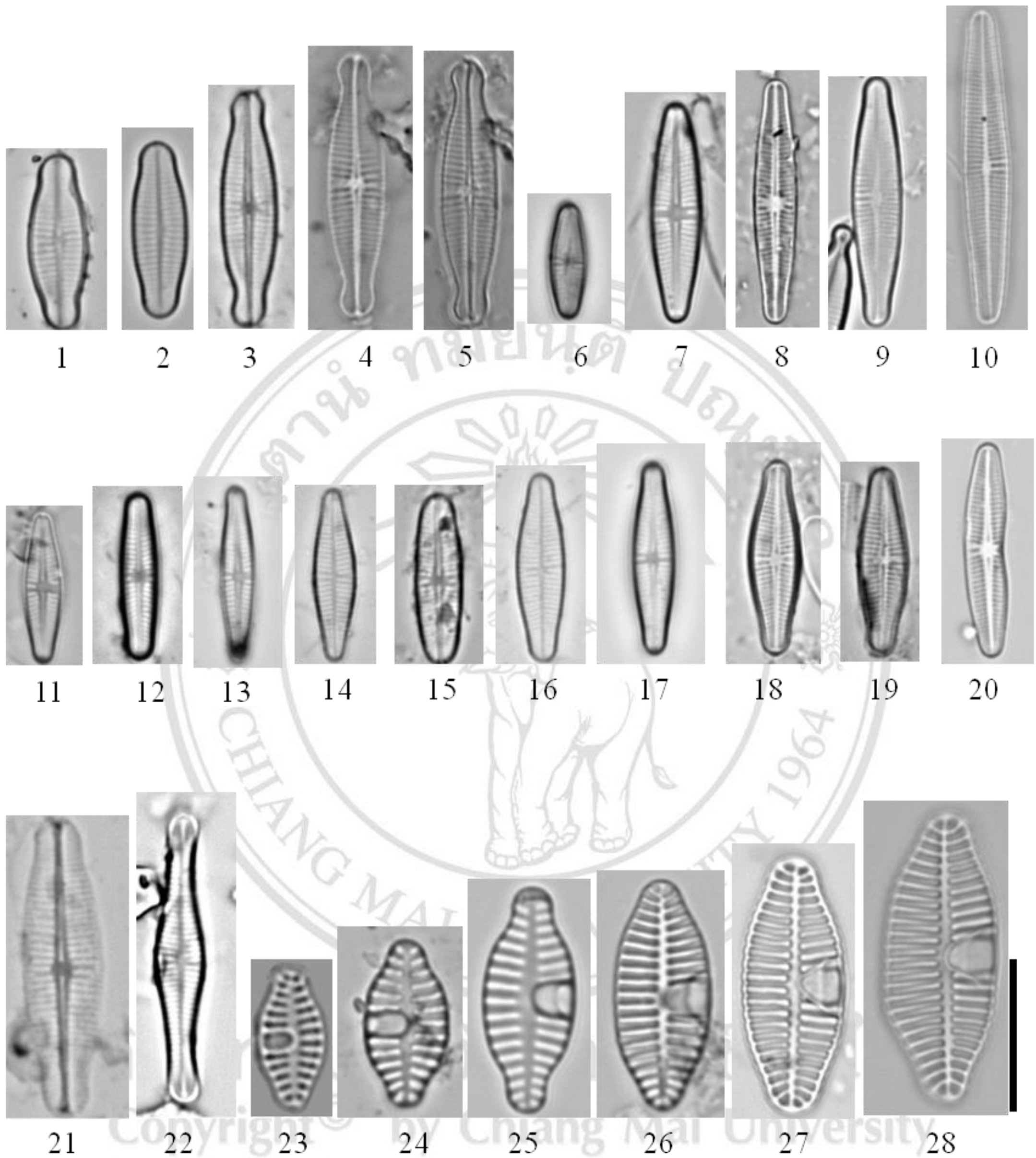
Scale bar = 10 µm.

Figure 14 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-5) *Cocconeis placentula Ehrenberg*, (6-9) *Diadesmis confervacea* Kützing (10) *Achnanthidium* cf. *subhudsonis* (Hustedt) H. Kobayasi in Kobayashi *et al*., (11-12) *A. jackii* Rabenhorst, (13-19) *A. exiguum* (Grunow) D.B. Czarnecki, (20) *A. straubianum* (Lange-Bertalot) Lange-Bertalot



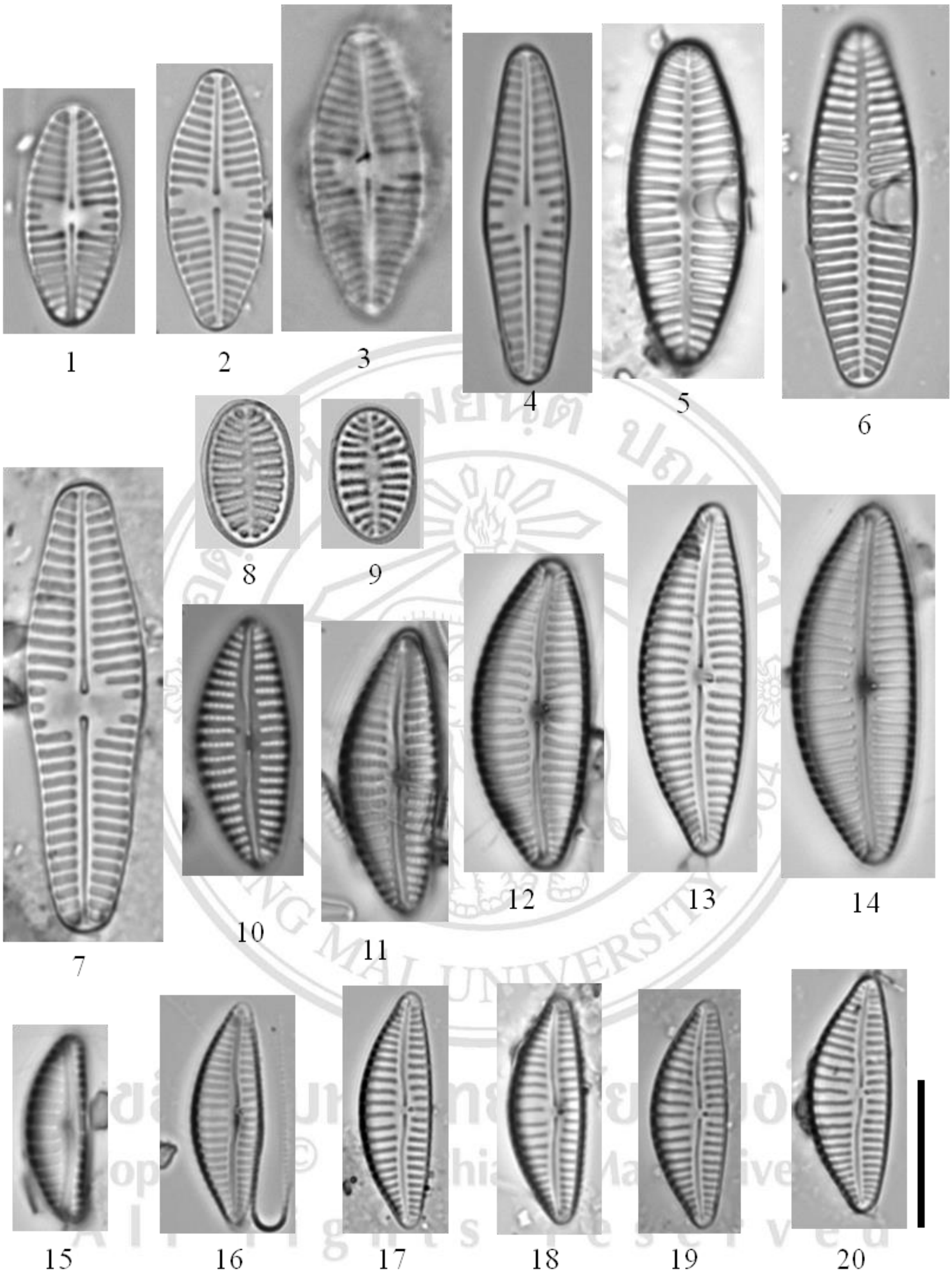
Scale bar = 10 µm.

Figure 15 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-13) *Achnanthidium exile* (Kützing) Heiberg, (14) *Achnanthes pusilla* Grunow in Cleve & Grunow, (15) *Achnanthes* sp.1, (16-17) *Achnanthes oblongella* Østrup, (18) *Achnanthes inflata* (Kützing) Grunow



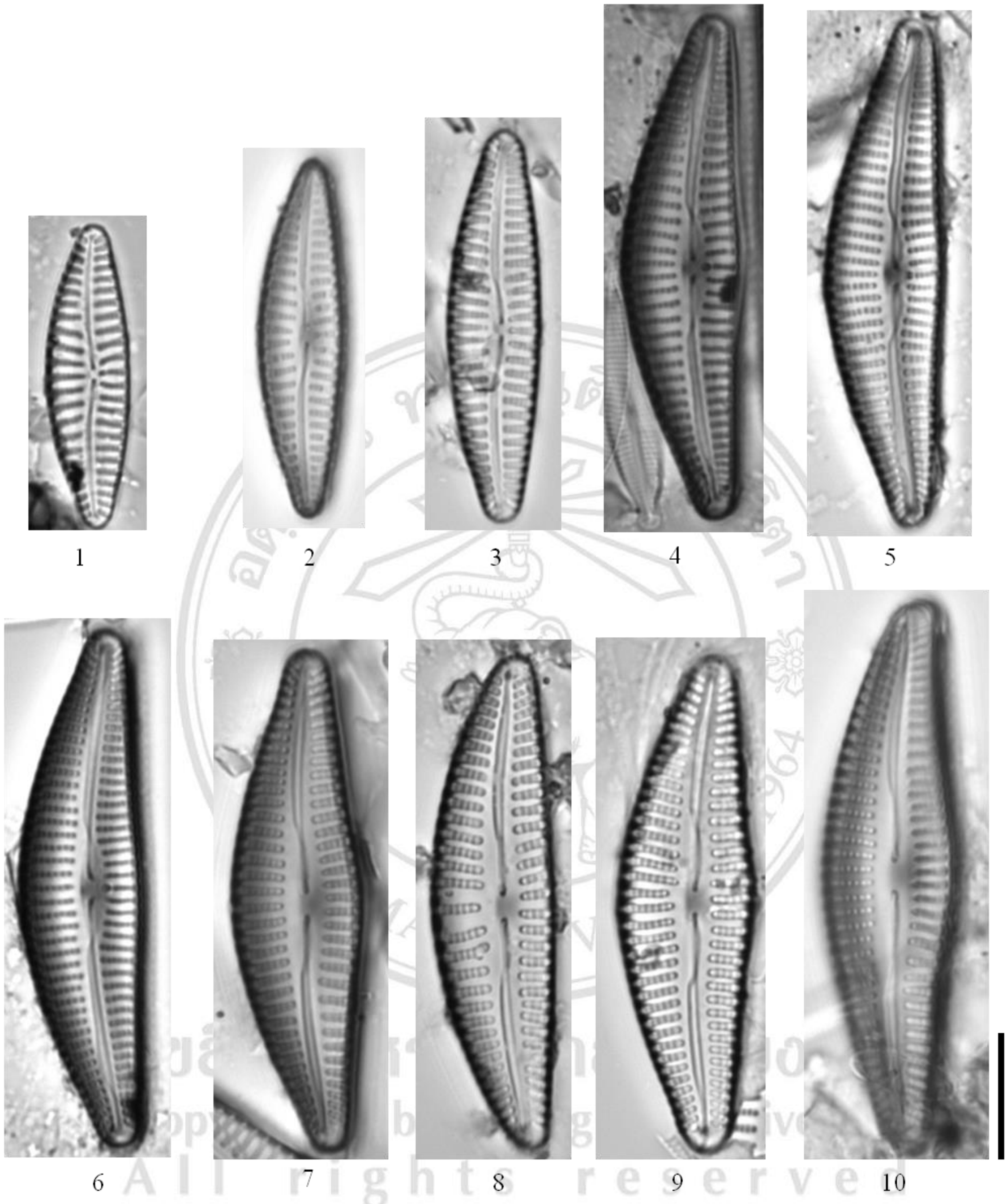
Scale bar = 10 µm.

Figure 16 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-5) *Achnanthidium latecephalum* H. Kobayasi, (6-20) *Achnanthidium minutissimum* (Kützing) Czarnecki, (21) *Achnanthidium* sp.1, (22) *Achnanthidium* sp.2, (23-25) *Planothidium rostratum* (Østrup) Lange-Bertalot, (26-28) *Planothidium frequentissimum* (Lange-Bertalot) Round & L. Bukhtiyarova



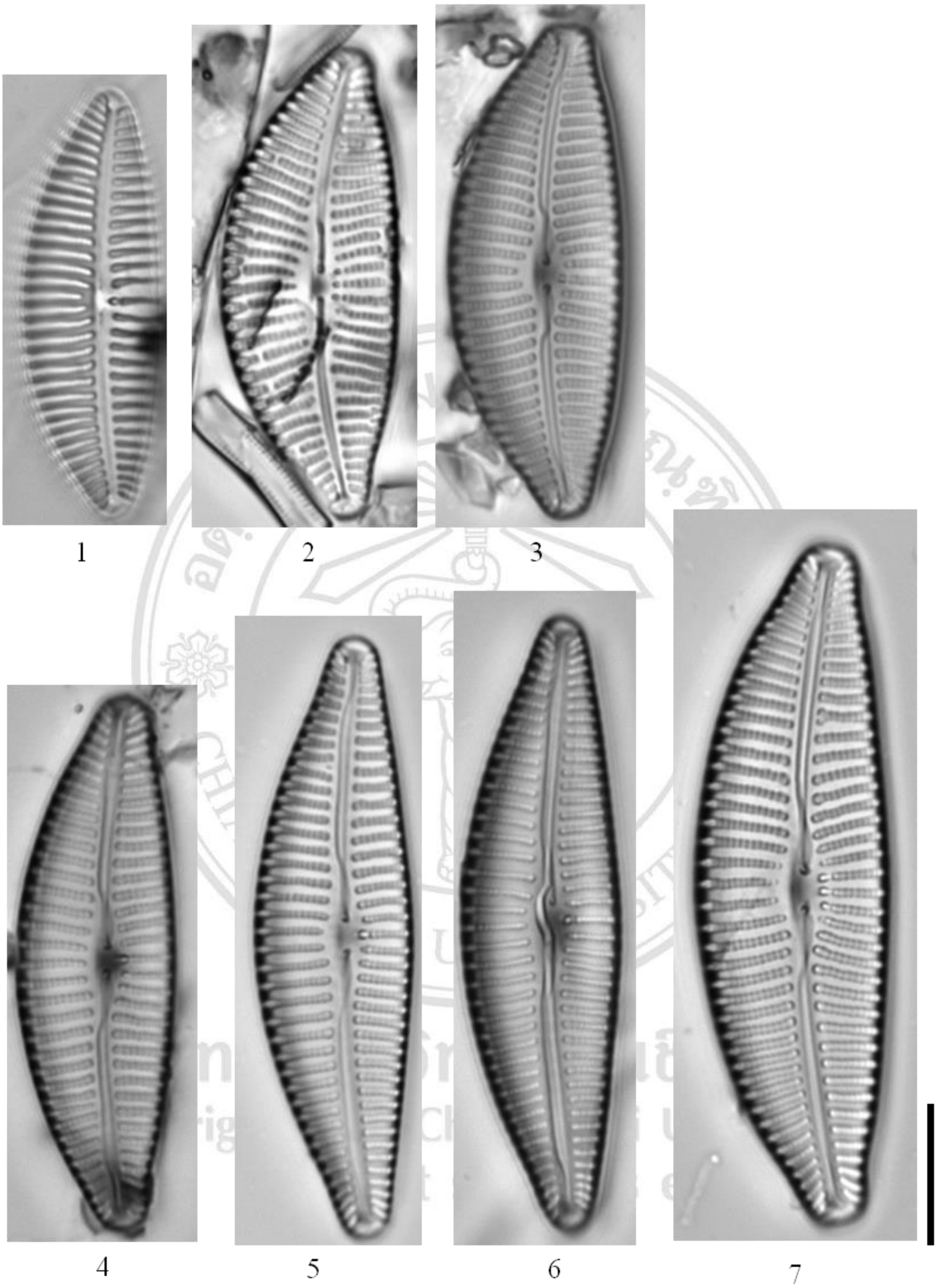
Scale bar = 10 µm.

Figure 17 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-7) *Planothidium frequentissimum* (Lange-Bertalot) Round & L. Bukhtiyarova, (8-9) *Planothidium* sp.1, (10-14) *Cymbella affinis* Kützing, (15-20) *Cymbella* sp.1



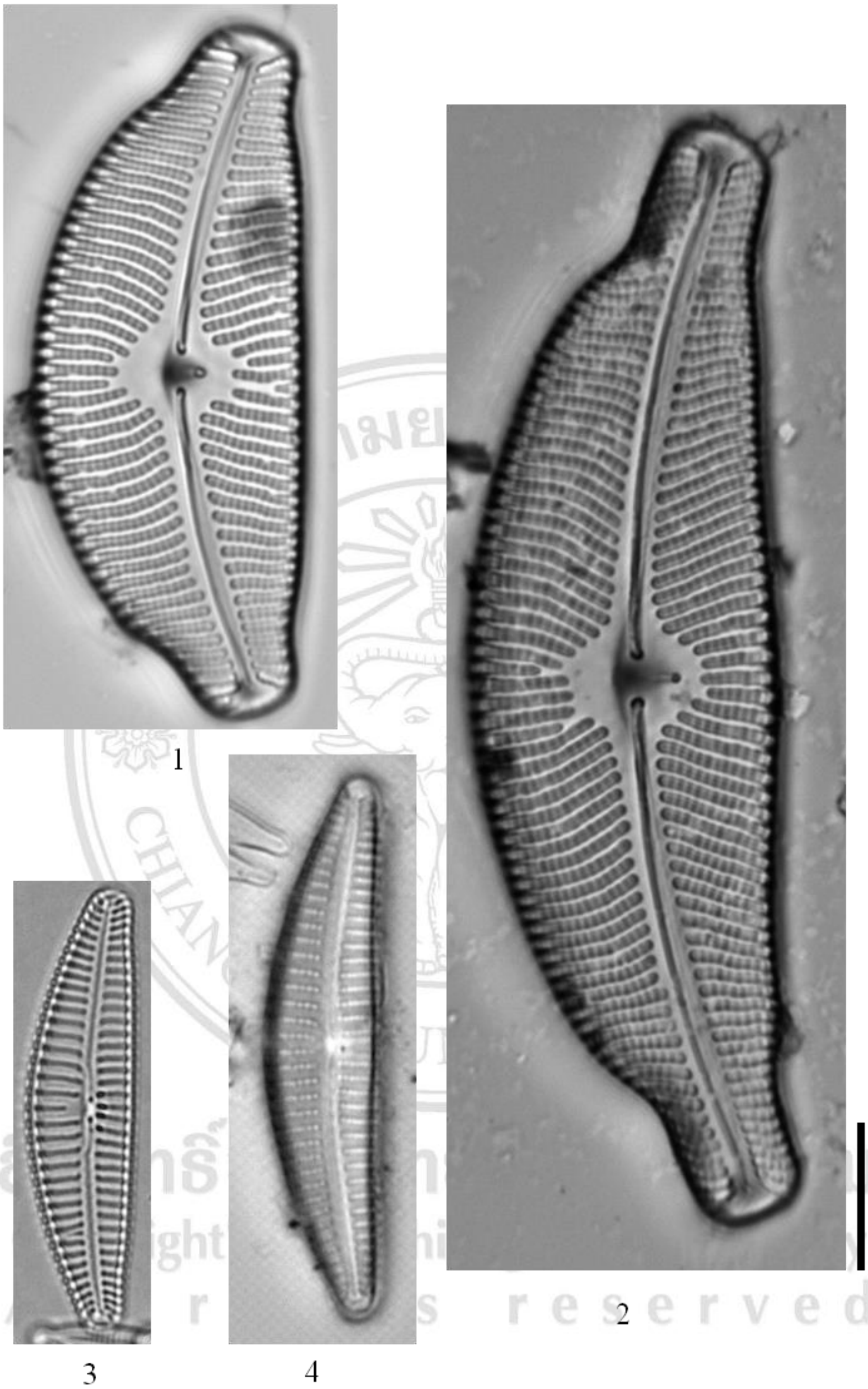
Scale bar = 10 µm.

Figure 18 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Cymbella* sp.2, (4-6) *Cymbella parva* (W.Smith) Kirchner, (7-10) *Cymbella subleptoceros* Krammer



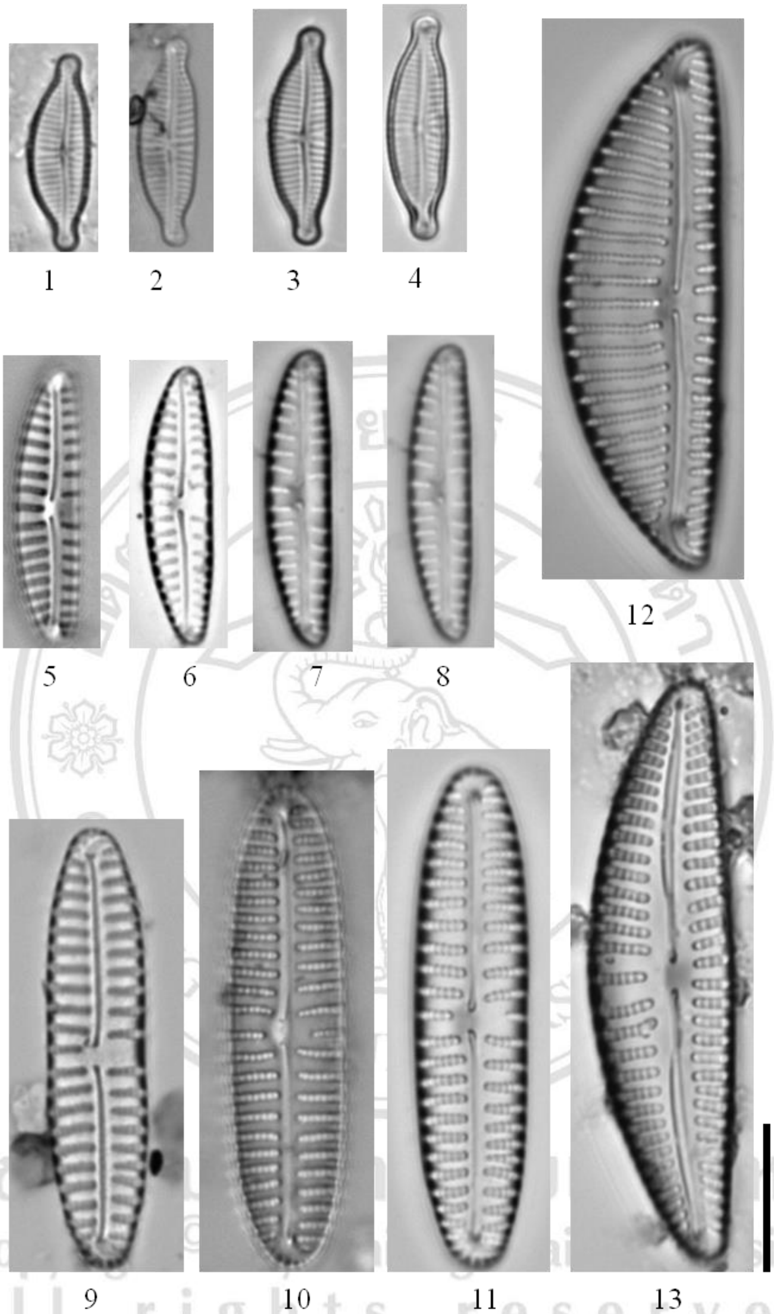
Scale bar = 10 µm.

Figure 19 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-7) *Cymbella turgidula* Grunow



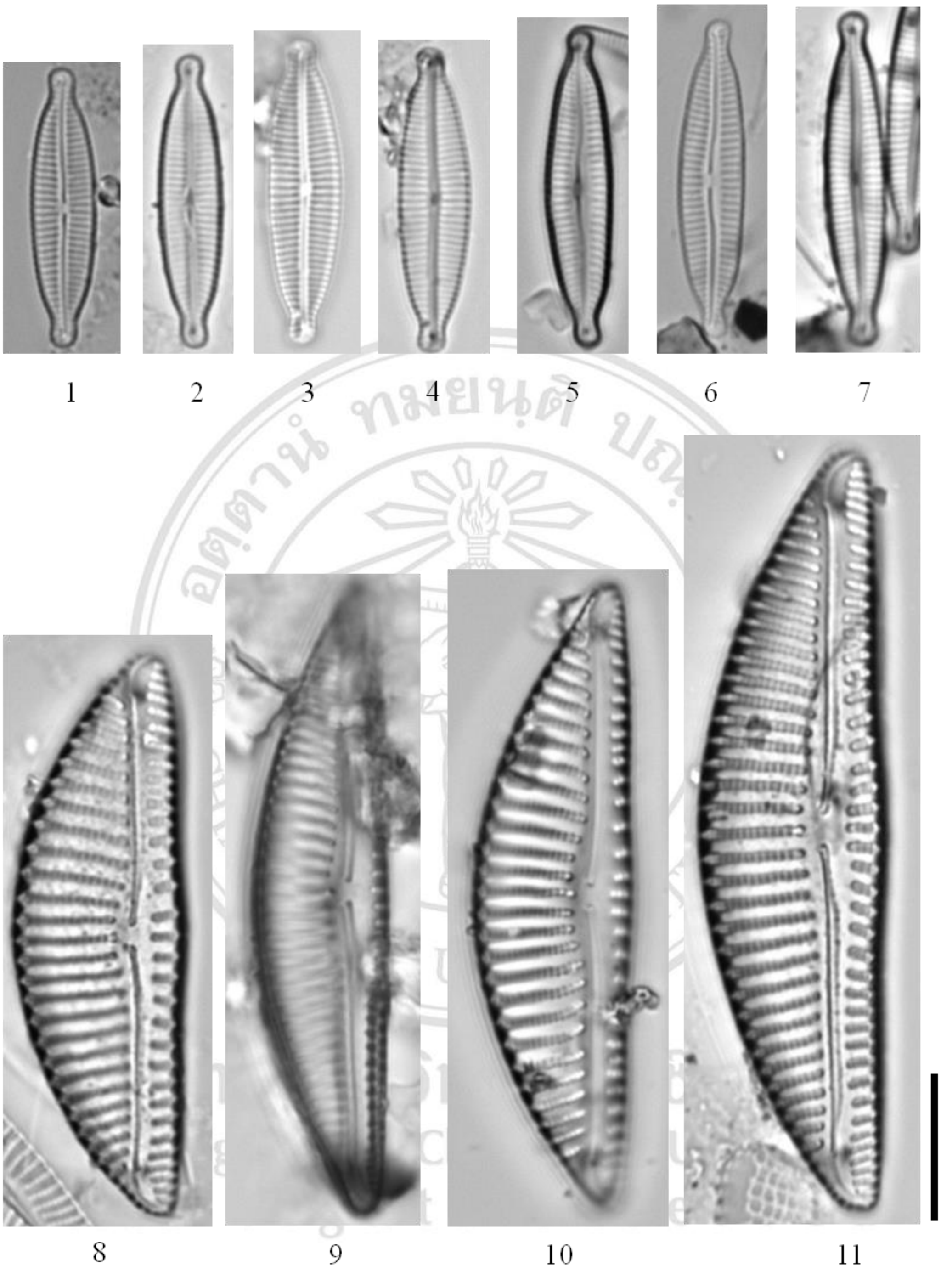
Scale bar = 10 µm.

Figure 20 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Cymbella tumida* (Brébisson) Van Heurck, (3-4) *Cymbella cistula* (Hemprich & Ehrenberg) O. Kirchner



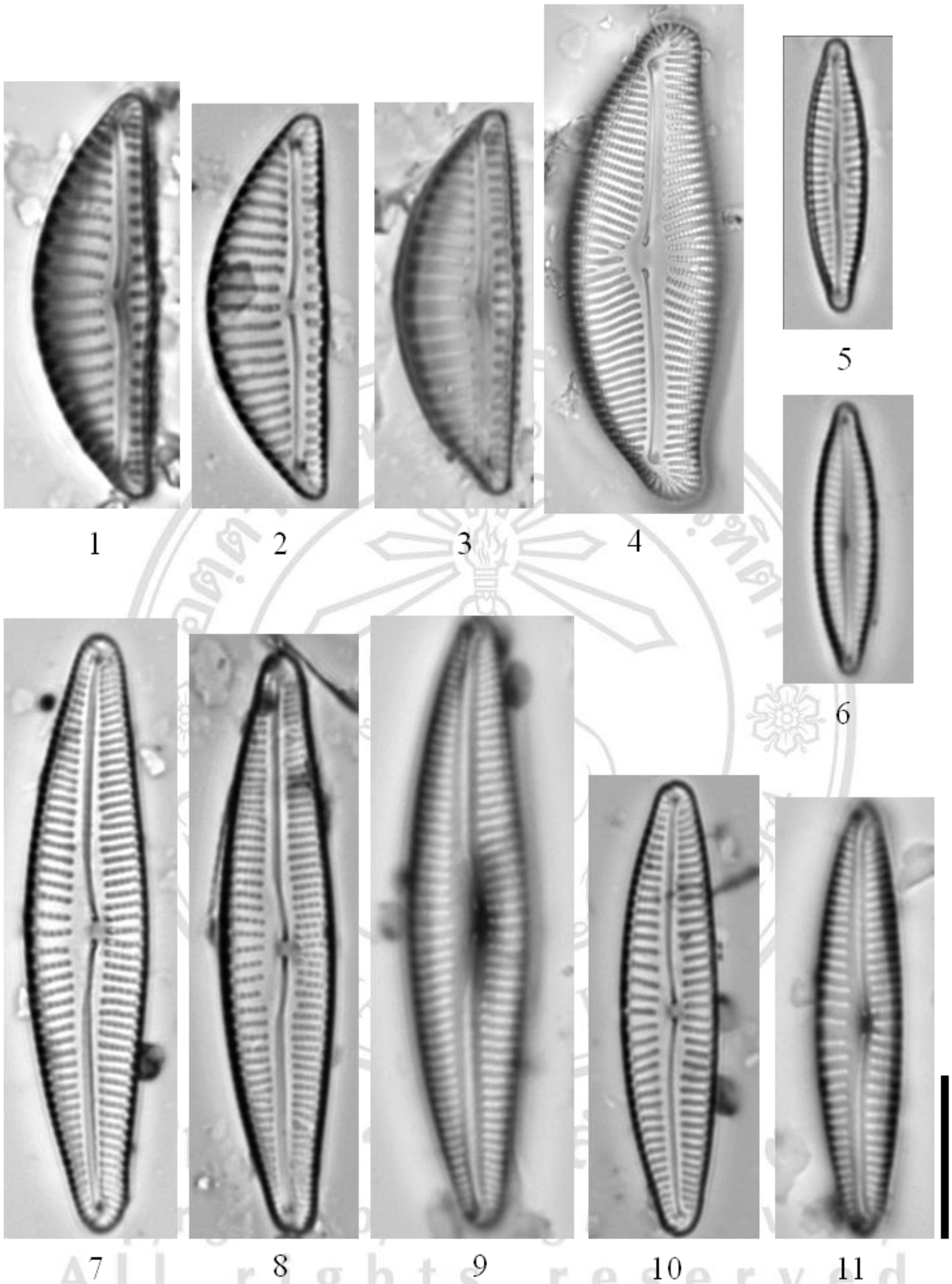
Scale bar = 10 µm.

Figure 21 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Encyonema gaeumannii* (Meister) Krammer, (5-8) *Encyonema malaysianum* Krammer, (9-11) *Encyonopsis leei* K. Krammer (12) *Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann in Round, Crawford & Mann, (13) *Encyonema* sp.1



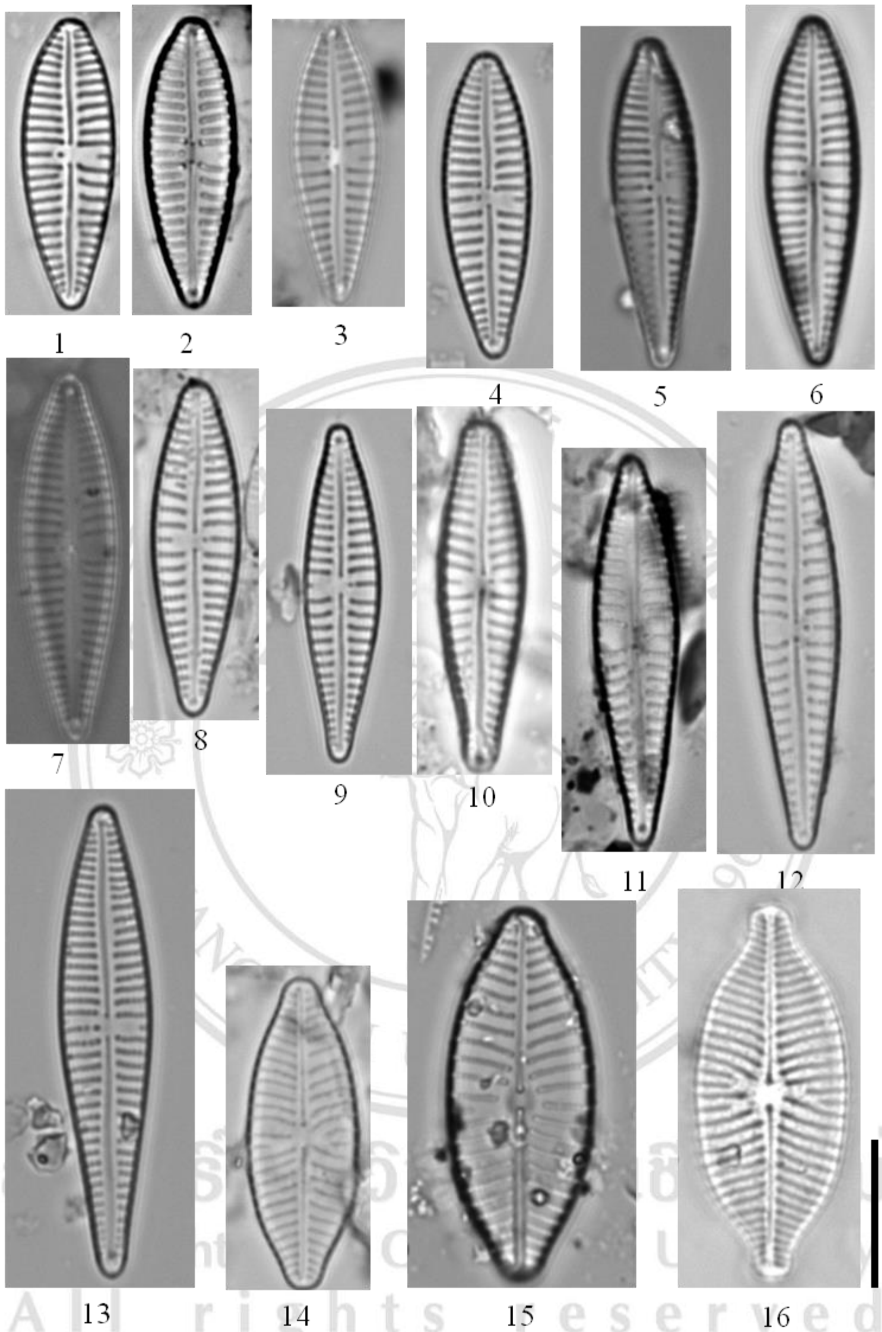
Scale bar = 10 µm.

Figure 22 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-7) *Encyonopsis microcephala* **(**Grunow) Krammer, (8-11) *Encyonema hustedtii* Krammer



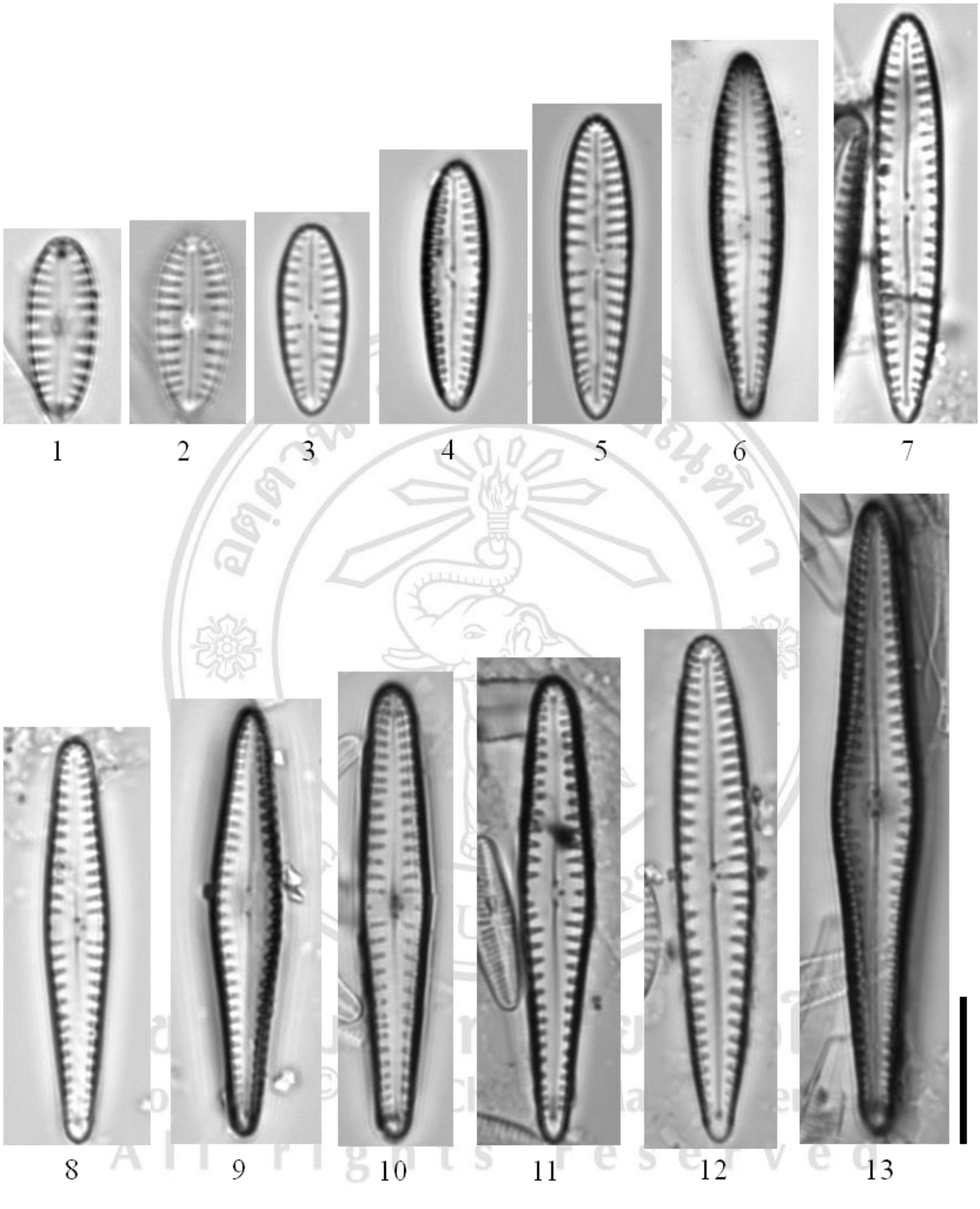
Scale bar = 10 µm.

Figure 23 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Encyonema mesianum* (Cholnoky) D.G.Mann in F.E. Round, R.M. Crawford & D.G. Mann, (4) *Encyonema prostratum* (Berkeley) Kützing, (5-6) *Delicata delicatula* (Kützing) Krammer, (7-11) *Delicata* cf. *sparsistriata* K. Krammer



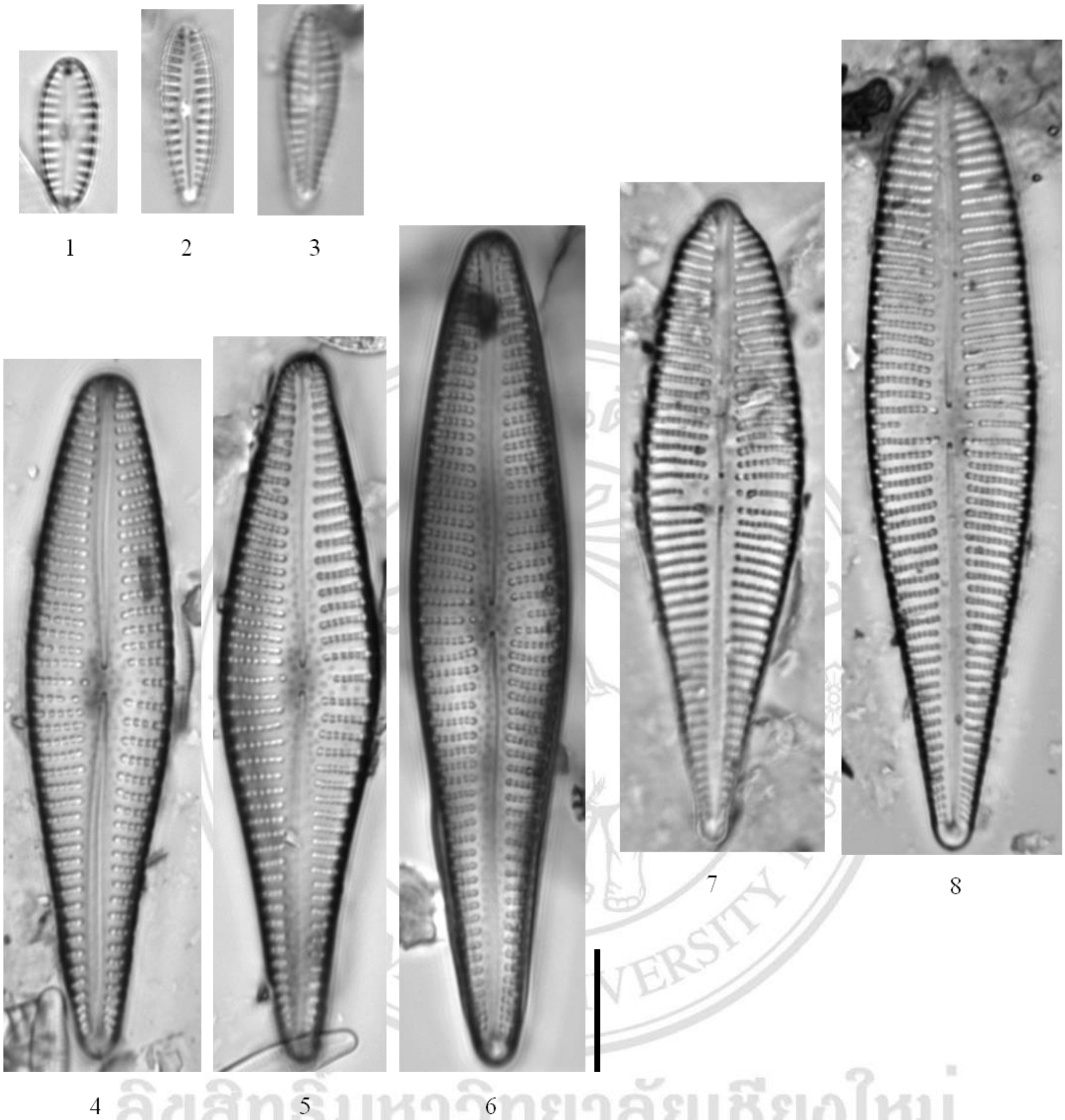
Scale bar = 10 µm.

Figure 24 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-13) *Gomphonema auritum* A. Braun ex Kützing, (14) *Placoneis witkowskii* Metzeltin, Lange-Bertalot & García-Rodríguez, (15) *Placoneis* cf. *elegans* Metzeltin, Lange-Bertalot & García-Rodríguez, (16) *Placoneis exigua* var. *capitata* Cox



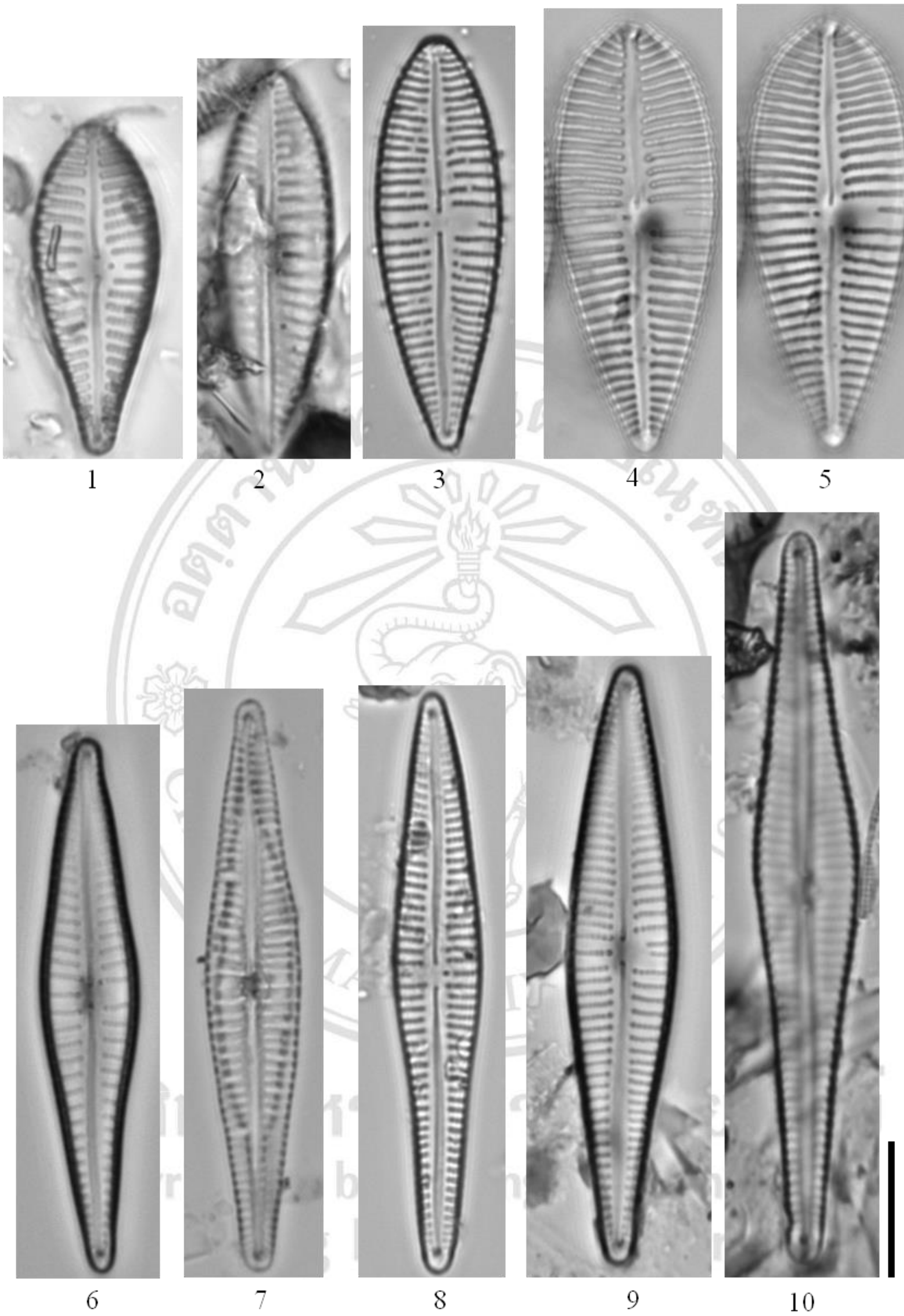
Scale bar = 10 µm.

Figure 25 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-13) *Gomphonema pumilum* (Grunow) Reichardt and Lange-Bertalot



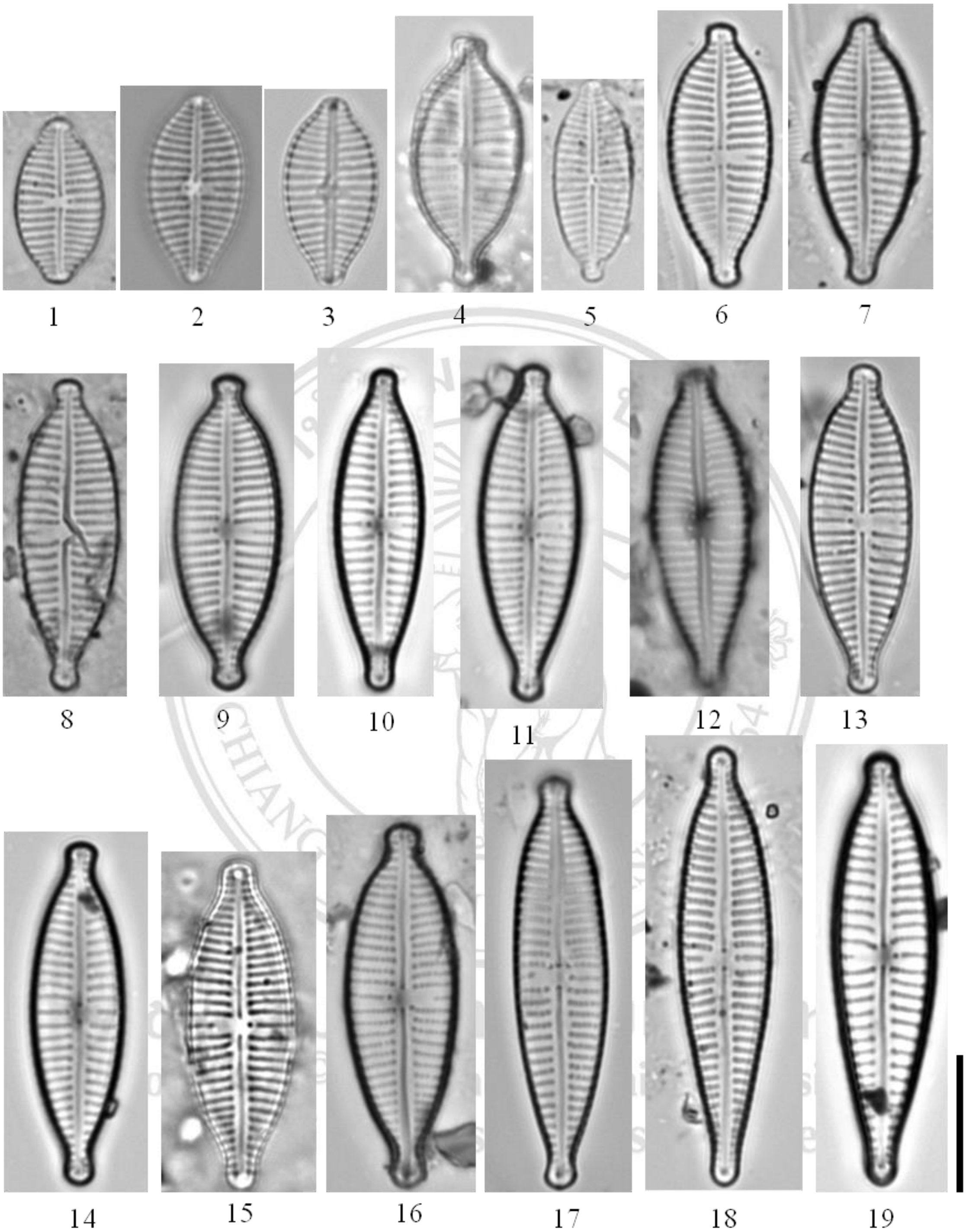
Scale bar = 10 µm.

Figure 26 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Gomphonema minatum* Agardh, (4-6) *Gomphonema affine* Kützing, (7-8) *Gomphonema turris* Ehrenberg



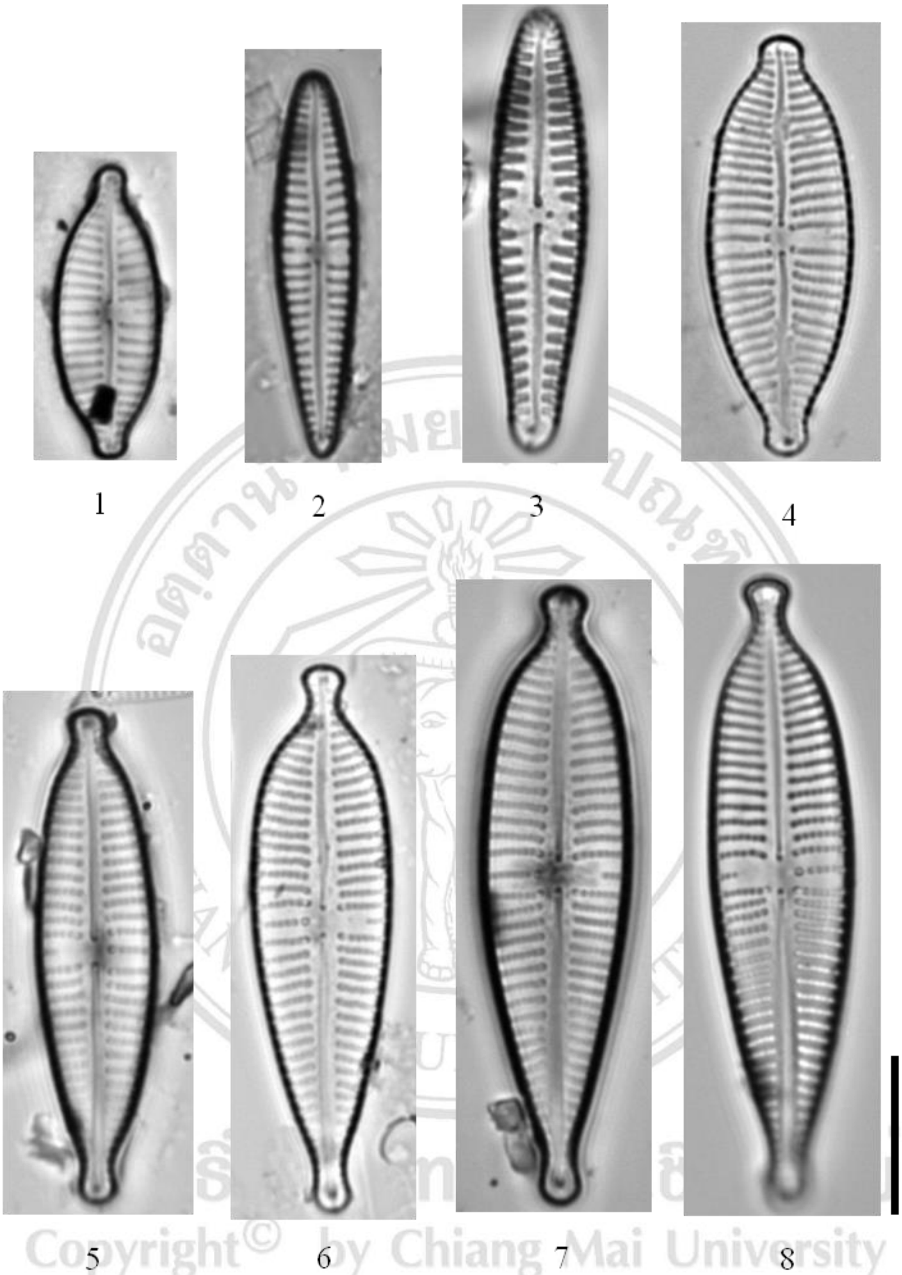
Scale bar = 10 µm.

Figure 27 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-5) *Gomphonema pseudoaugur* Lange-Bertalot, (6-10) *Gomphonema gracile* Ehrenberg



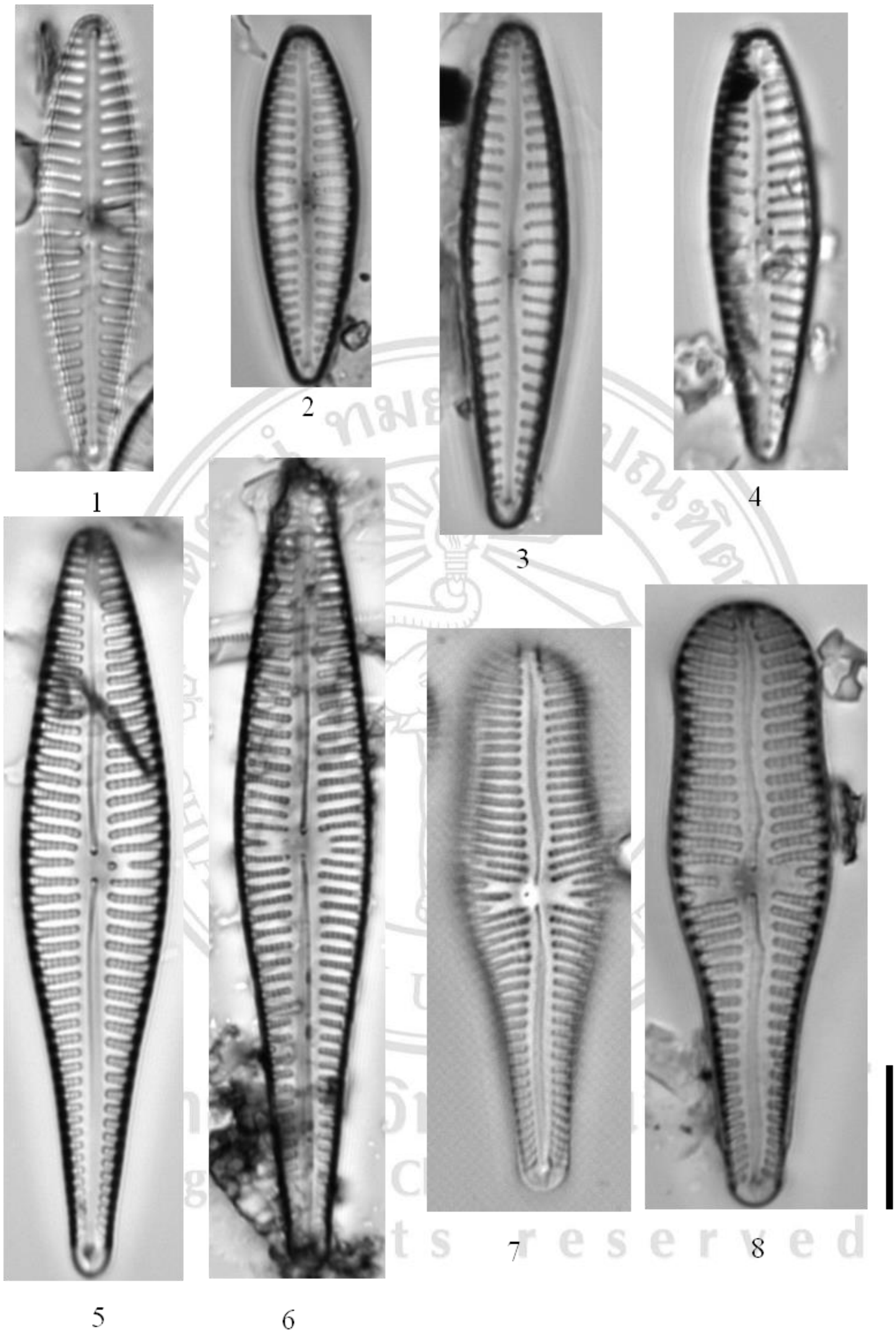
Scale bar = 10 µm.

Figure 28 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-19) *Gomphonema parvulum* Kützing



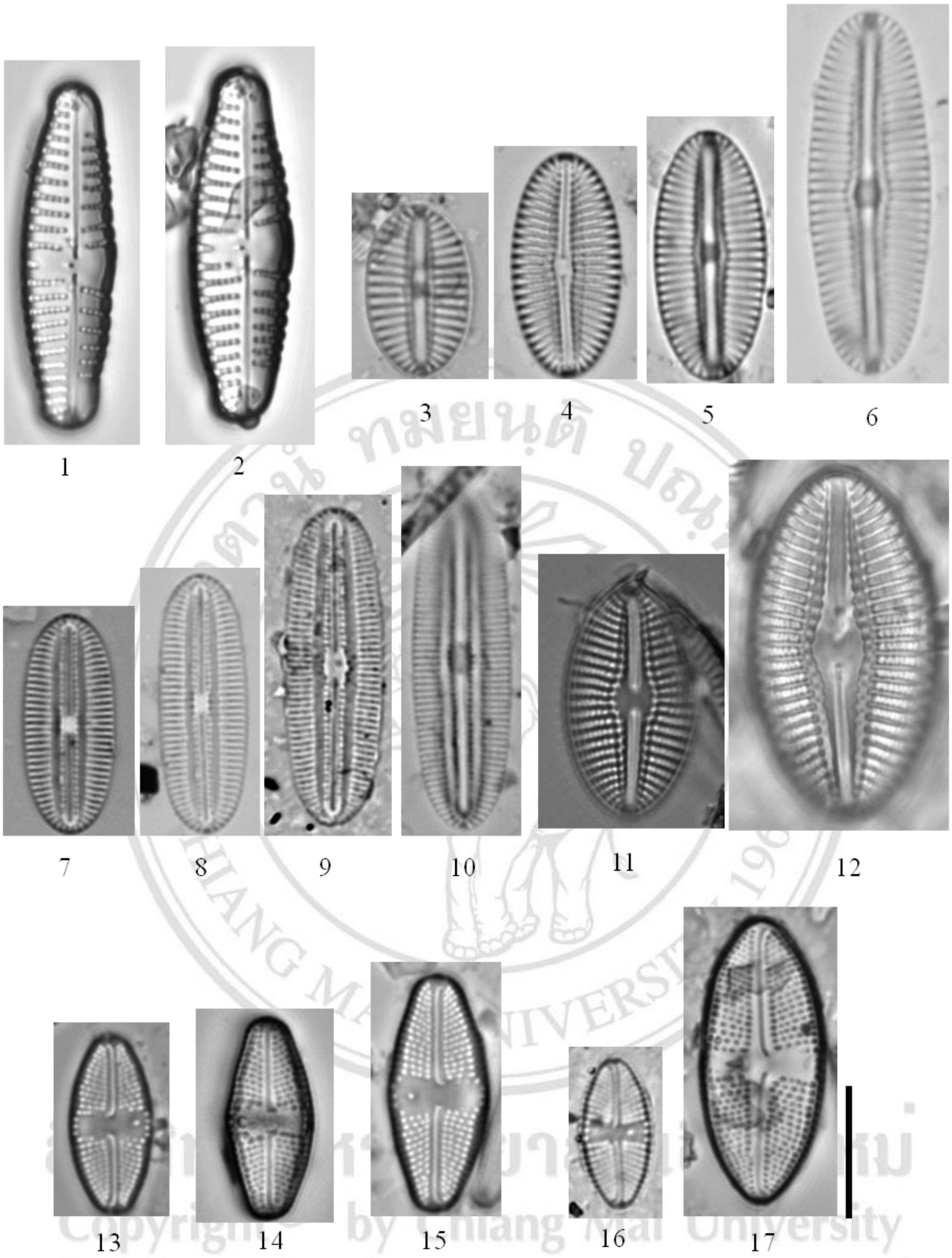
Scale bar = 10 µm.

Figure 29 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Gomphonema productum* Grunow, (2) *Gomphonema bohemicum* Reichelt & Schmids, (3) *Gomphonema javanicum* Hustedt, (4-8) *Gomphonema lagenulum* H. Kobayashi



Scale bar = 10 µm.

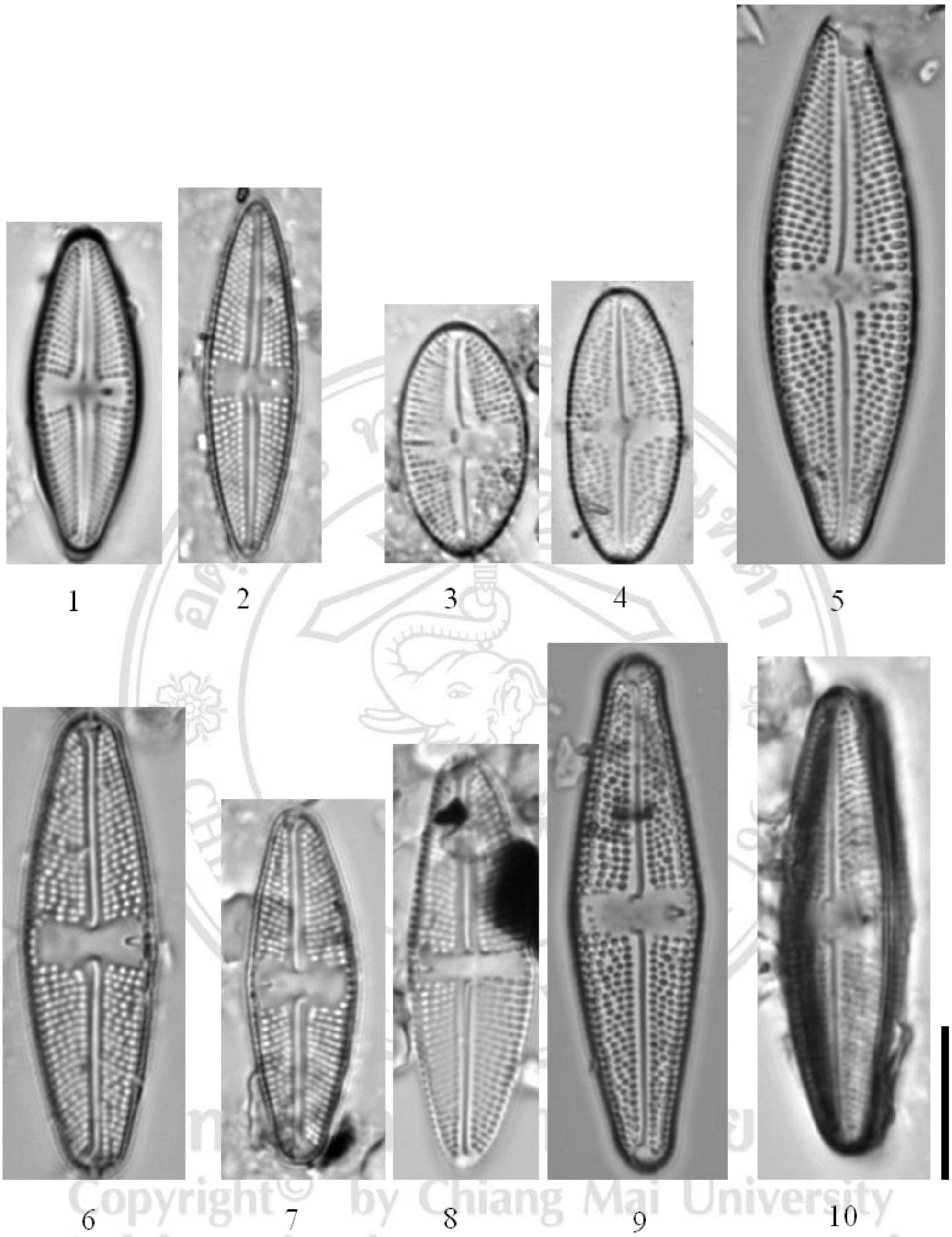
Figure 30 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Gomphonema micropus* Kützing, (5-6) *Gomphonema lanceolatum* Ehrenberg, (7-8) *Gomphonema truncatum* E. Reichardt



Scale bar = 10 µm.

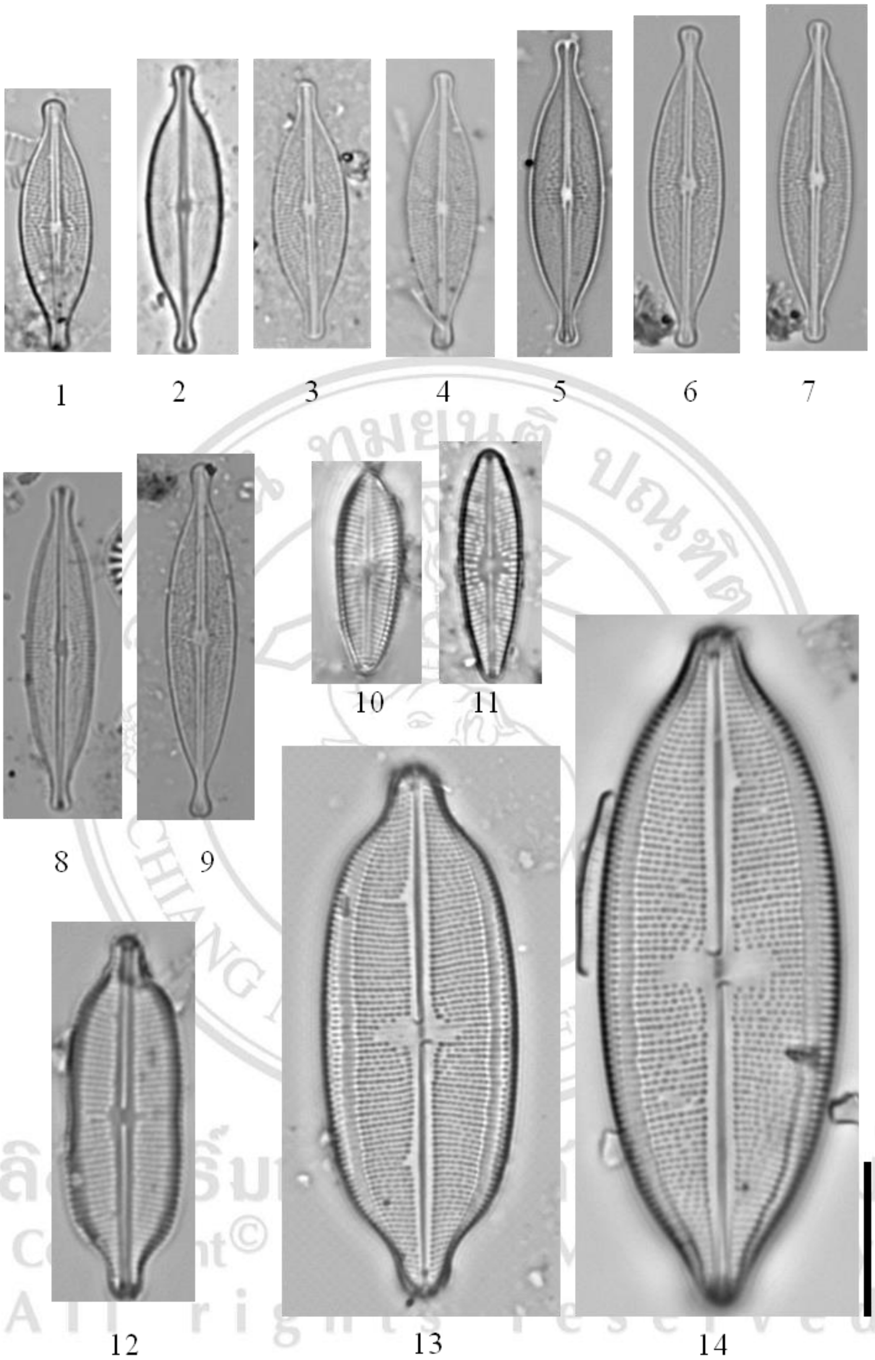
Figure 31 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1-2) *Reimeria uniseriata* Sala, Guerrero & Ferrario, (3-6) *Diploneis oblongella* (Nägeli ex Kützing) Cleve-Euler in Cleve-Euler & Osvald, (7-10) *D. oculata* (Breb) Cleve, (11-12) *D. smithii* Cleve, (13-15) *Luticola simplex* Metzeltin, Lange-Bertalot & Rodriquez (16-17) *L.* cf. *pseudokotschyi* Lange-Bertalot



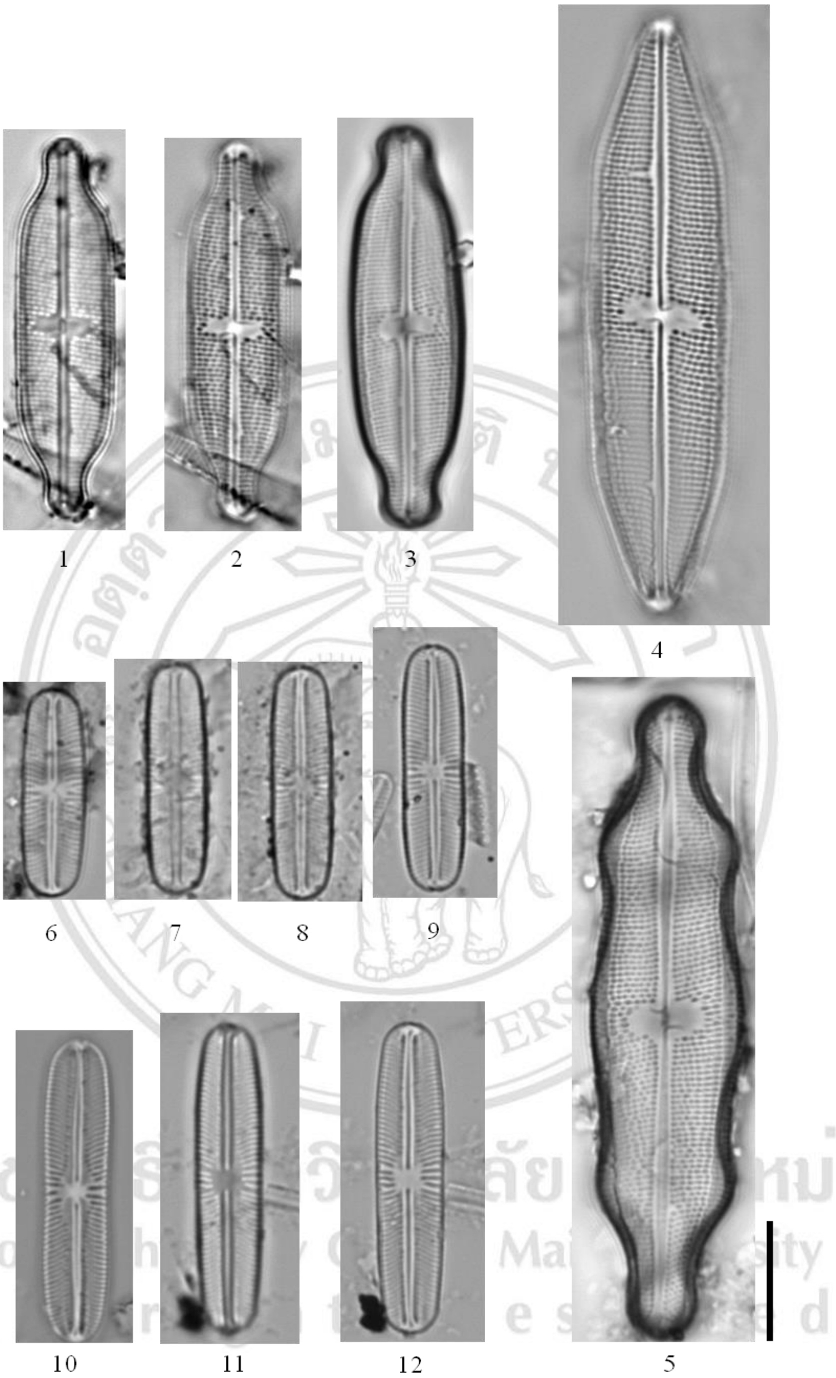
Scale bar = 10 µm.

Figure 32 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Luticola mutica* var. *lanceolata* (Frenguelli) M. Aboal, (3-4) *L. saxophila* (Bock ex Hustedt) D.G. Mann, (5) *L. tropica* (Hustedt) Johansen, (6-8) *L.* sp.1, (9-10) *L. mitigata* (Hustedt) D.G. Mann



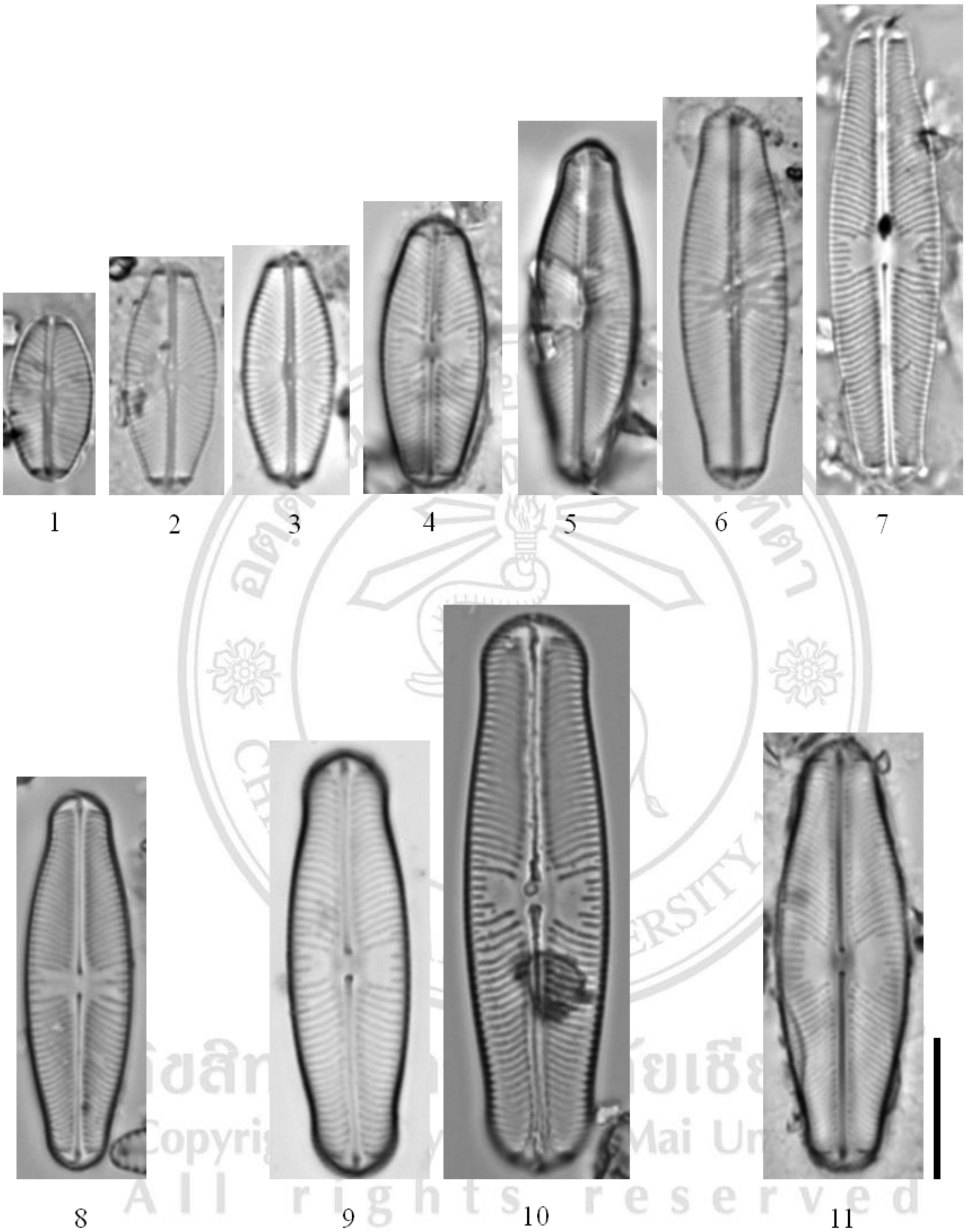
Scale bar = 10 µm.

Figure 33 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-9) *Brachysira neoexilis* Lange-Bertalot, (10-11) *B.* cf. *microclava* Lange-Bertalot & Gerd Moser, (12) *Neidium binodeforme* Krammer, (13-14) *N. dubium* (Ehrenberg) Cleve



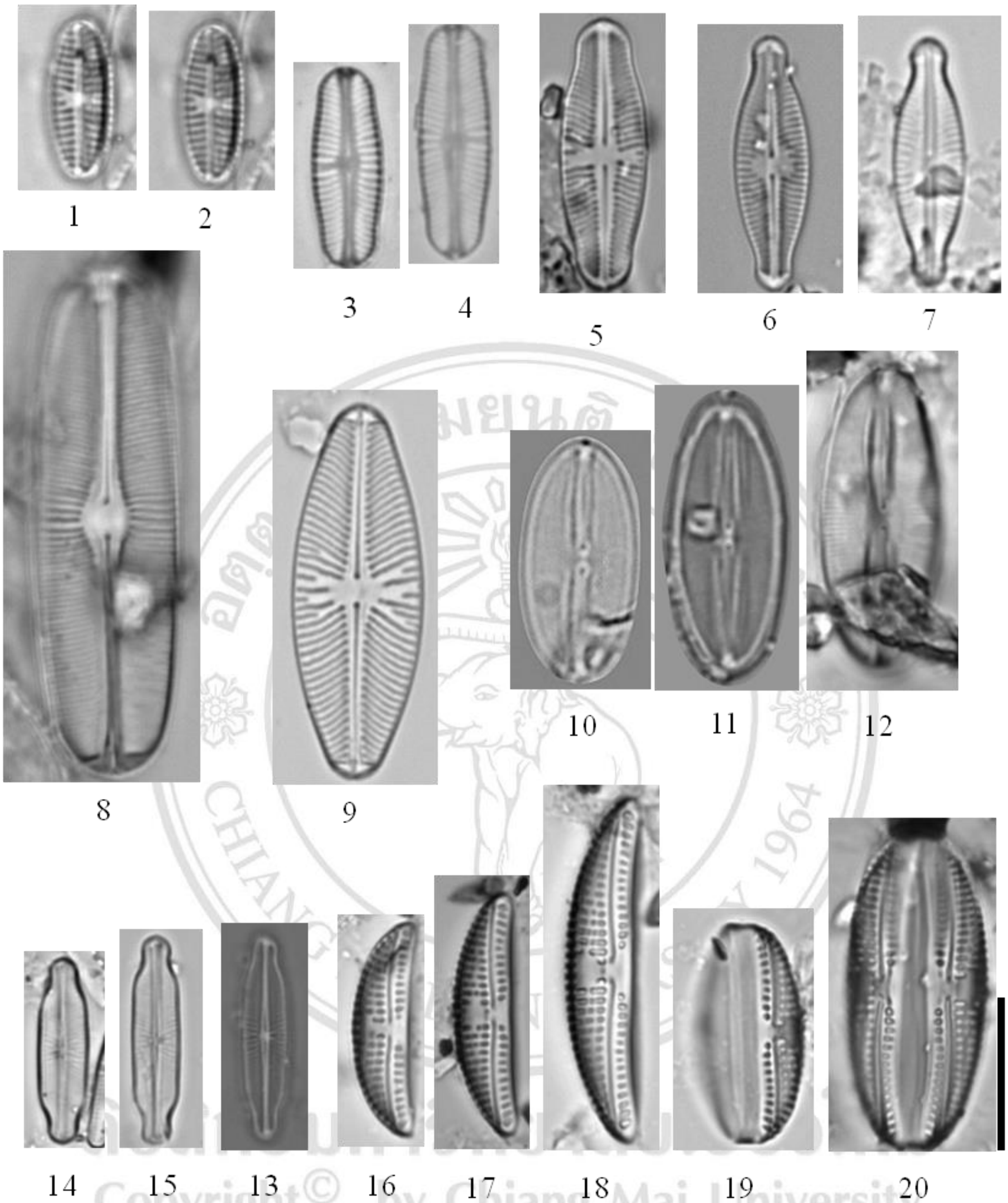
Scale bar = 10 µm.

Figure 34 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Neidium longiceps* (Gregory) R. Ross, (4) *N. affine* (Ehrenberg) Pfizer (5) *N. gracile* (Hustedt), (6-12) *Sellaphora subbacillum* (Hustedt) Falasco & Ector



Scale bar = 10 µm.

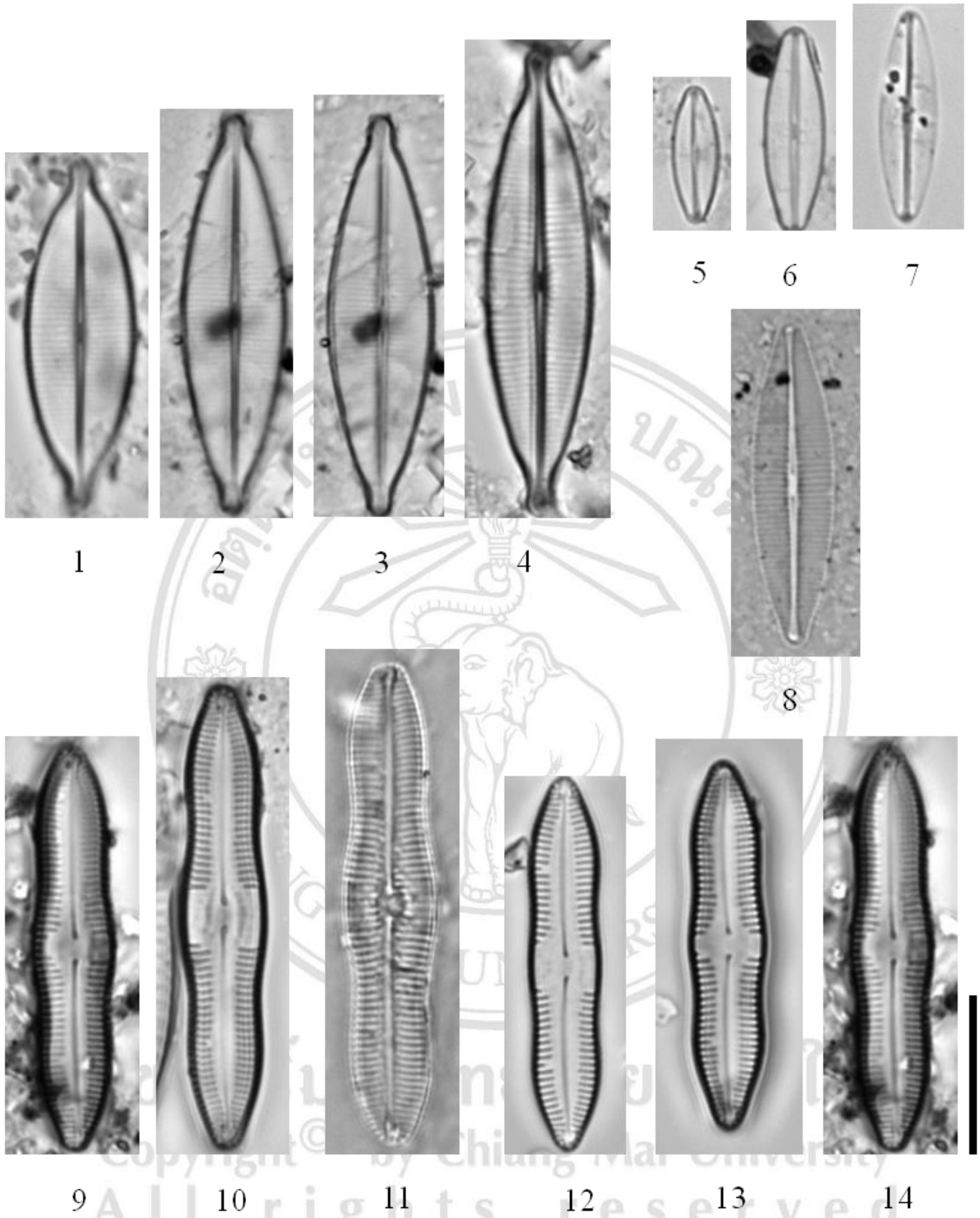
Figure 35 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-7) *Sellaphora lanceolata* D.G. Mann & S.Droop, (8) *S. pupula* (Kützing) Mereschkovsky, (9-10) *S. blackfordensis* D.G. Mann & S. Droop, (11) *Sellaphora obesa* D.G. Mann *et* M.M. Bager



Scale bar = 10 µm.

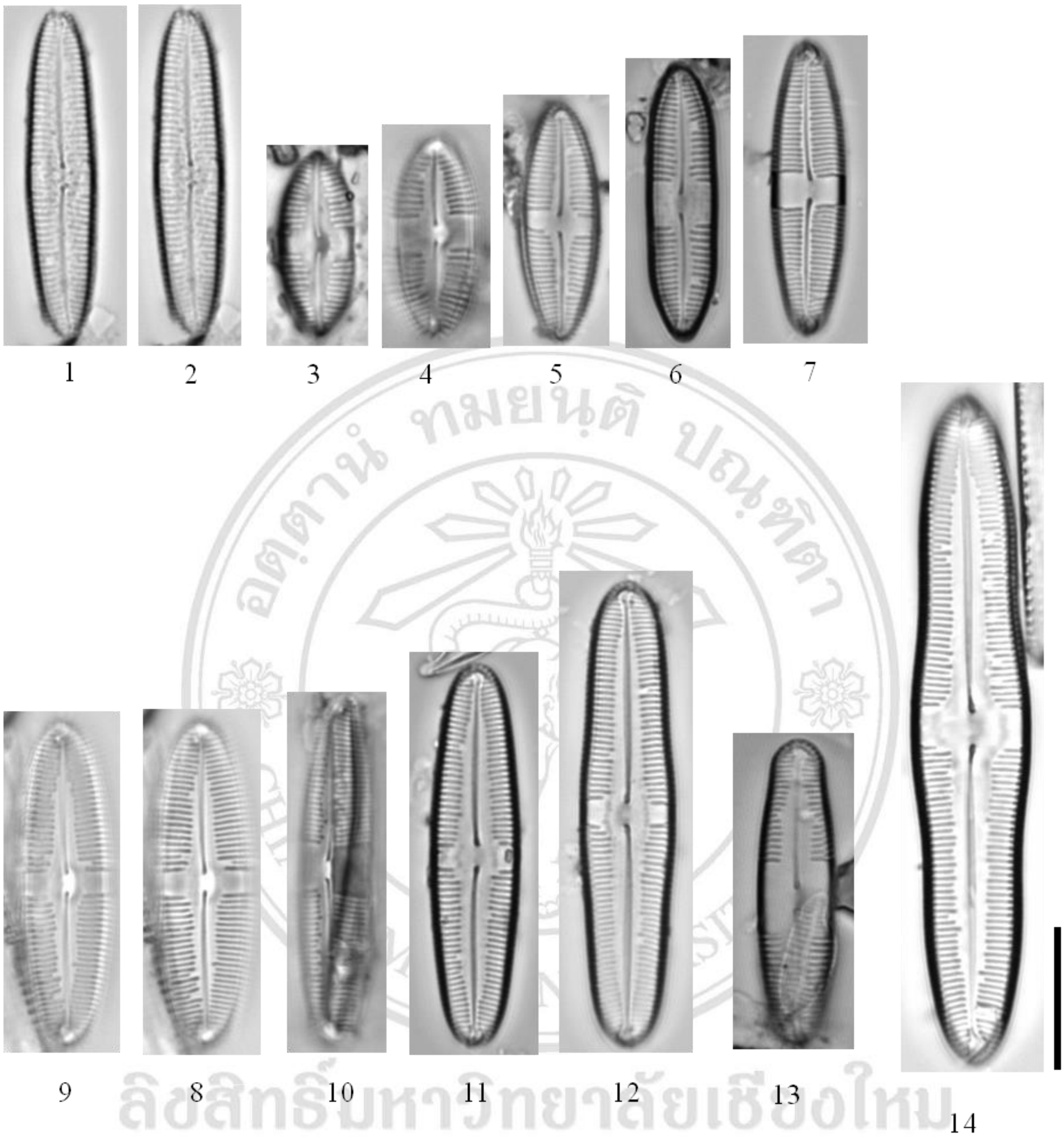
Figure 36 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1-2) *Sellaphora seminulum* (Gronow) D.G. Mann, (3-4) *S. stroemii* Hustedt, (5) *S. capitata* D.G. Mann *et* S.M. Mcdonal, (6-7) *S.* sp.1, (8) *S. bacillum* (Ehrenberg) D.G. Mann, (9) *S.* sp.2, (10-12) *Fallacia pygmaea* (Kützing) A.J. Stickle & D.G. Mann, (13-15) *Adlafia bryophila* (J.B. Petersen) Gerd Moser, Lange-Bertalot & D. Metzeltin, (16-20) *Amphora* cf. *liriope* Nagumo



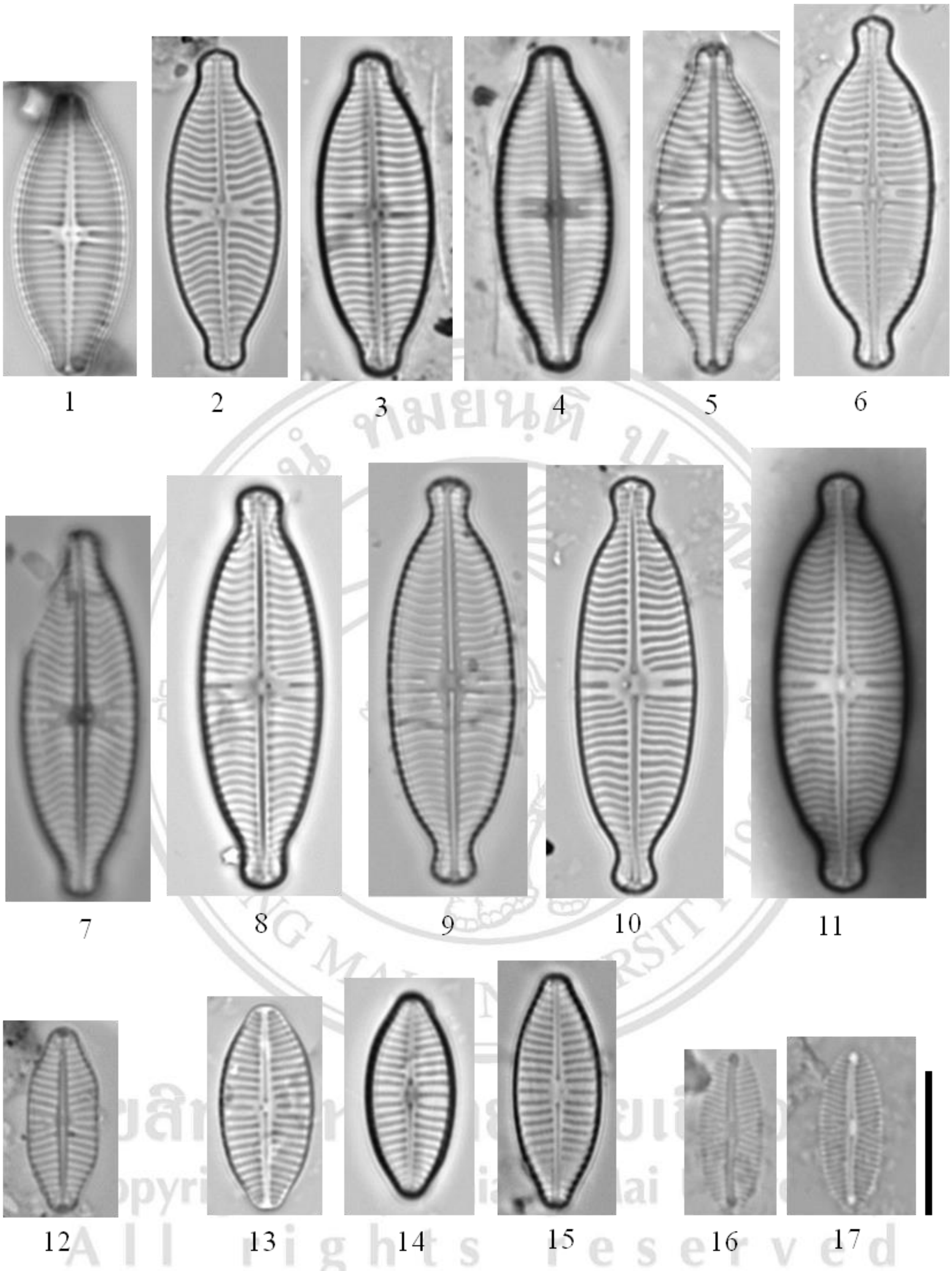
Scale bar = 10 µm.

Figure 37 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Craticula riparia* var. *mollenhaueri* Lange-Bertalot, (5-7) *C. molestiformis* (Hustedt) Mayama, (8) *C. vixnegligenda* Lange-Bertalot, (9-10) *Caloneis siricula* cf. *alpina* (Cleve) Krammer, (11) *C.* sp. 1, (12-14) *C. ventricosa* (Cleve) Krammer



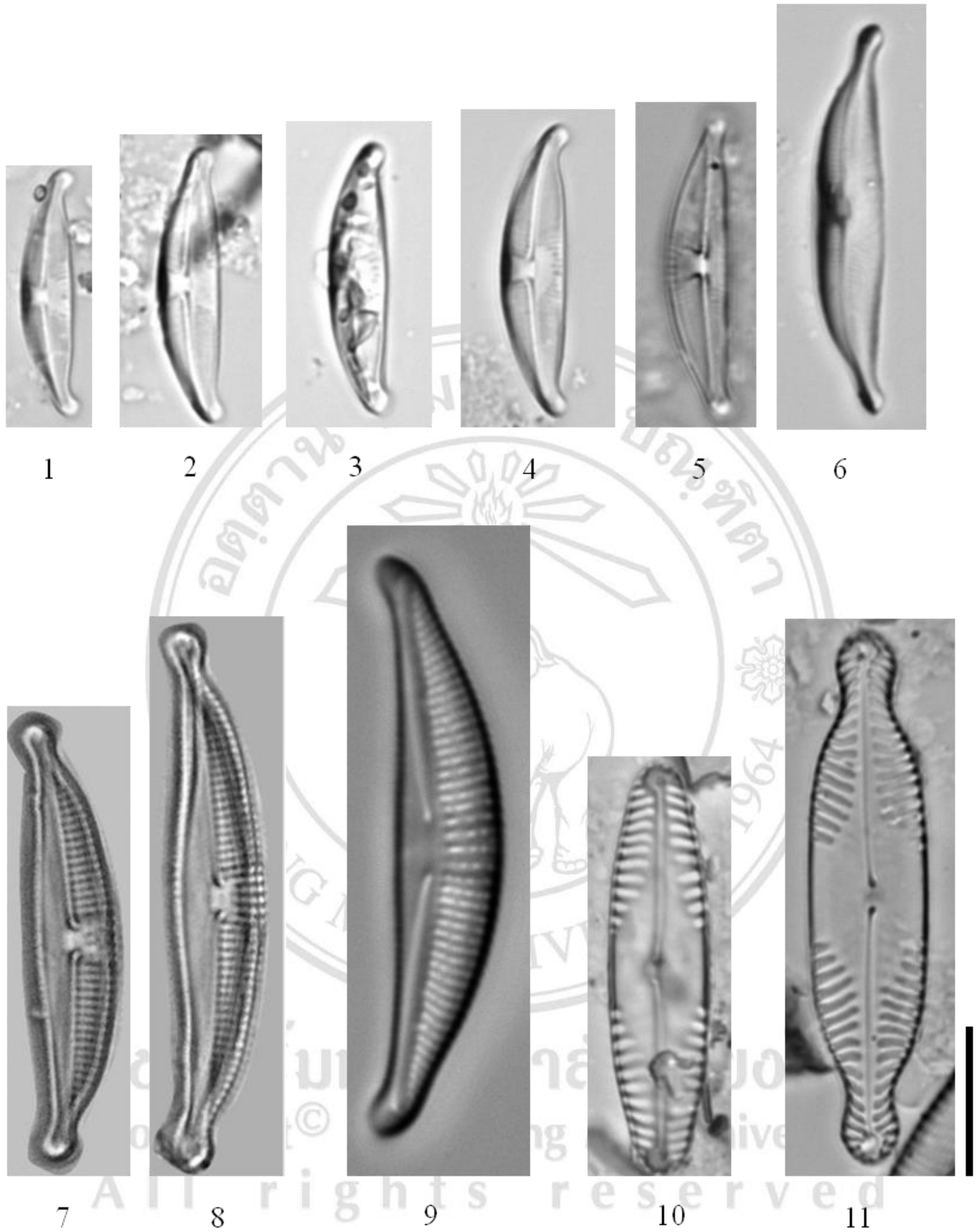
Scale bar = 10 µm.

Figure 38 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Caloneis tenuis* (W. Gregory) Krammer, (3-12) *C. bacillum* (Ehrenberg) Cleve, (13) *C.* sp.2, (14) *C. silicula* var. *peisonis* (Gronow) Krammer



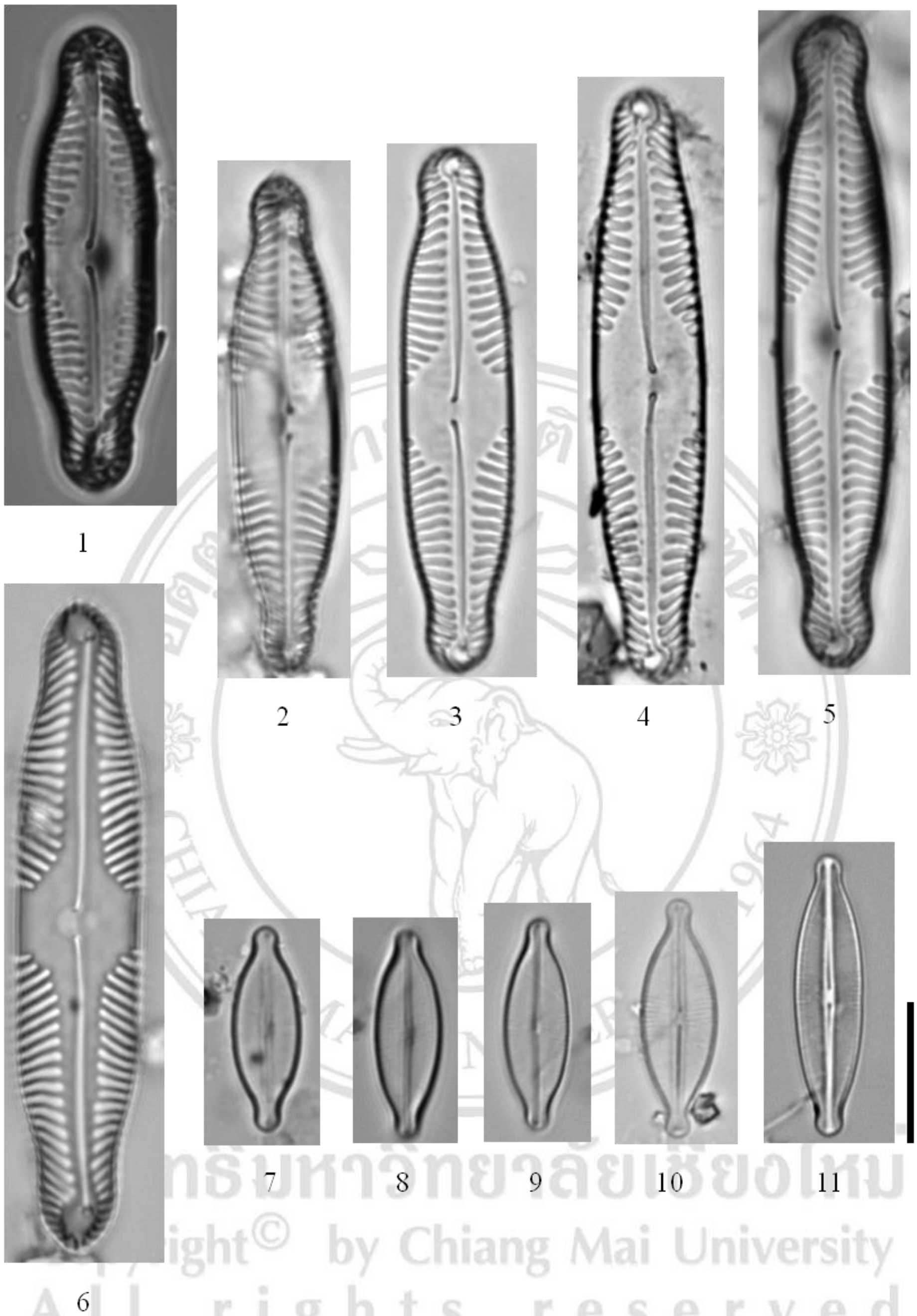
Scale bar = 10 µm.

Figure 39 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-11) *Geisleria decussis* (Østrup) Lange Bertalot & Metzeltin, (12) *G. cummerowi* (Kützing) Lange-Bertalot, (13-15) *G. punctifer* (Hustedt) Metzeltin,Lange- Bertalot & Garcia-Rodriguez, (16-17) *Mayamaea agrestis* (Kützing) H. Lange-Bertalot



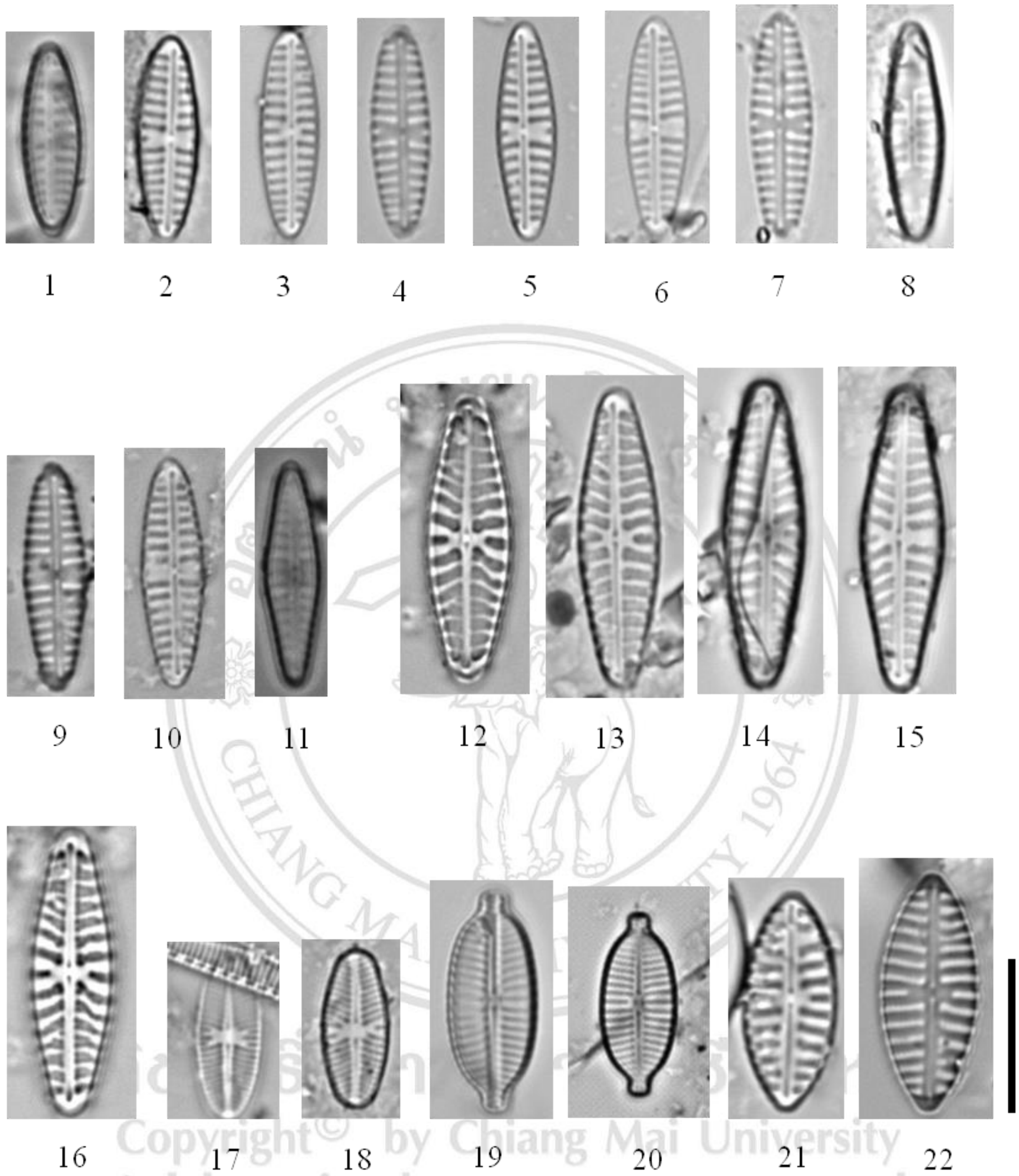
Scale bar = 10 µm.

Figure 40 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-6) *Halamphora montana* (Krasske) Levkov, (7-8) *H. bullatoides* Hohn & Hellerman Levkov, (9) *H. veneta* (Kützing) Levkov, (10) *Pinnularia* sp.1, (11) *Pinnularia biceps* W. Gregory



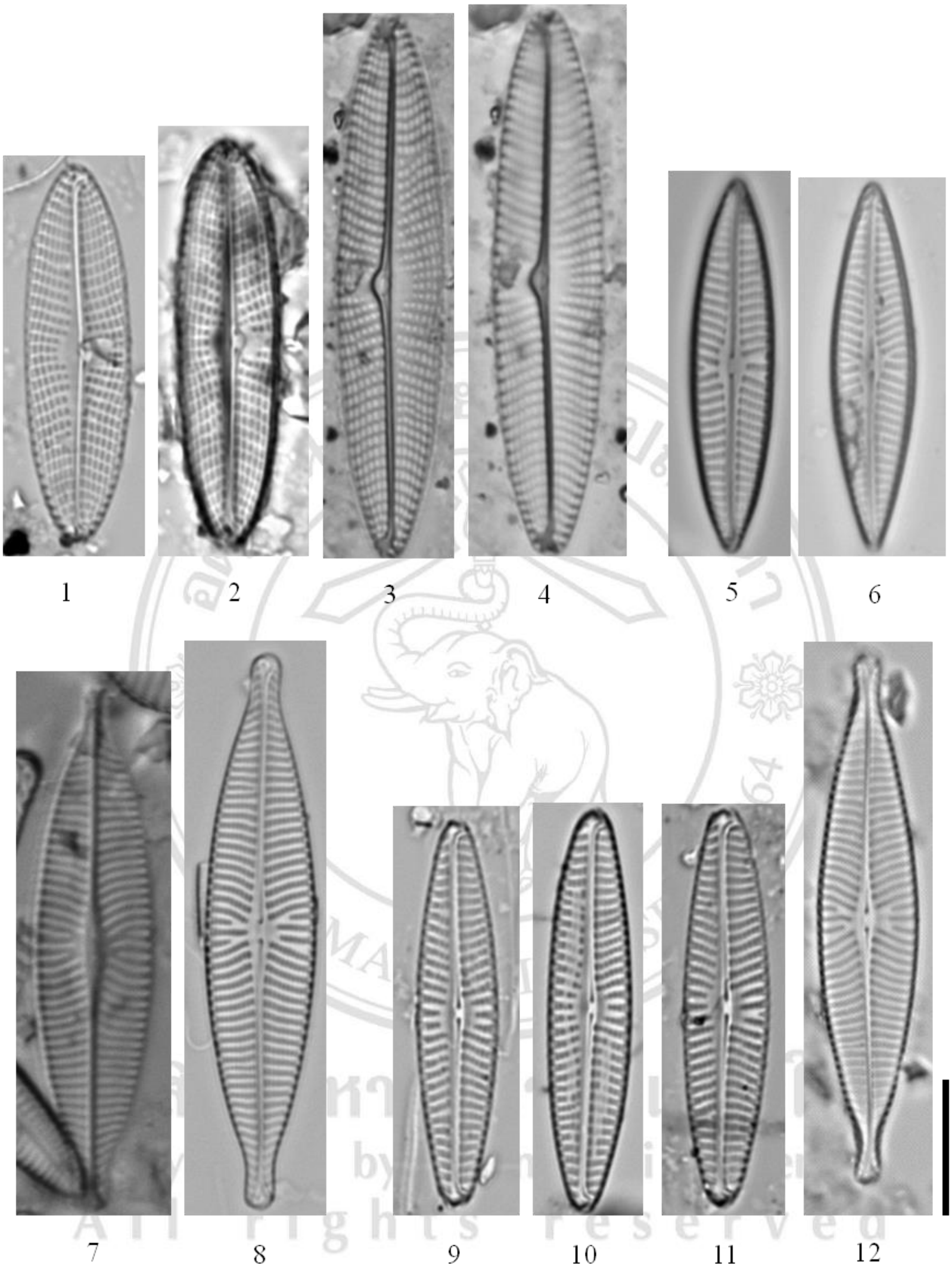
Scale bar = 10 µm.

Figure 41 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-6) *Pinnularia acidojaponica* Idei & H. Kobayashi, (7-11) *Kobayasiella* sp.1



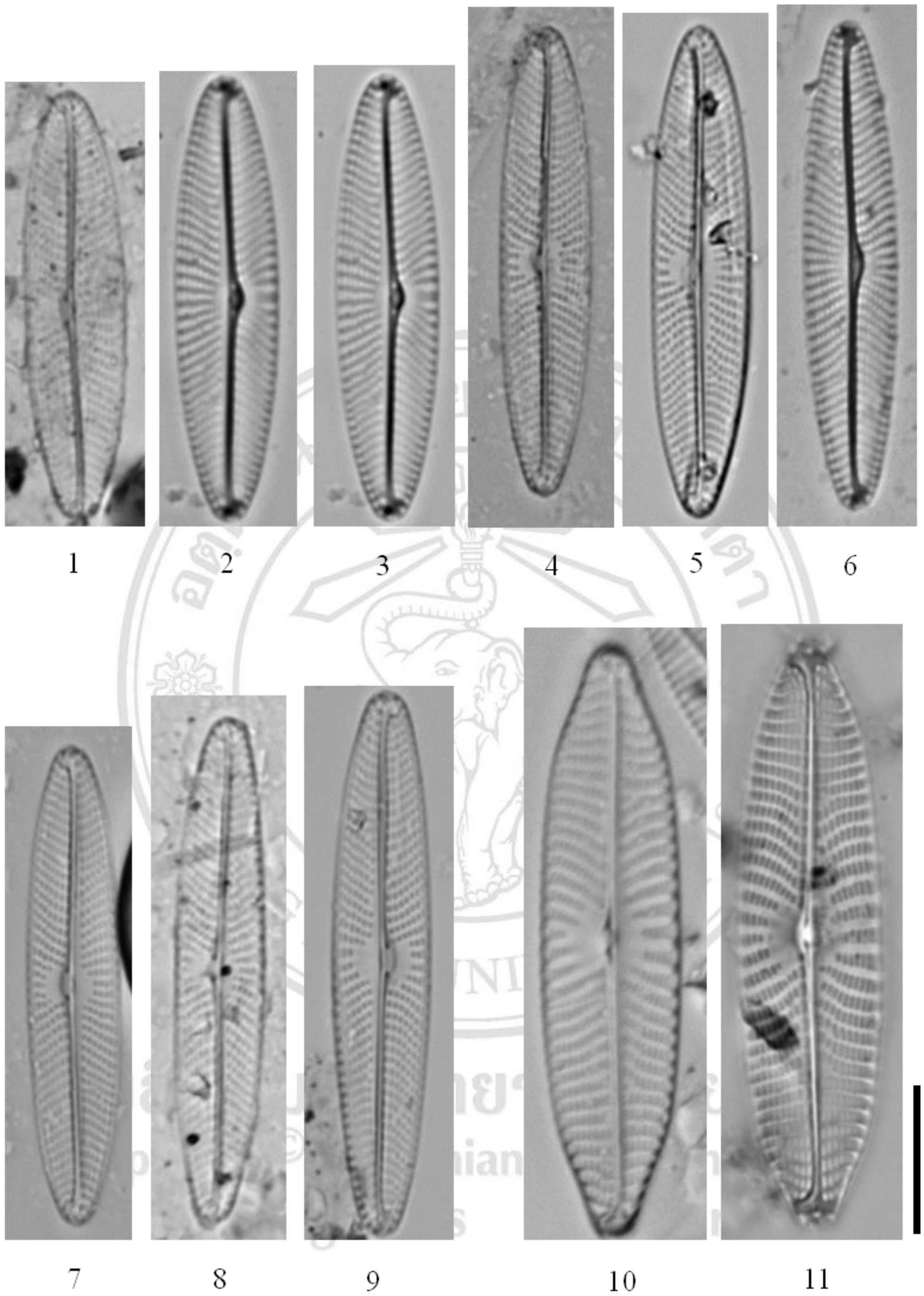
Scale bar = 10 µm.

Figure 42 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-11) *Hippodonta pseudoacceptata* (Kobayashi) comb nov, (12-16) *H. avittata* Cholnoky, (17-18) *Eolimna minima* (Grunow) Lange-Bertalot, (19-20) *Naviculadicta nanogomphonema* Lange-Bertalot, (21-22) *Navicula* cf. *antonii* Lange-Bertalot



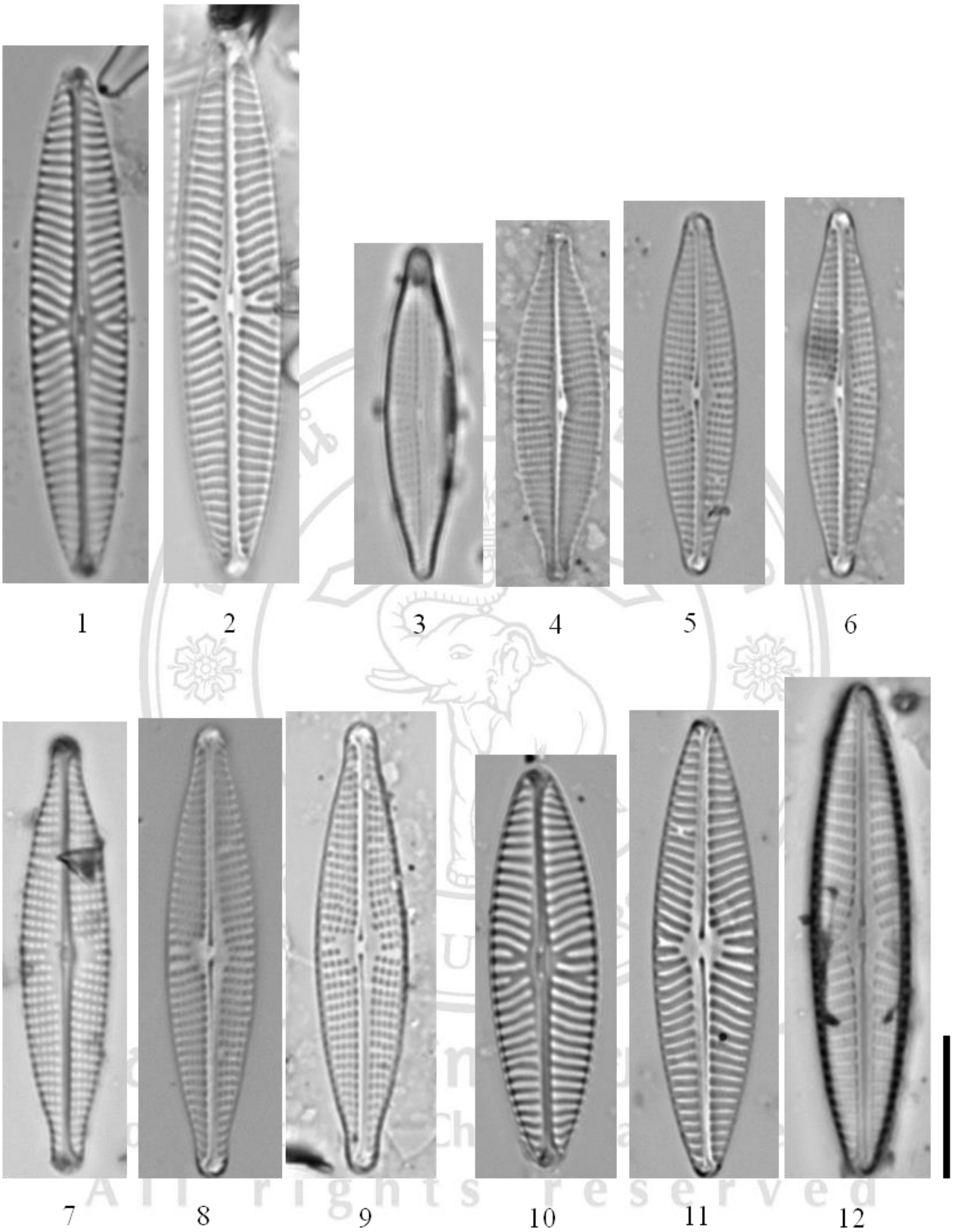
Scale bar = 10 µm.

Figure 43 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Navicula escambia* (Patrick) Metzelin *et* Lange-Bertalot, (5-6) *N. surprinii* Moser Lange-Bertalot et Metzeltin, (7-9) *N. capitatoradiata* Germain, (10-12) *N. erifuga* Lange-Bertalot



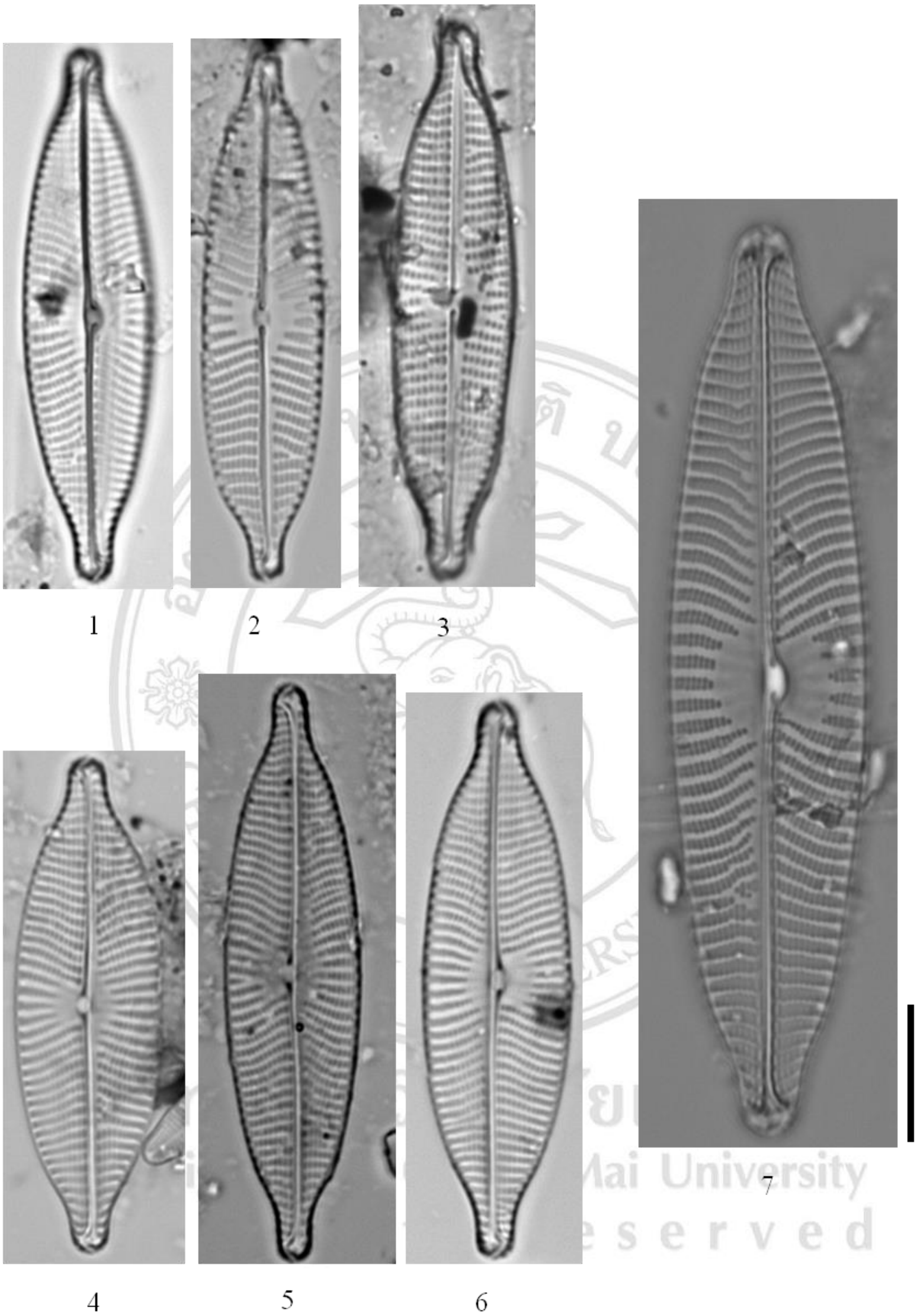
Scale bar = 10 µm.

Figure 44 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-9) *Navicula simulata* Manguin, (10-11) *N. viridulacalcis* Lange-Bertalot in Rumrich *et al.*



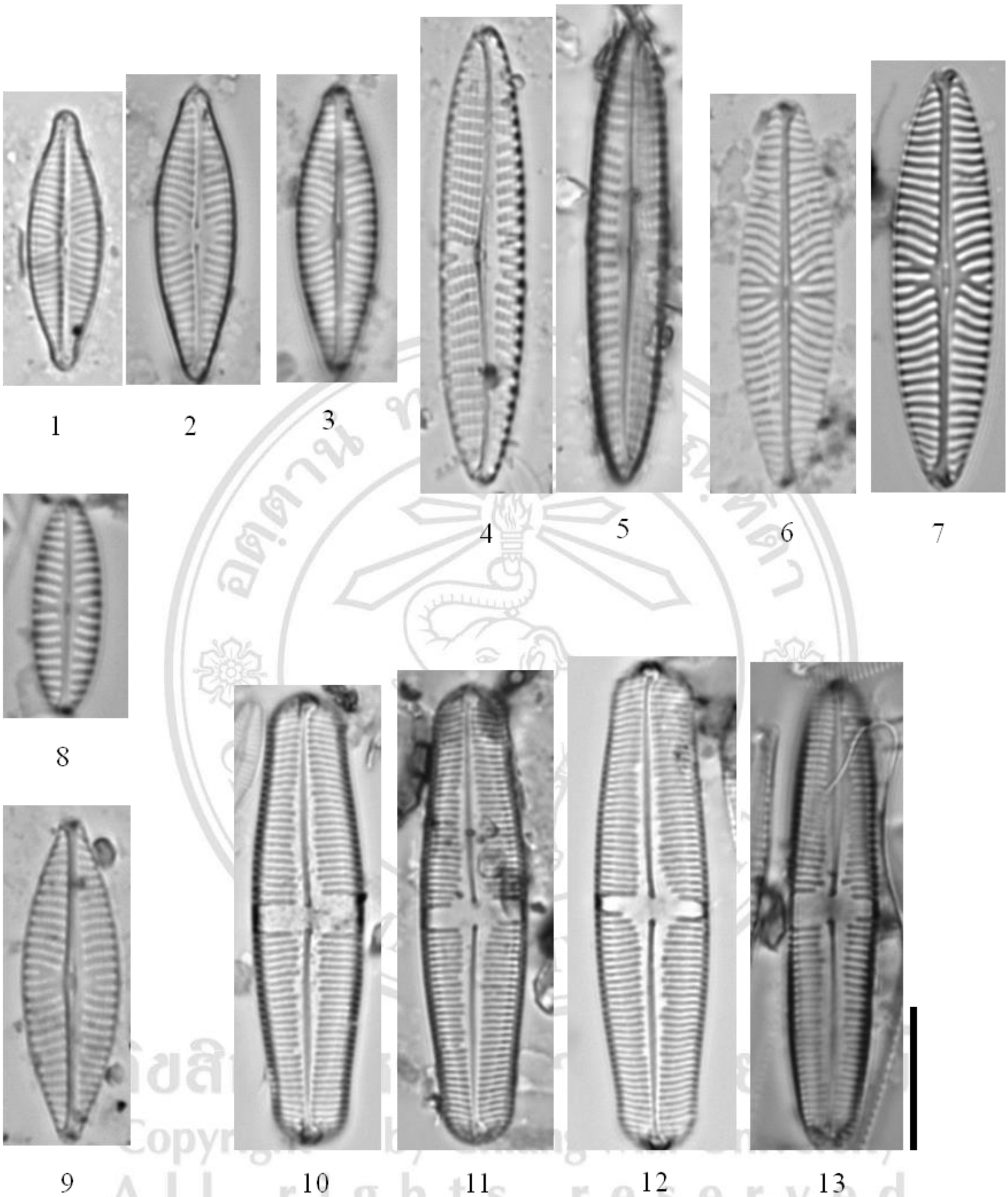
Scale bar = 10 µm.

Figure 45 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Navicula radiosafallax* Lange-Bertalot, (3-6) *N. vandamii* var. *mertensiae* Lange-Bertalot, (7-9) *N. vandamii* Schoeman & Archibald, (10-12) *N. hintzii* Lange-Bertalot



Scale bar = 10 µm.

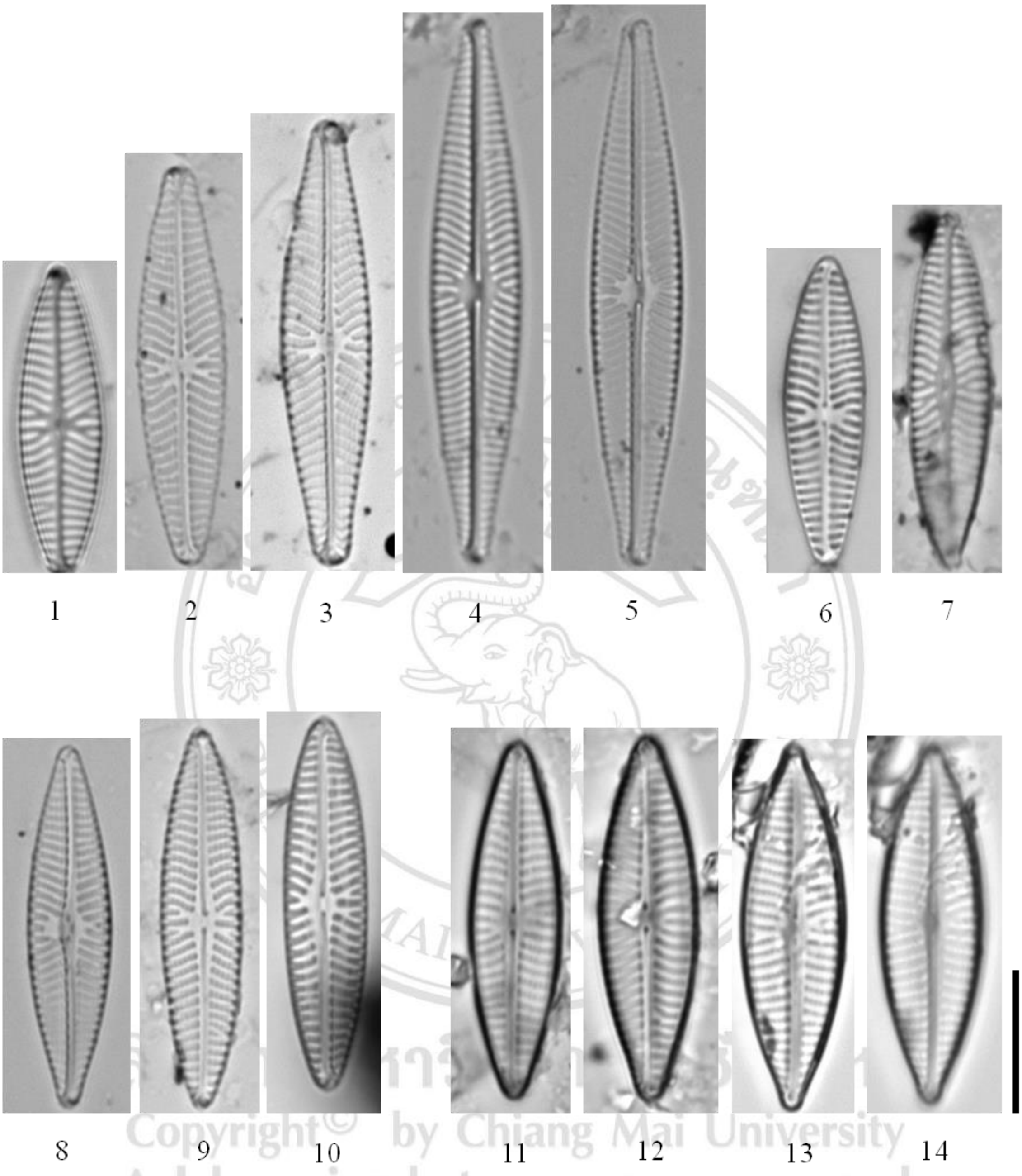
Figure 46 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Navicula amphiceropsis* Lange-Bertalot & Rumrich, (4-6) *N. rostellata* Kützing, (7) *N. viridula* (Kützing) Ehrenberg



Scale bar = 10 µm.

Figure 47 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

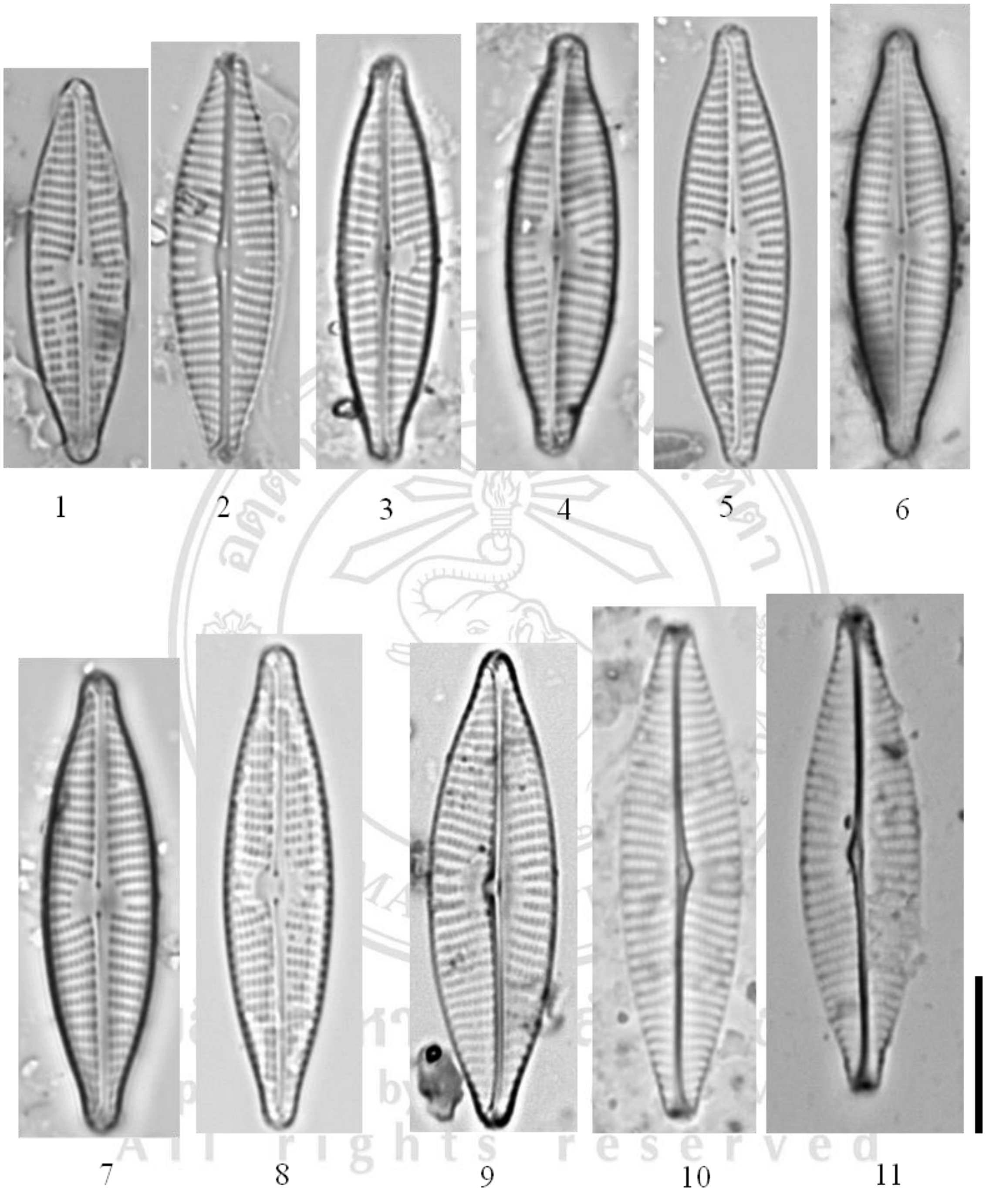
(1-2) *Navicula reichardtiana* Lange-Bertalot, (3) *N. caterva* Hohn and Hellerman, (4-5) *N. jacobii* Manguin, (6-7) *N. cataracta-rheni* Lange-Bertalot, (8) *N. vekhovii* Lange-Bertalot & Genbel, (9) *N. crptotenella* Lange-Bertalot, (10-13) *N. pseudostauropteroides* Fritsch



Scale bar = 10 µm.

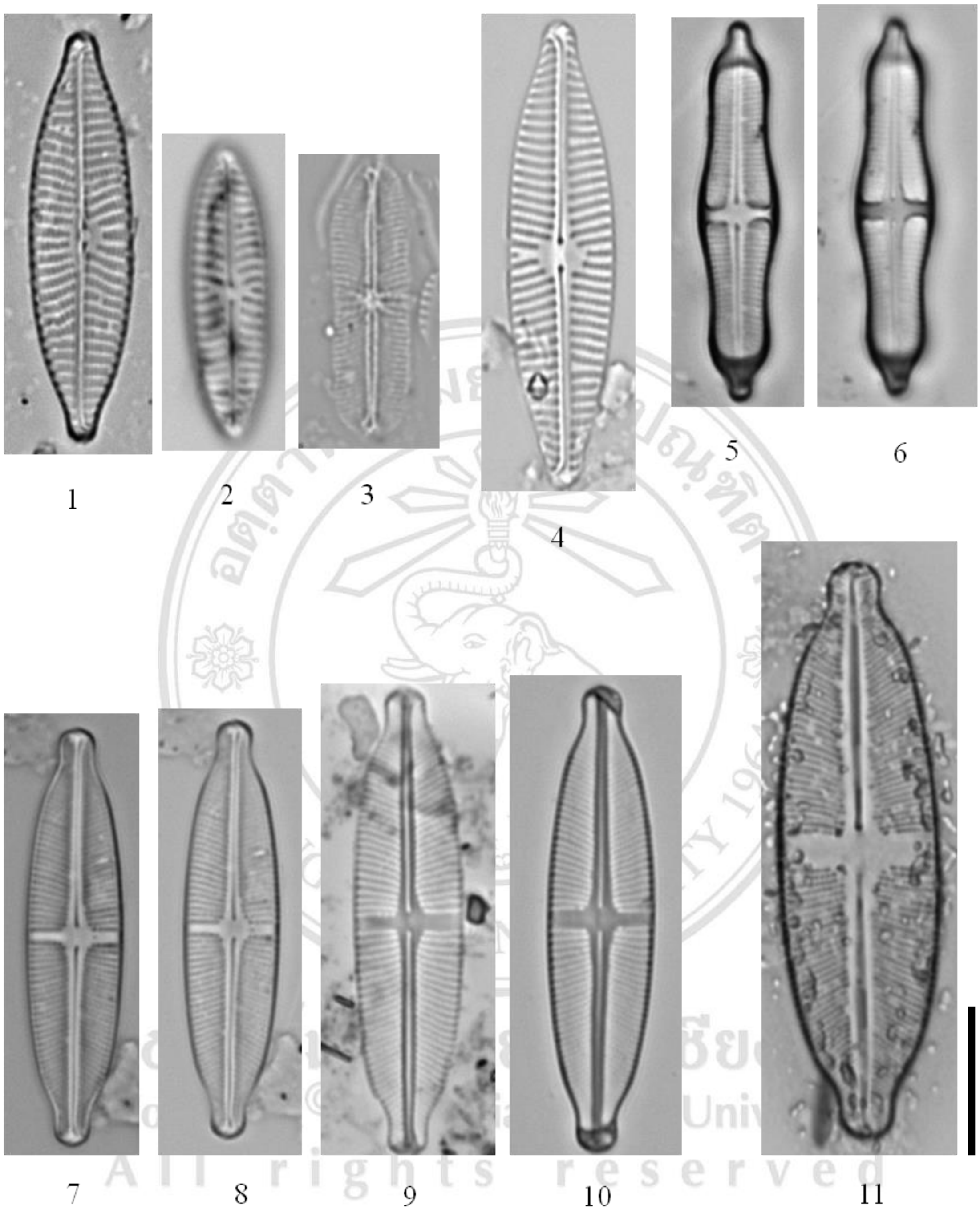
Figure 48 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1-5) *Navicula heimansiodes* Lange-Bertalot, (6-10) *N.* cf. *leistikowii* Lange-Bertalot, (11-14) *N.* cf. *parablis* M.H. Hohn & Hellerman



Scale bar = 10 µm.

Figure 49 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-8) *Navicula* cf. *aquaedurae* (Lange-Bertalot), (9-11) *N. germainii* J. H. Wallace



Scale bar = 10 µm.

Figure 50 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Navicula cinctaeformis* Hustedt, (2) *N.* sp.1, (3) *N.* cf. *bella* Hustedt, (4) *N.* sp.2, (5-6) *Stauroneis smithii* Grunow, (7-10) *S. kriegeri* Patrick, (11) *S. anceps* Ehrenberg

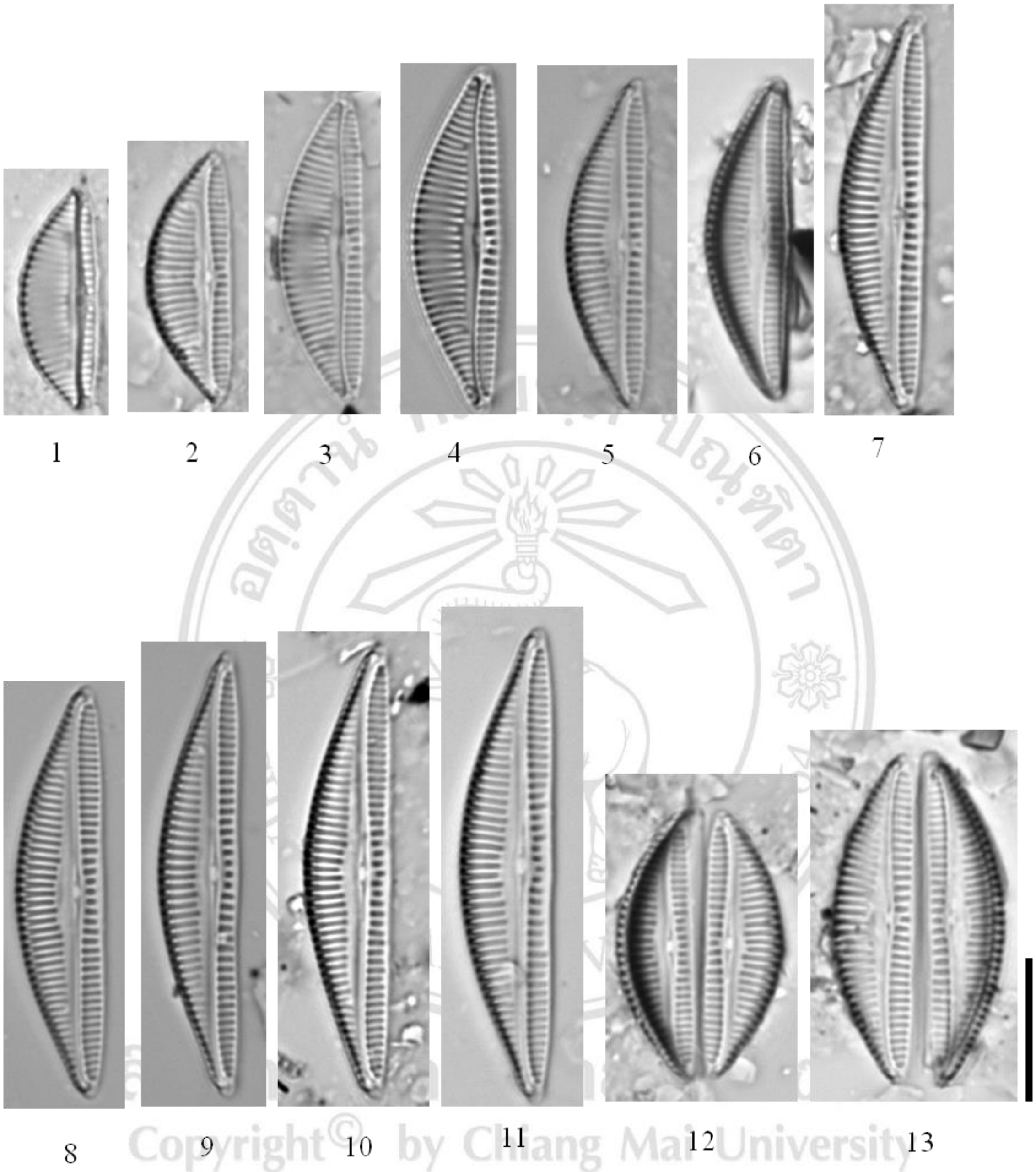
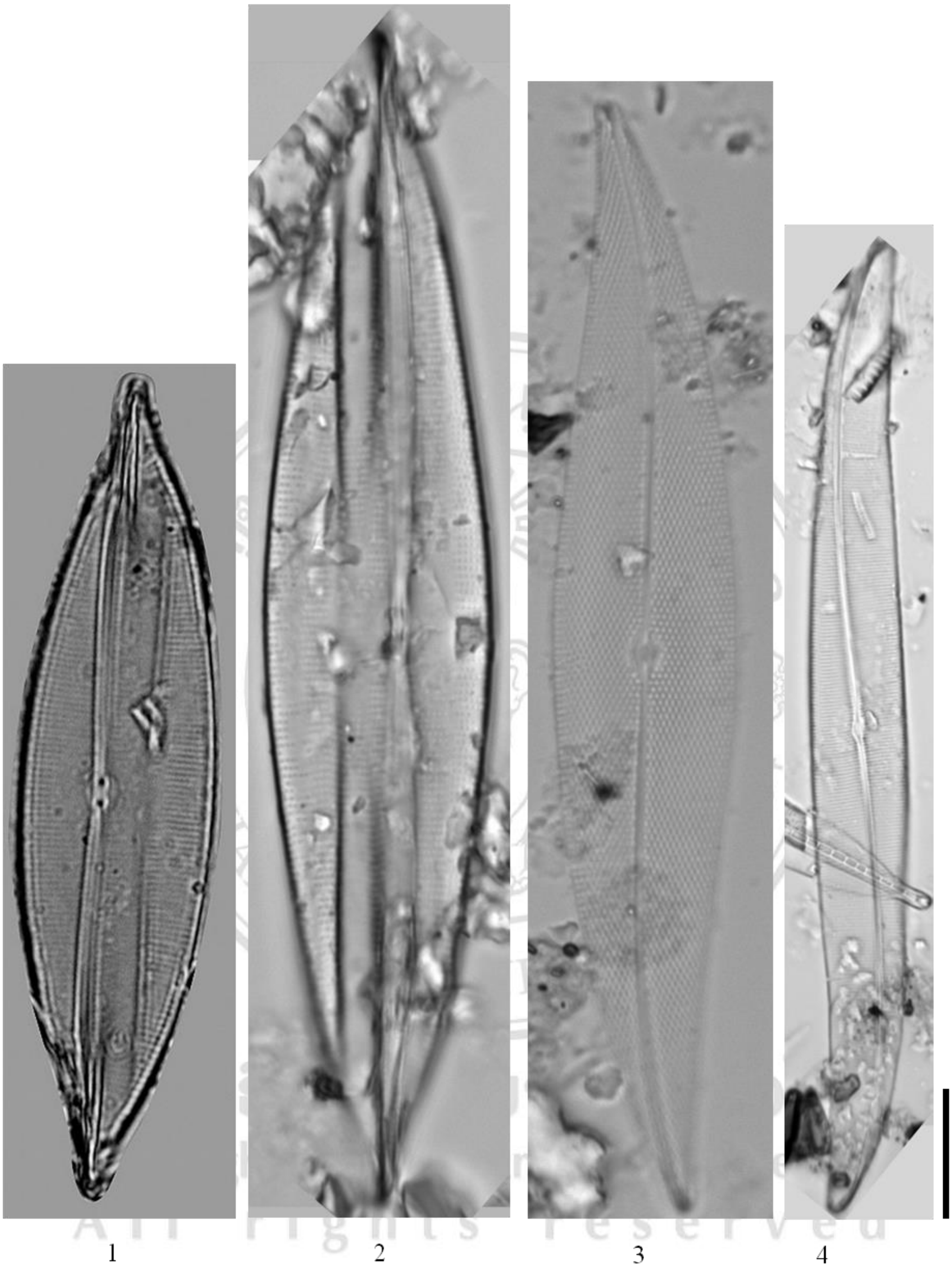
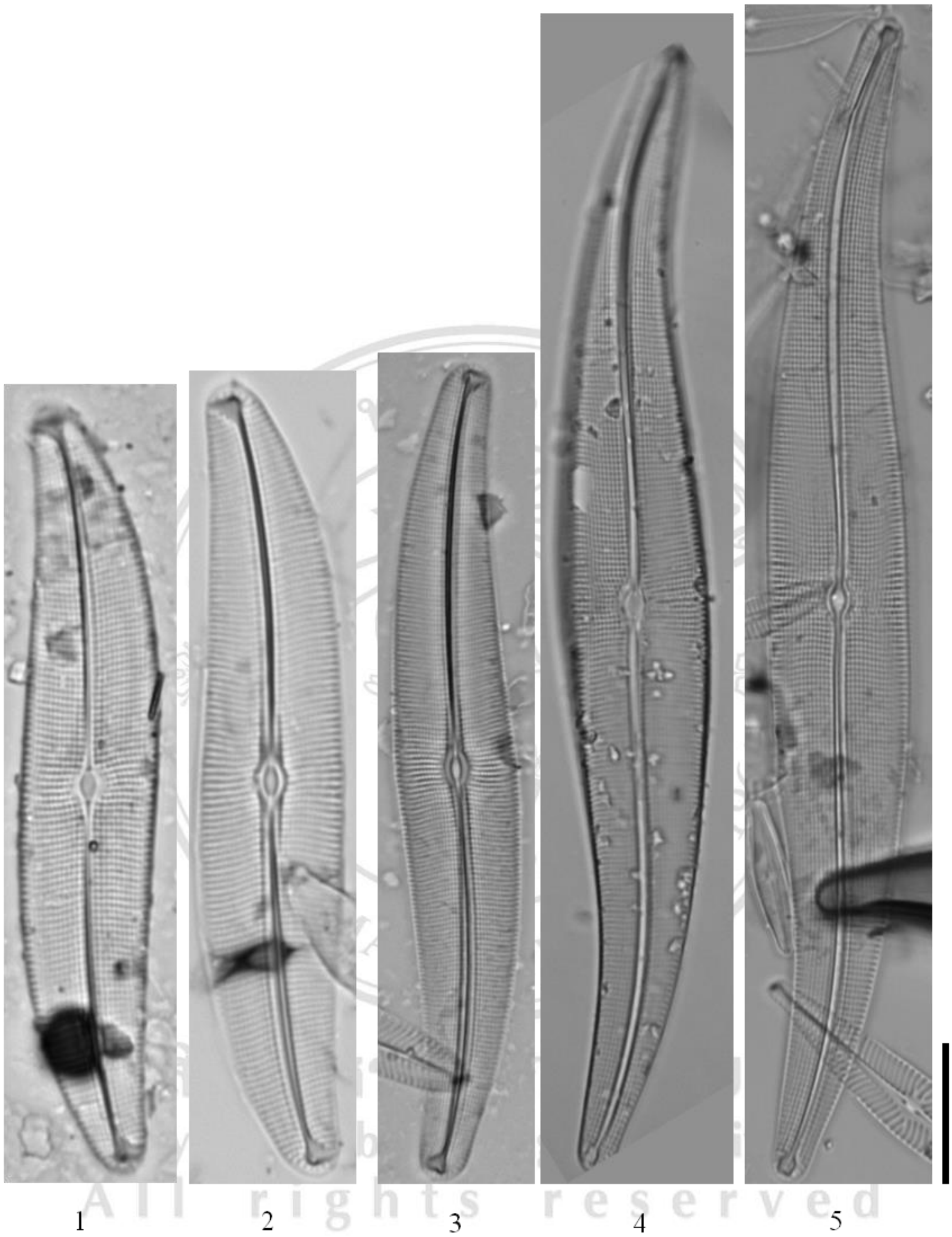


Figure 51 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-13) *Seminavis strigosa* (Hustedt) D.G.Mann & A. Economou



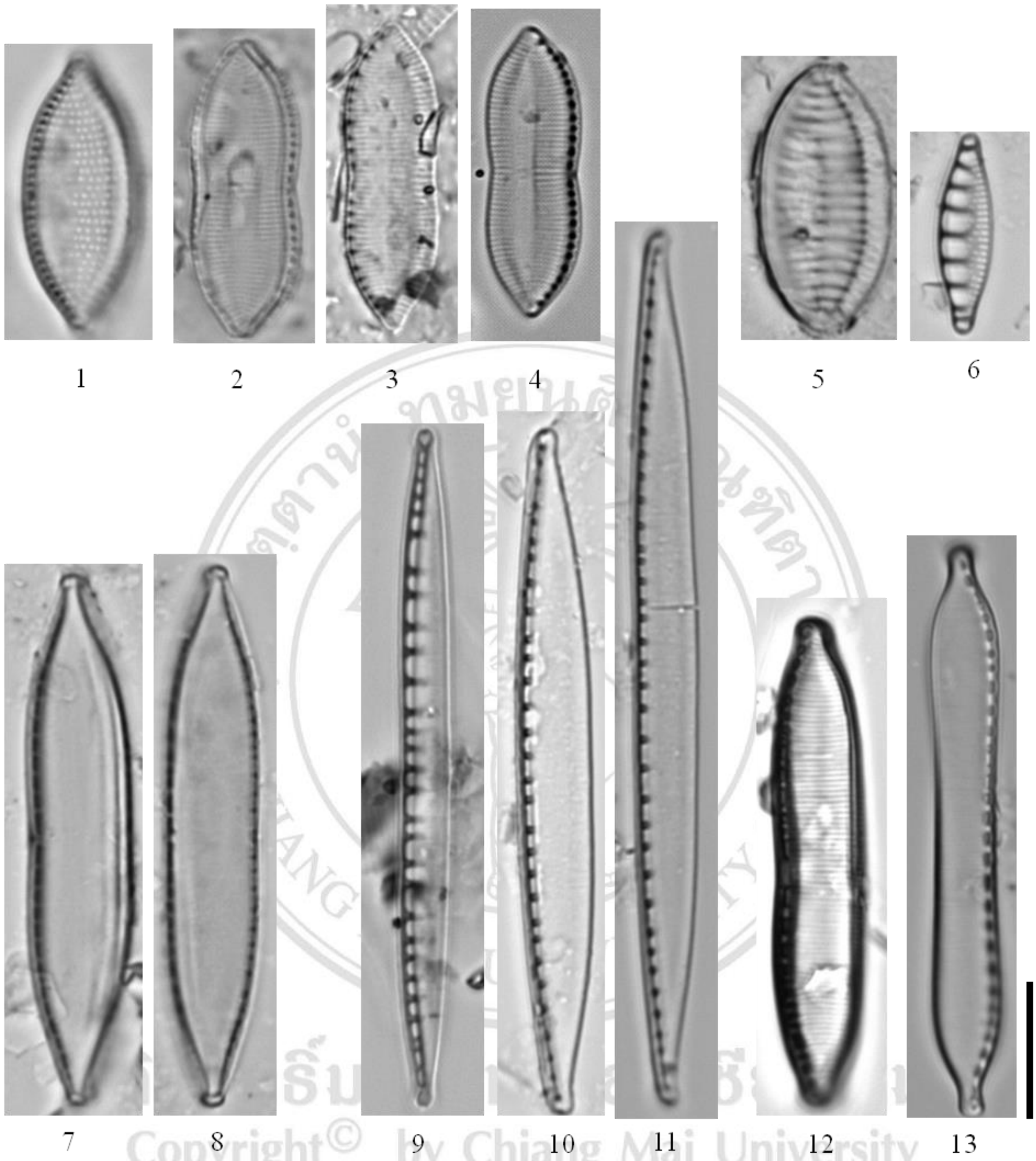
Scale bar = 10 µm.

Figure 52 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Plagiotropis lepidoptera* var. *proboscidea* (Cleve) Reimer in Patrick and Reime, (3) *Pleurosigma negoroi* T. Gotoh in J.H. Lee, J. Chung & T., (4) *Gyrosigma obscurum* (Smith) Griffith & Henfrey



Scale bar = 10 µm.

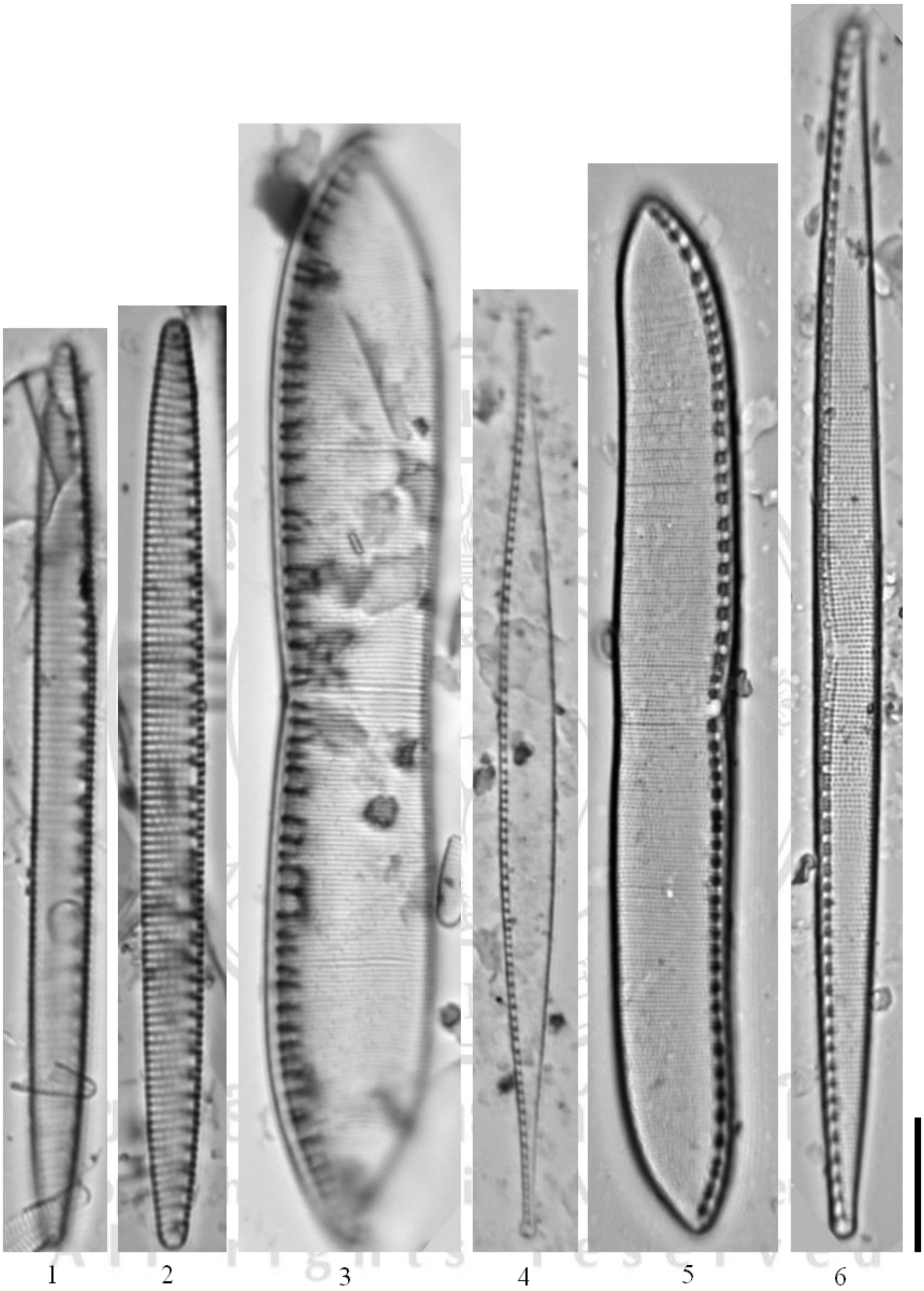
Figure 53 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Gyrosigma scalproides* (Rabenhorst) Cleve, (3-5) *Gyrosigma spencerii* (Bailey ex Quekett) Griffith & Henfr



Scale bar = 10 µm.

Figure 54 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

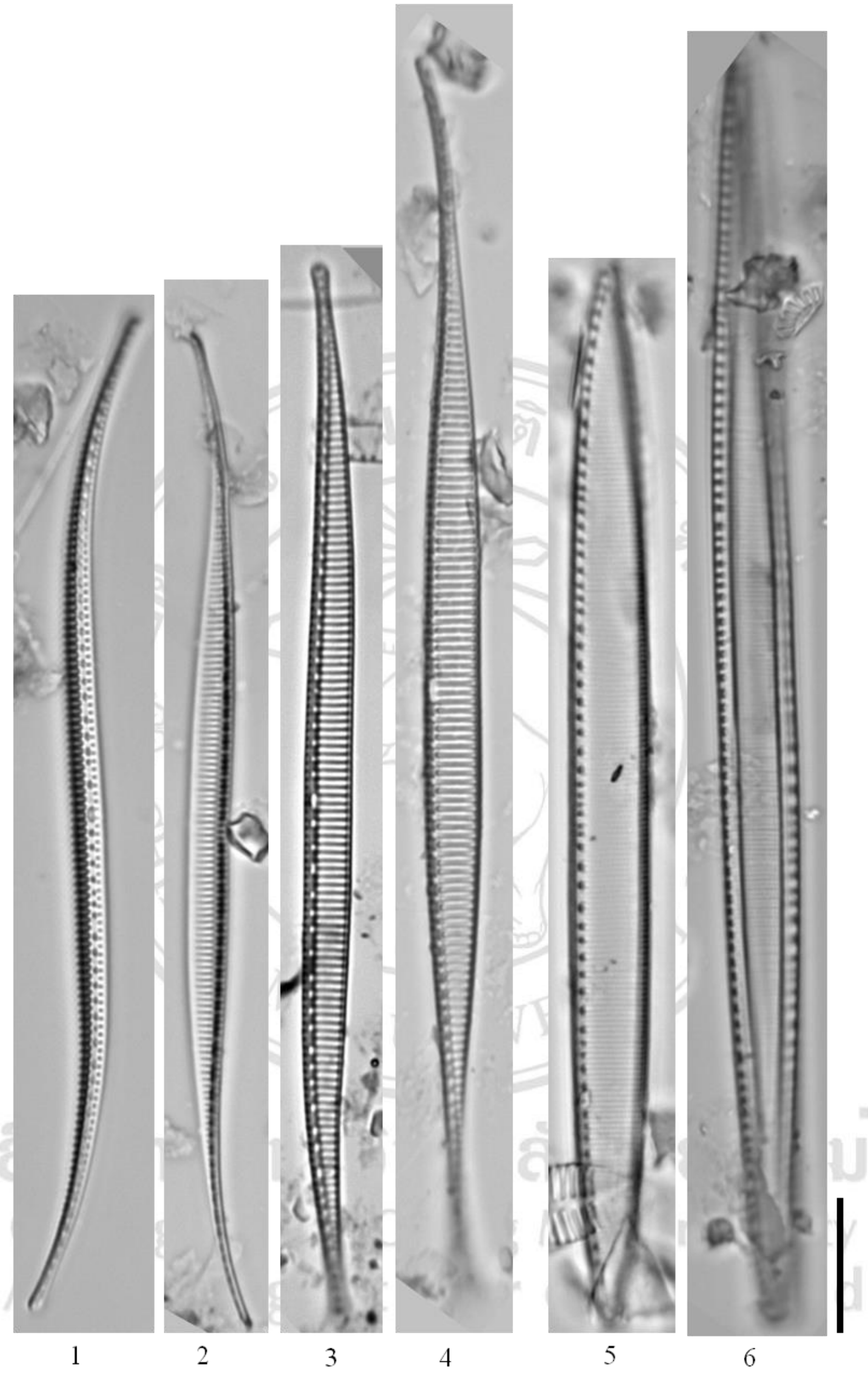
(1) *Nitzschia compressa* var. *balatonis* (Grunow) Lange-Bertalot, (2-4) *Nitzschia persuadens* Cholnoky, (5) *Tryblionella salinarum* (Grunow) Pantocsek,(6) *Nitzschia solgensis* Cleve-Euler, (7-8) *N. salinicola* Aleem & Hustedt, (9-11) *N. recta* Hantzsch ex Rabenhorst,(12-13) *Hantzchia amphioxys* (Ehrenberg) Grunow



Scale bar = 10 µm.

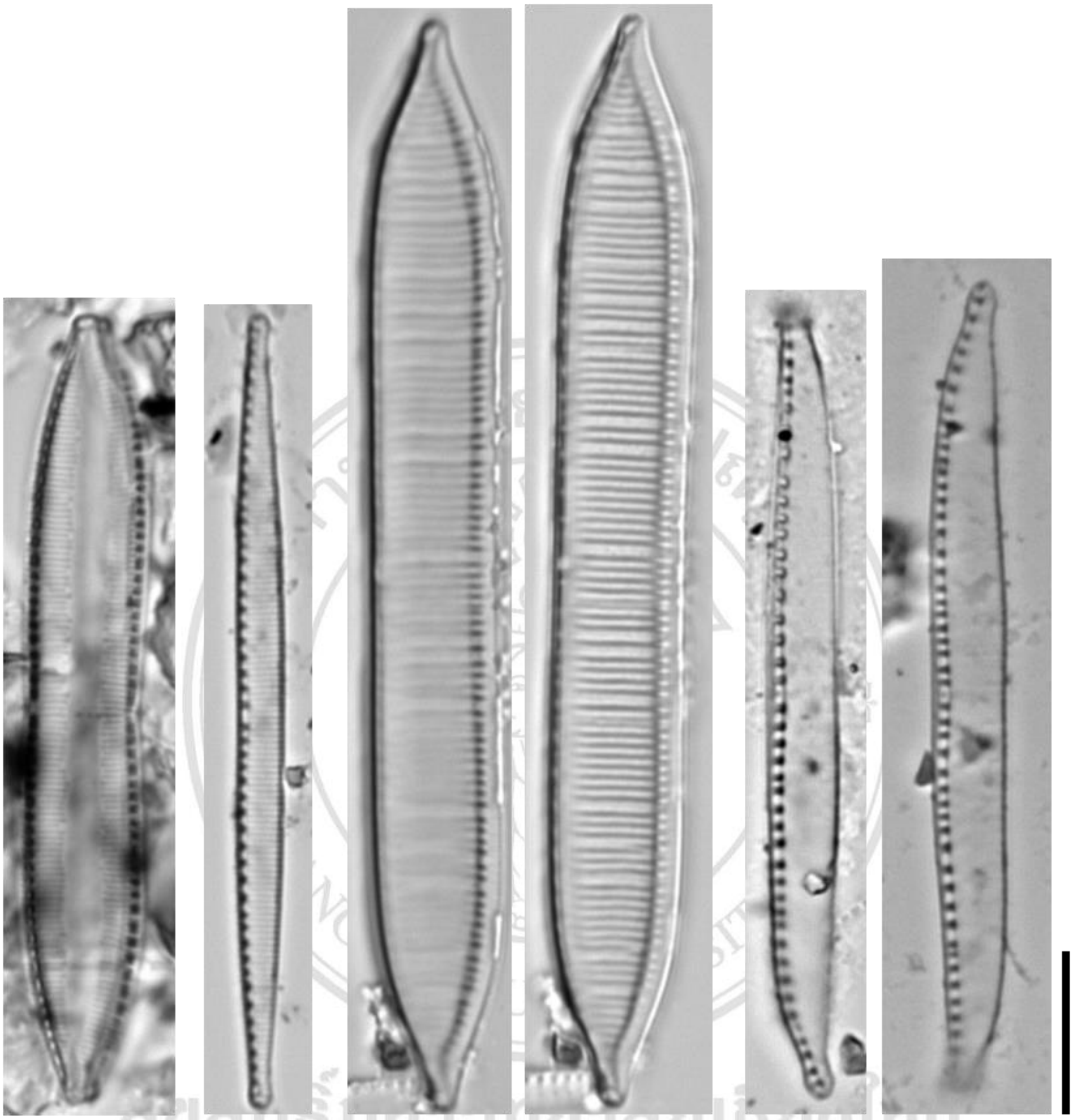
Figure 55 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1-2) *Nitzschia amphibia* Grunow, (3) *N. commutata* Grunow in Cleve & Grunow, (4) *N. gracilis* Hantzsch, (5) *N. scalpelliformis* Grunow, (6) *N. hoehnkii* Hustedt



Scale bar = 10 µm.

Figure 56 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Nitzschia lorenziana* Grunow in Cleve & Möller, (5-6) *N. intermedia* Hantzsch

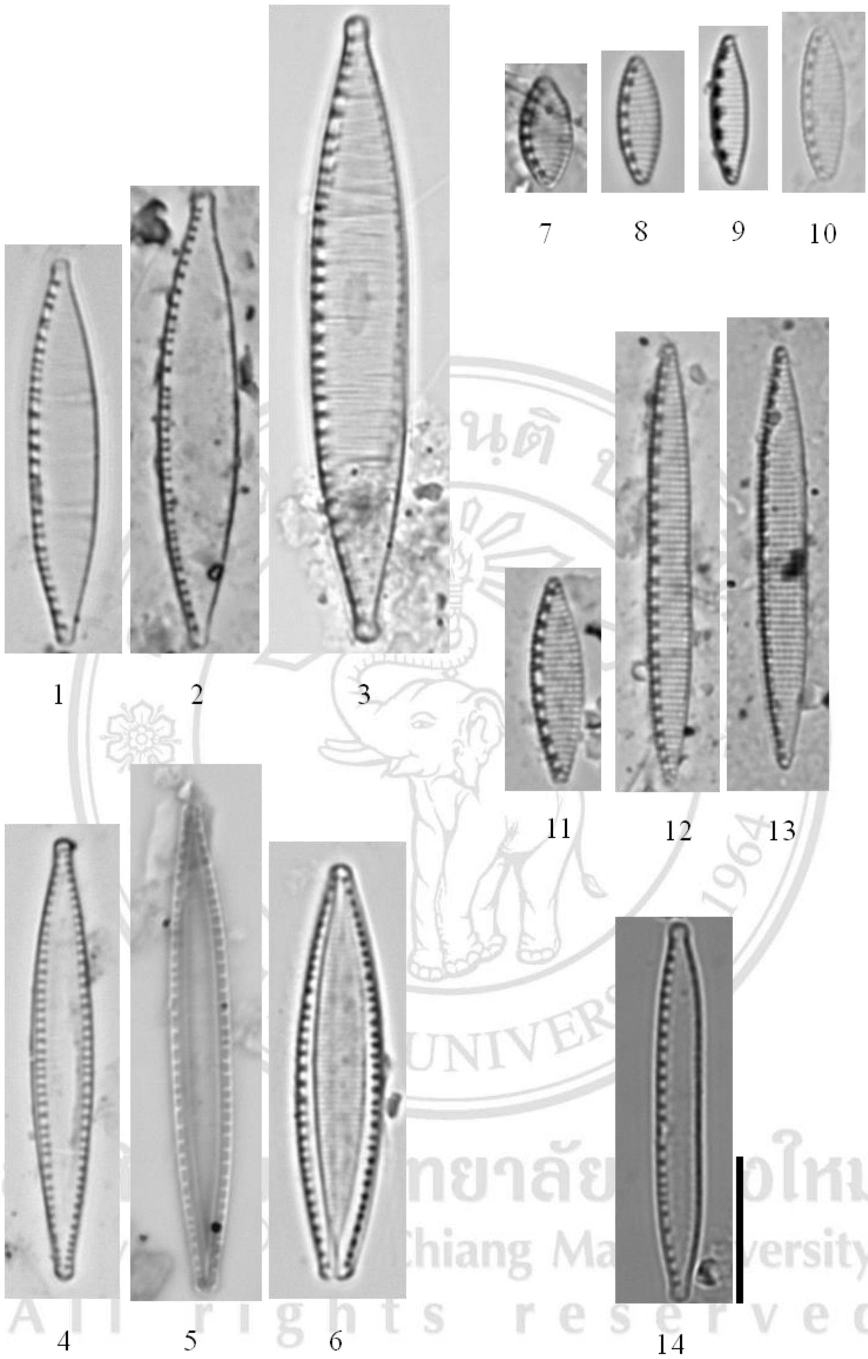


1 2 3 4 5 6

Scale bar = 10 µm.

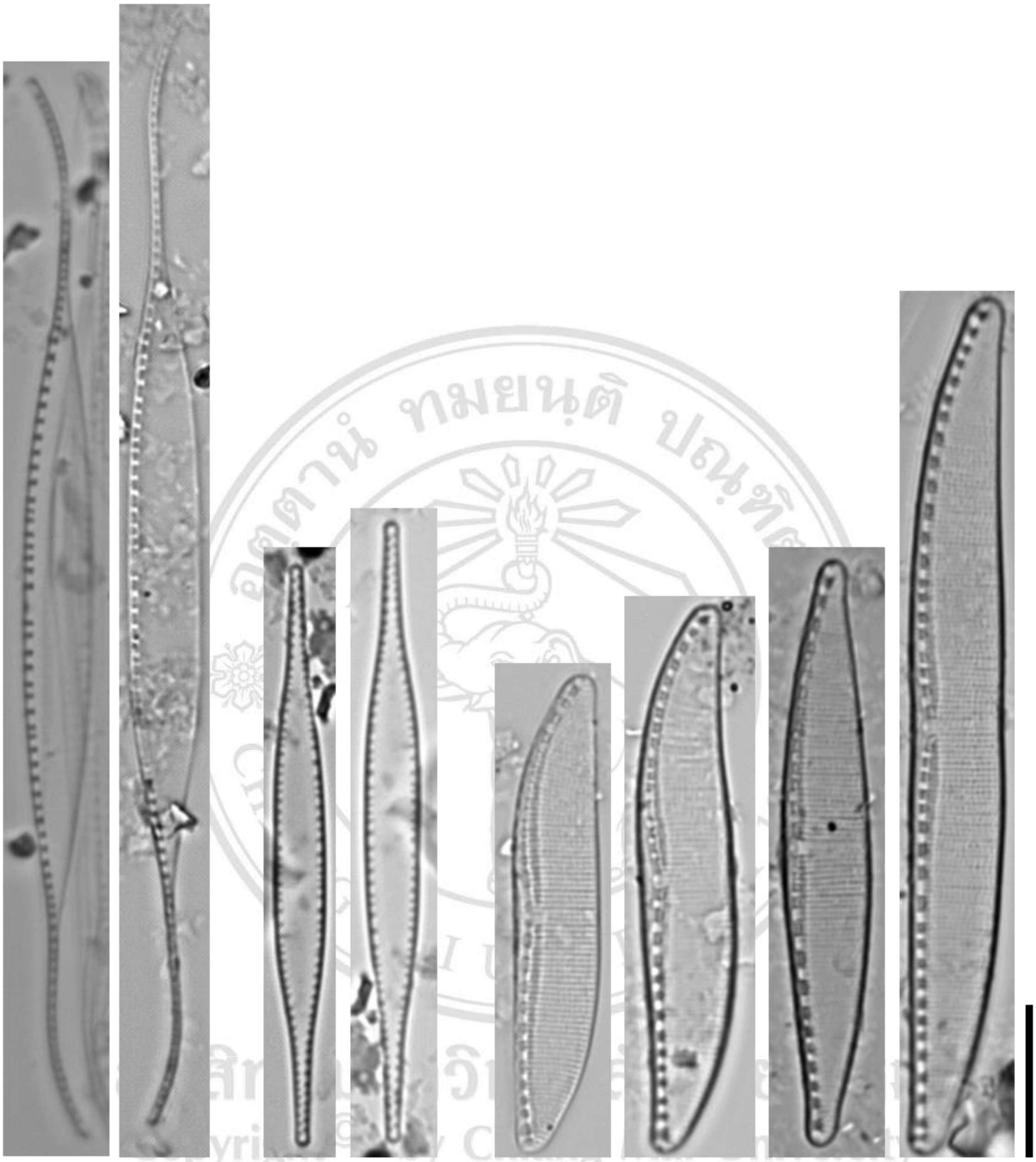
Figure 57 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1) *Nitzschia parvula* Typenprap Coll. W. Smith, (2) *N. frequens* Hustedt and Simonsen, (3-4) *N. angustata* (W. Smith) Grunow, (5-6) *N. filiformis* var. *conferta* (Richt) Lange-Bertalot



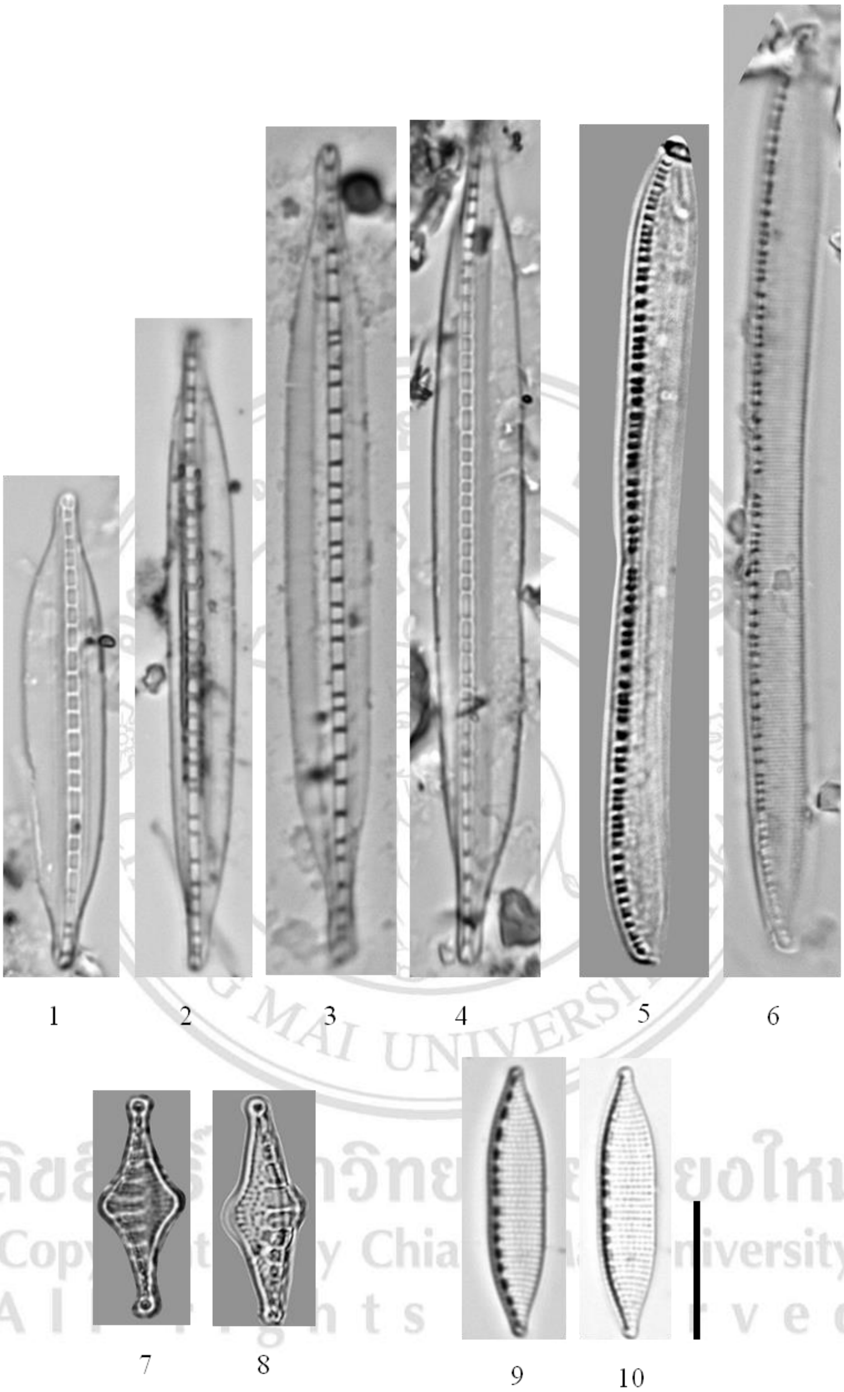
Scale bar = 10 µm.

Figure 58 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-3) *Nitzschia palea* (Kützing) W. Smith, (4-6) *N. palea* var. *deblis* (Kützing) Grunow, (7-13) *N. frustulum* (Kützing) Grunow in Cleve & Grunow, (14) *N.* cf. *ruttneri* Hustedt



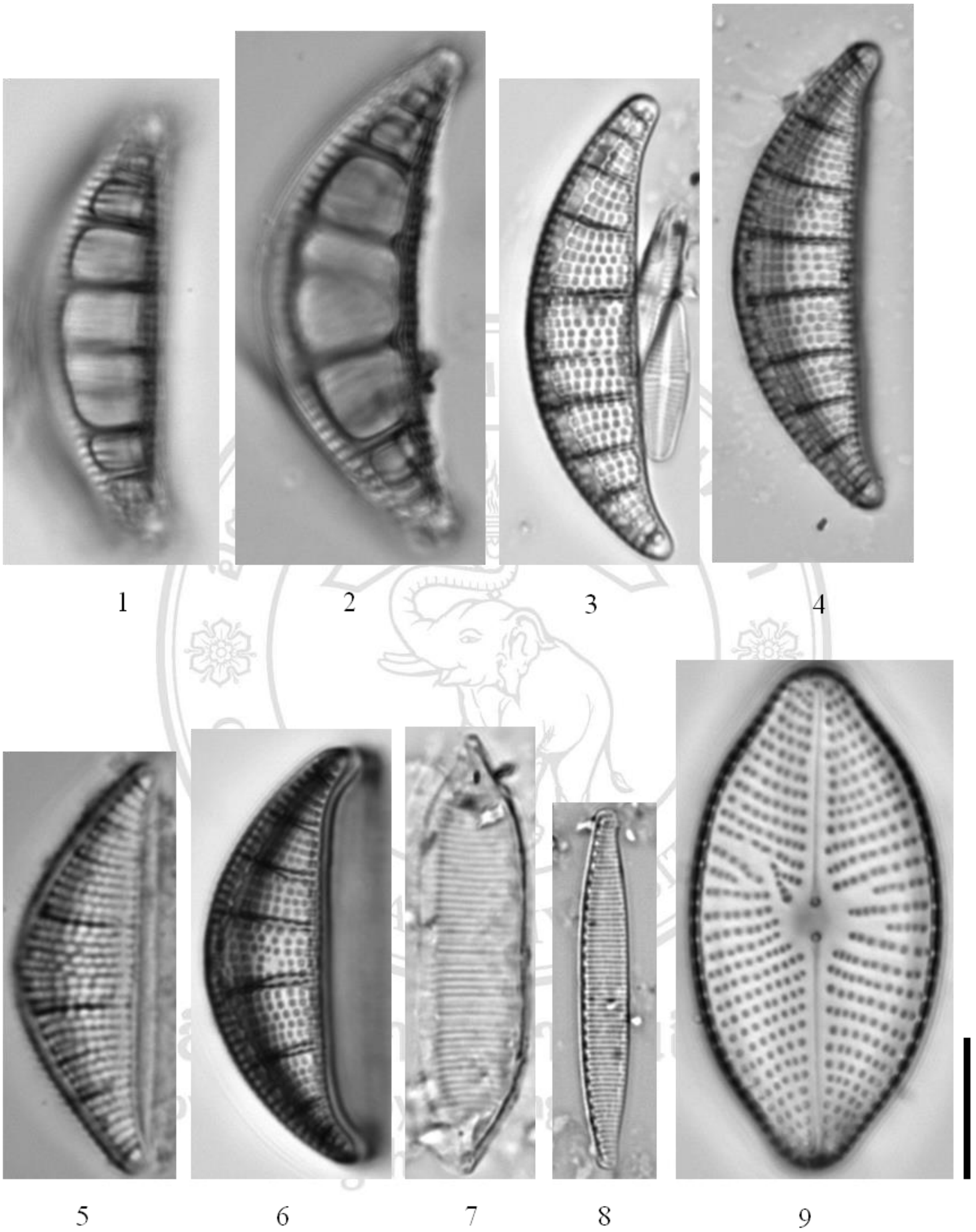
Scale bar = 10 µm.

Figure 59 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Nitzschia reversa* W.Smith, (3-4) *N. pumila* Hustedt, (5-8) *N. clausii* Hantzsch



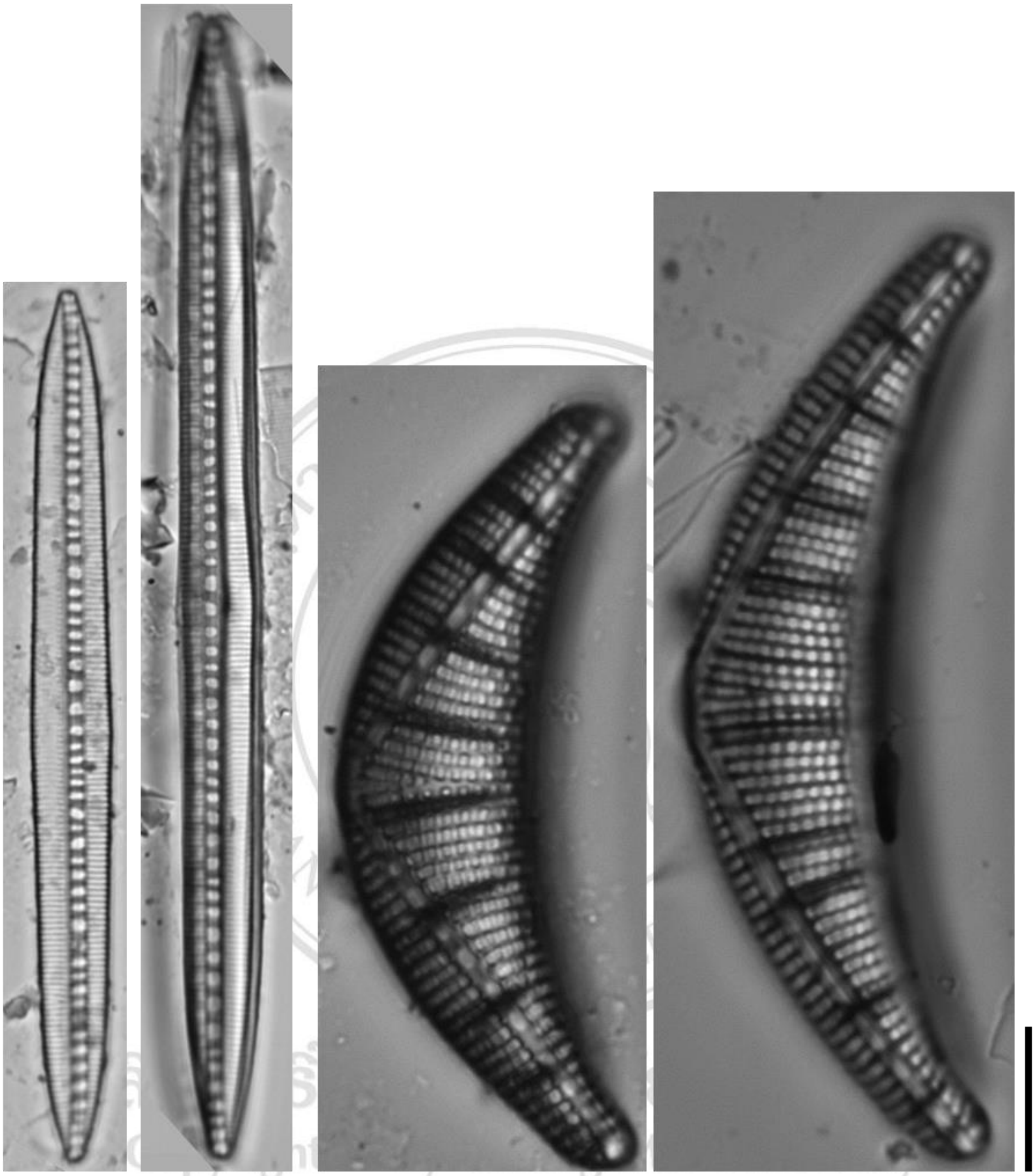
Scale bar = 10 µm.

Figure 60 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4) *Nitzschia dissipata* (Kützing) Grunow, (5-6) *N*. sp.1, (7-8) *N. sinuata* var. *tabellaria* Grunow, (9-10) *N. desertorum* Hustedt



Scale bar = 10 µm.

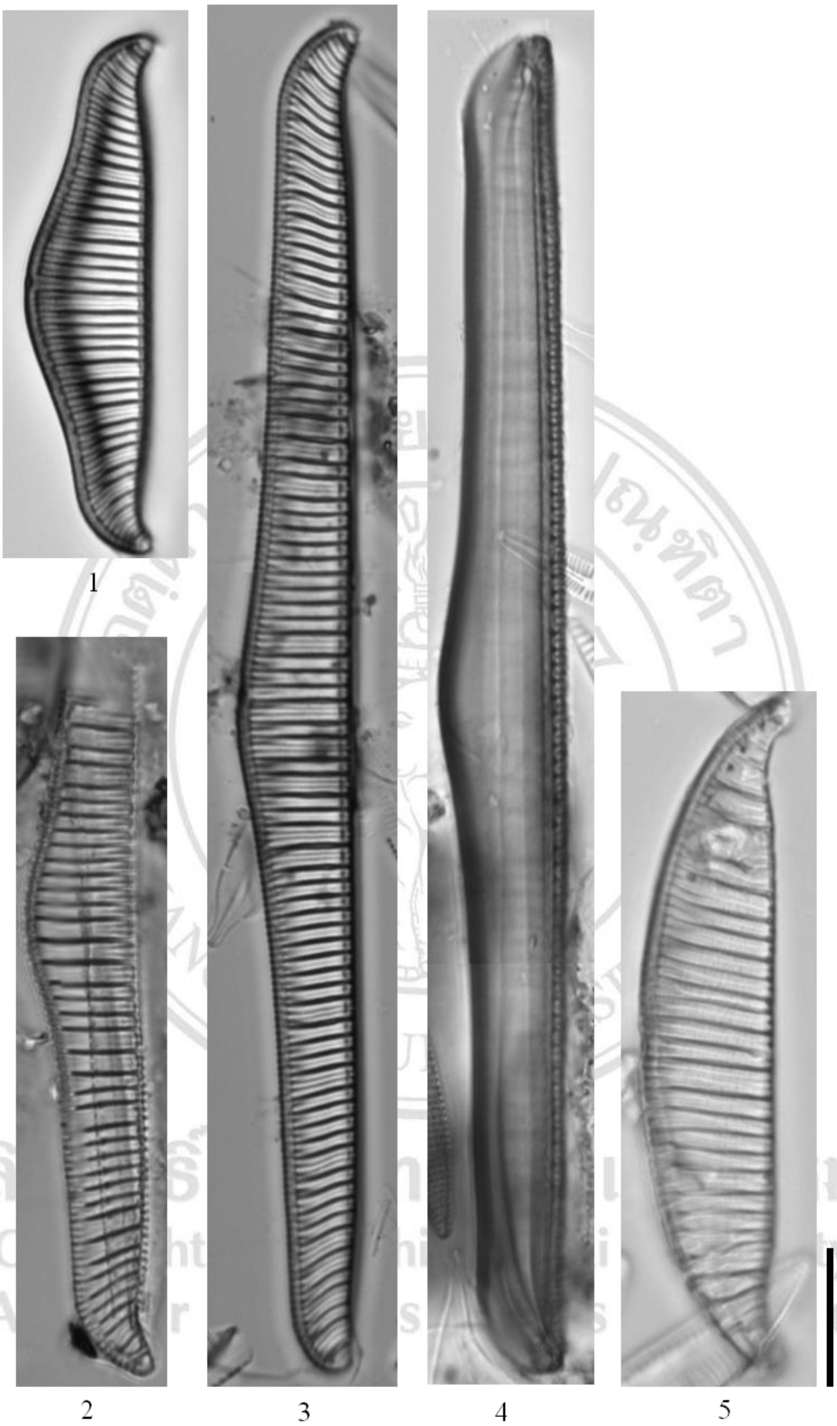
Figure 61 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-6) *Rhopalodia musculus* (Kützing) Otto Müller, (7) *Nitzschia lanceolata* var. *minutula* Grunow, (8) *N. hantzschiana* Rabenhorst, (9) *Aneumastus* sp.1



1 2 3 4

Scale bar = 10 µm.

Figure 62 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2*)* *Bacillaria paxillifer* (O.F. Müller) Hendey, (3-4*)* *Epithemia cistula* (Ehrenberg) Ralfs in Pritch



Scale bar = 10 µm.

Figure 63 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-4*) Rhopalodia gibba* (Ehrenberg) O. Müller, (5) *R. contorta* Hustedt

1 2

Scale bar = 10 µm.

Figure 64 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Surirella tenera* W. Gregory, (2) *Surirella* sp.1

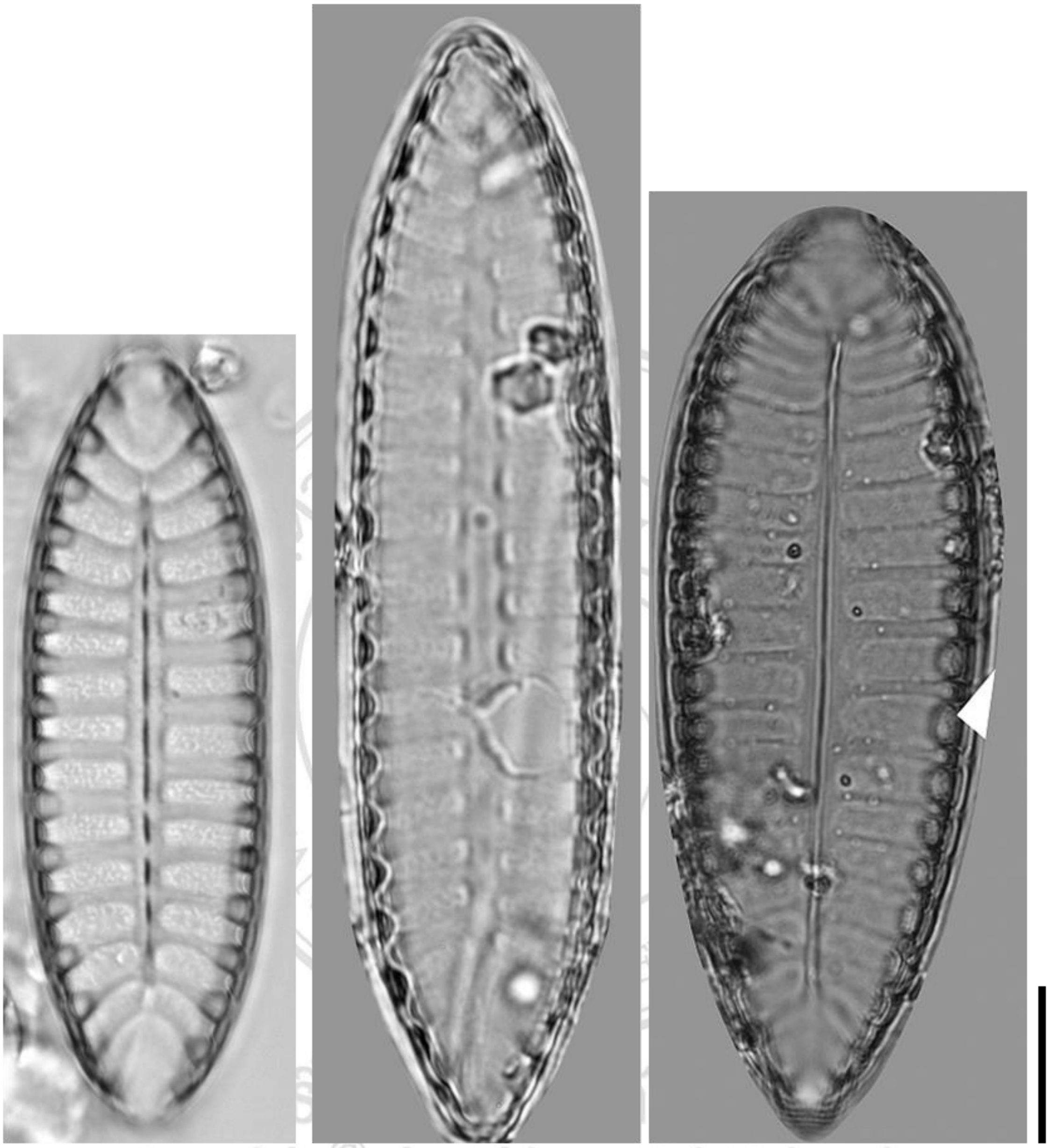
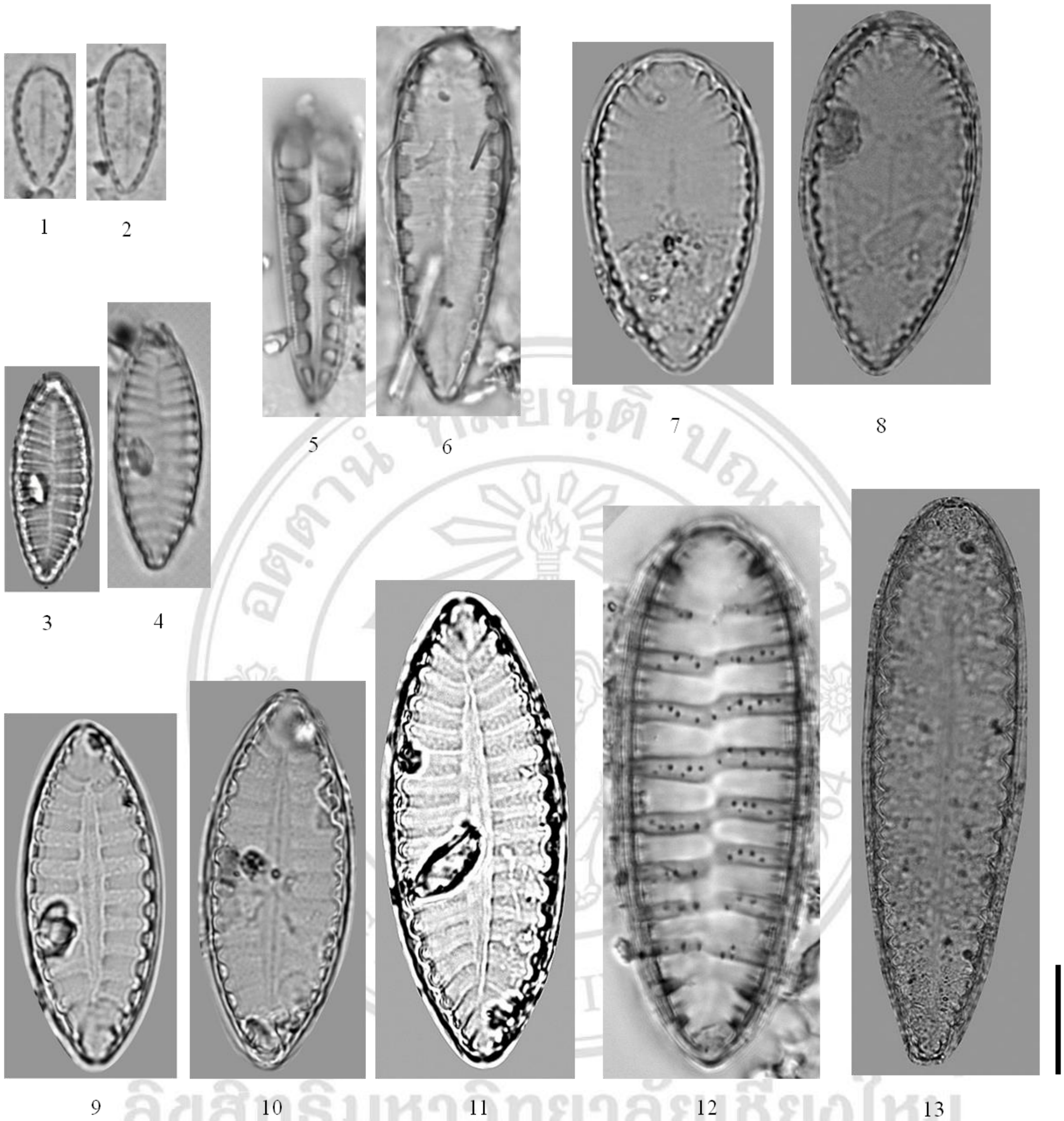


Figure 65 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012
(1-2) *Surirella linearis* W. Smith, (3) *Surirella splendida* Kützing



Scale bar = 10 µm.

Figure 66 Light micrographs of benthic diatoms in the Wang River during October 2011 to September 2012

(1-2) *Surirella ostentata* Cholnoky, (3-4) *S. angusta* Kützing, (5-6) *Surirella* sp.2, (7-8) *Surirella fonticola* F. Husted, (9-11) *Surirella* sp.3, (12) *Surirella* sp.4, (13) *Surirella tenera* var. *nervosa* A. Schmidt in Schmidt *et al*.

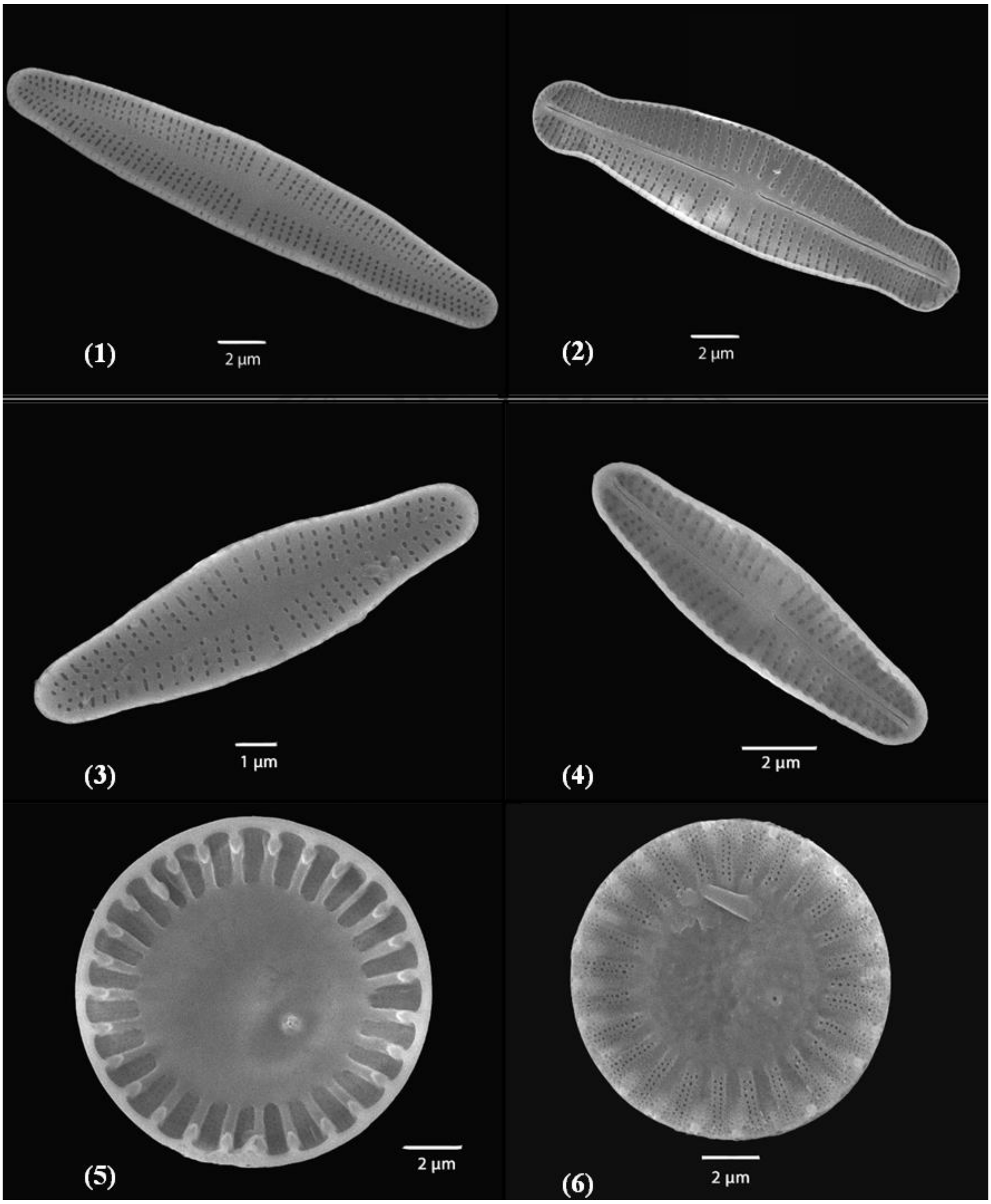


Figure 67 Scanning electron microscrope of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Achnanthidium exile* (Kützing) Heiberg, (2) *Achnanthidium latecephalum* Kobayasi, (3) *Achnanthidium minutissimum* (Kützing) Czarneck (araphid valve), (4) *Achnanthidium minutissimum* (Kützing) Czarneck (raphid valve), (5) *Cyclotella meneghiniana* Kützing, (6) *Cyclotella shanxiensis* Xie & Qi

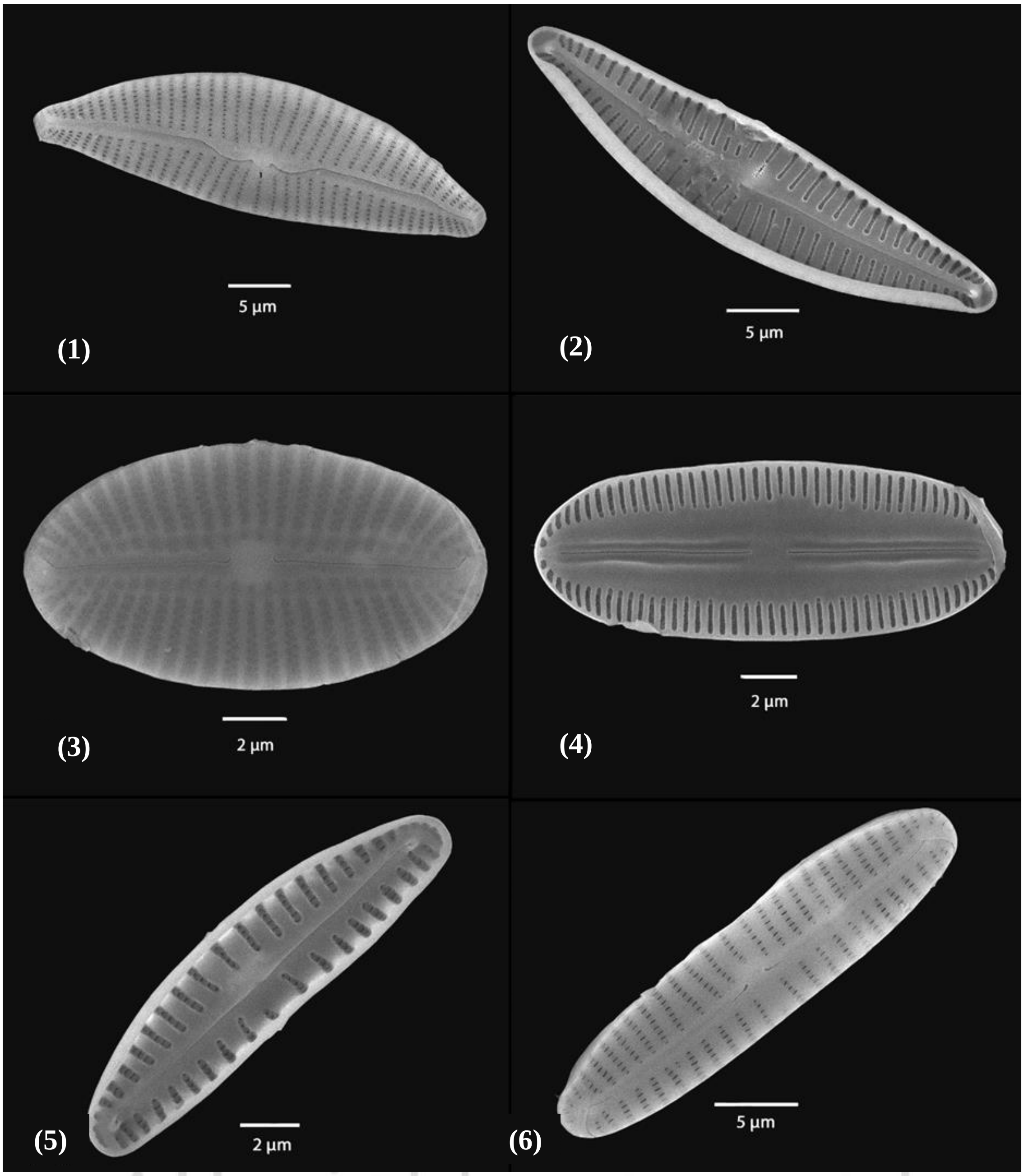


Figure 68 Scanning electron microscrope of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Cymbella affinis* Kützing, (2) *C. parva* (W.Smith) Kirchner, (3) *Diploneis oblongella* (Nägeli ex Kützing) Cleve-Euler in Cleve-Euler & Osvald, (4) *D. oculata* (Breb) Cleve, (5) *Encyonema malaysianum* Krammer, (6) *Encyonopsis leei* Krammer

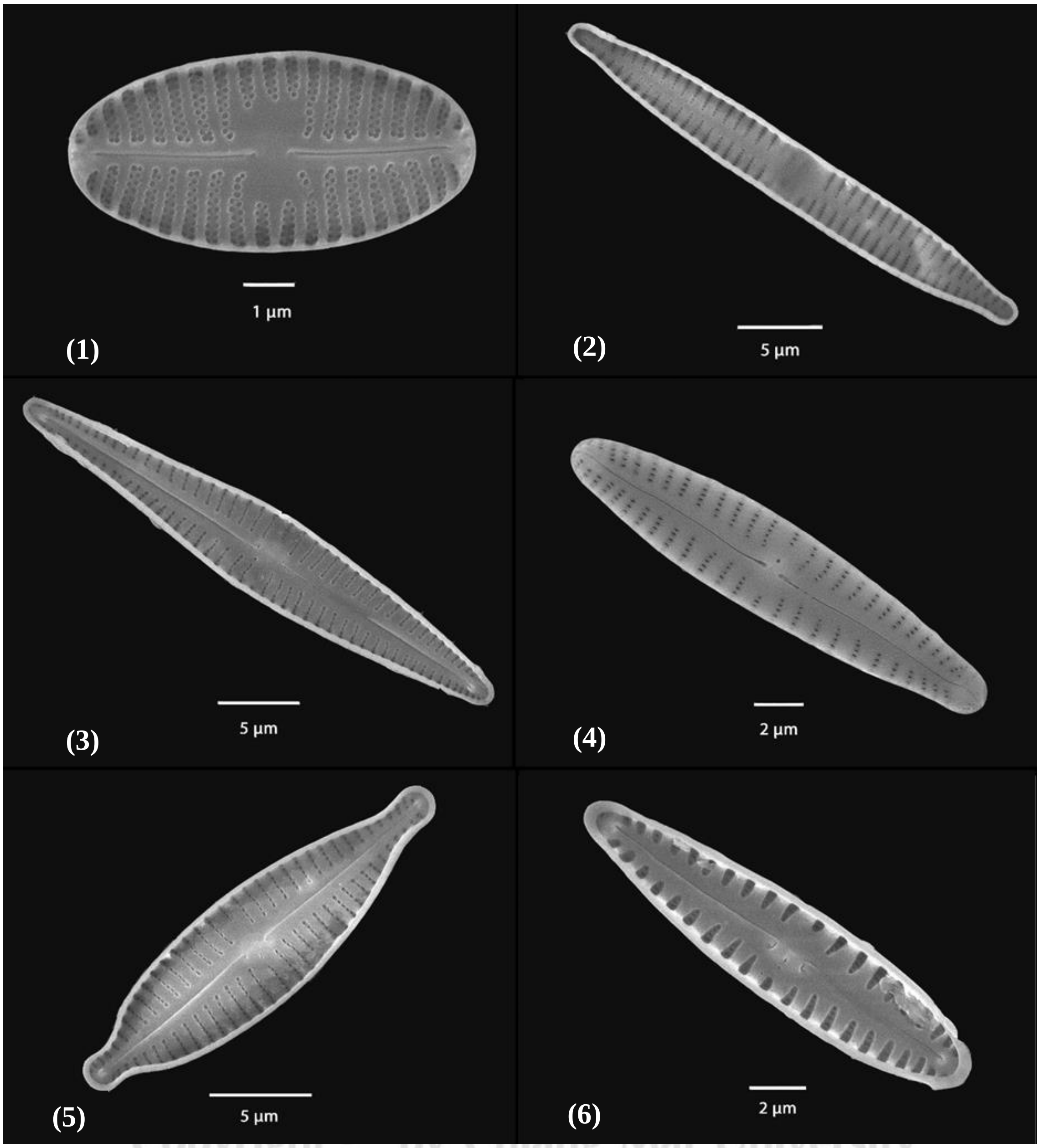


Figure 69 Scanning electron microscrope of benthic diatoms in the Wang River during October 2011 to September 2012

(1) *Eolimna minima* (Grunow) Lange-Bertalot, (2) *Fragilaria rumpens* (Kützing) G.W.F.Carlson, (3) *Gomphonema gracile* Ehrenberg, (4) *G. micropus* Kützing, (5) *G. parvulum* var. *lagenulum* (Grunow) Husted, (6) *G. pumilum* (Grunow) E.Reichardt & Lange- Bertalot

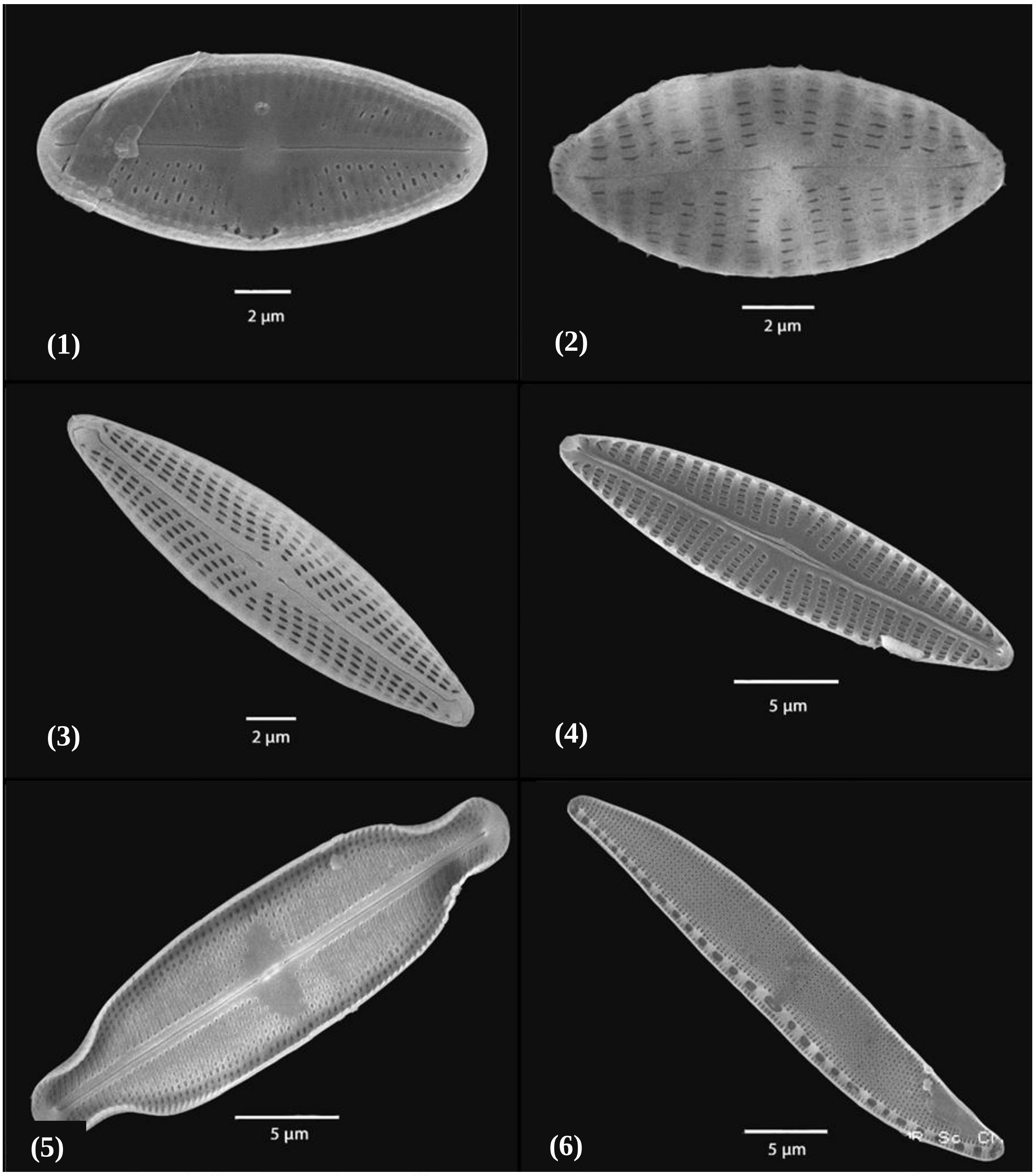


Figure 70 Scanning electron microscrope of benthic diatoms in the Wang River during October 2011 to September 2012

(1) *Luticola simplex* Metzeltin, Lange-Bertalot & García- Rodríguez, (2) *Navicula* cf. *antonii* Lange-Bert in Rumrich *et al*, (3) *N.* cf. *leistikowii* Lange-Bertalot, (4) *N. suprinii* Gerd Moser, (5) *Neidium longiceps* (W.Gregory) Cleve, (6) *Nitzschia clausii* Hantzsch

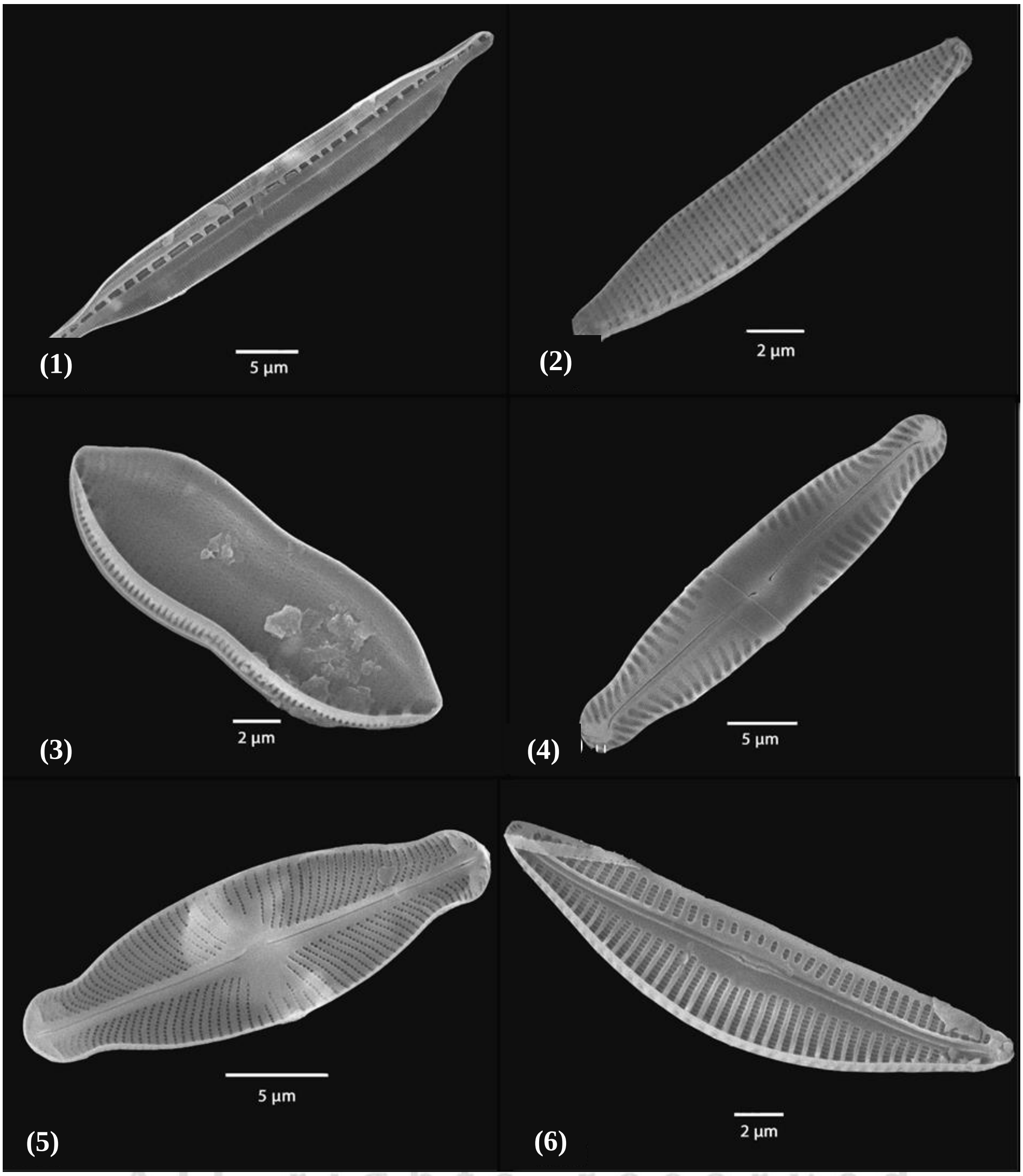


Figure 71 Scanning electron microscrope of benthic diatoms in the Wang River during October 2011 to September 2012
(1) *Nitzschia dissipata* (Kützing) Rabenhorst, (2) *N. hantzschiana* Rabenhorst, (3) *N. persuadens* Cholnoky, (4) *Pinnularia interrupta* W. Smith, (5) *Sellaphora lanceolata* D.G. Mann & S. Droop, (6) *Seminavis strigosa* (Hustedt) D.G. Mann & A. Economou

4.1.3 Newly recorded benthic diatoms species of Thailand

A total of 42 species of benthic diatoms were revealed to be new records for Thailand (Figures 81-84). These were classified into 2 classes, 3 subclasses, 6 orders, 14 families and 19 genera. The benthic diatoms species were compared with the checklist of freshwater algae in Thailand and other relevant books (Lewmanomont *et al*., 1995; Pekthong, 1998 and 2002; Pekthong and Peerapornpisal, 2001; Kunpradid, 2005; Suphan, 2004 and 2009; Inthasotti 2006a, b; Leelahakriengkrai, 2007a, b; Pruetiworanan, 2008; Yana 2010; Suphan and Peerapornpisal, 2010; Leelahakriengkrai, 2011; Yana, 2014). The details of the new species recorded in Thailand are described below:

(1) *Achnanthidium exile* (Kützing) Round & Bukhtiyarova (Figures 15 and 72)
Basionym *Achnanthes exilis* Kützing
Length Range: 12-33 µm
Width Range: 4-6 µm
Striae in 10 µm: 25-30
Description: Frustules are mono-raphid with a curving inward raphe valve and rapheless valve. Valves are linear-lanceolate with slightly capitate ends. Central raphe ends are simple. The terminal raphe fissures are short and almost straight. Striae are radiating and conspicuous in the middle. Striae are composed of one row of areolae. The central area is rounded. The striae are often interrupted in the central part of the raphe valve to form a symmetrical structure.

(2) *Caloneis silicula* var. *alpina* Cleve (Figures 37 and 72)
Basionym: C*aloneis ventricosa* var. *alpigena* (Cleve) Patrick
Length Range: 20-45 µm
Width Range: 7-8 µm
Striae in 10 µm: 18-22
Description: Valves are linear and biconstricted, with rounded aspices. The striae are radiated to parallel with 18-22 in 10 µm. This variety differs from the nominated variety by the weaker constriction of the valve, the less cuneate ends, and the wider axial area.

(3) *Caloneis silicula* var. *peisonis* Hustedt (Figures 38 and 72)

Basionym: -

Length Range: 27-45 µm

Width Range: 5-7 µm

Striae in 10 µm: 14-20

Description: Valves are linear and biconstricted, with apices rounded. Axial area is narrow, broadening to a transverse fascia with lunate thickenings on either side of the central area. The raphe is lateral and slightly. The striae are radiate to parallel with 14-20 in 10 µm. A fine longitudinal line is present.

(4) *Caloneis ventricosa* (C.G. Ehrenberg) F. Meister (Figures 37 and 72)

Basionym: Navicula ventricosa Ehrenberg

Length Range: 50-85 µm

Width Range: 13-15 µm

Striae in 10 µm: 16-20

Description: Valves are biconstricted. The longitudinal area is lanceolate, irregularly shaped and dilate the center, extending from each side in the end of the raphe. The raphe is straight ending in the central area of two small nóduios and the distal part is bent toward the side of the valve. The striae are thin, parallel and slightly radiat. A thin line follows the contour of the valve and is separated from the valvar limit by a row of marks.

(5) *Eunotia curvata* (Kützing) Lagerstedt (Figures 13 and 72)

Basionym: *Eunotia alpina* (Nägeli) Hustedt

Eunotia lunaris var. *excisa* Grunow

Eunotia lunaris var. *lunaris* (Ehrenb.) Grunow

Length Range: 20-150 µm

Width Range: 3.-6 µm

Striae in 10 µm: 13-18

Description: Valves are usually arcuate in shape, sometime almost straight; usually gradually narrowed toward rounded, sometimes slightly woolen ends. Dorsal and ventral sides are parallel. Terminal nodule is small and raphe is indistinct. A thin line occasionally is seen extending from the terminal nodule toward the center of the valve.

(6) *Halamphora veneta* (Kützing) Levkov (Figures 40 and 72)

Basionym: *Amphora veneta* Kützing

Length Range: 10-40 µm

Width Range: 3.5-6 µm

Striae in 10 µm: 20-25 in central area, 27-30 at the ends

Description: Valves are semi-lanceolate and sharply dorsiventral. Valve ends are rostrate and ventrally curved. The raphe is located near the ventral margin, and is straight. Proximal raphe endings are straight. The axial area is narrow. Dorsal striae are distinctly punctate and radiate throughout. Ventral striae are composed of a continuous row of short striae near the valve margin.

(7) *Halamphora bullatoides* (Hohn & Hellerman) Levkov (Figures 40 and 72)

Basionym: *Amphora bullatoides* Hohn & Hellermann

Length Range: 22-33 µm

Width Range: 3.9-4.6 µm

Striae in 10 µm: 26-30 in the center, 32-34 near the poles

Description: Valves are semi-lanceolate and dorsiventral. The ventral margin is slightly tumid near the central portion. The valve ends are capitate. The raphe occurs near the ventral margin, is straight and gently deflects dorsally as it nears the central area. The proximal raphe ends are widely spaced; the distal ends are deflected dorsally. The axial area is narrow throughout. Dorsal and ventral fascia are both absent. Dorsal striae are punctate and radiate throughout and ventral striae are continuous, but difficult to observe in the LM.

(8) *Delicata delicatula* (Kützing) Krammer (Figures 23 and 72)

Basionym: *Cymbella delicatula* Kützing

Length Range: 17-47 µm

Width Range: 3-7 µm

Striae in 10 µm: 16-19

Description: The raphe is distinctly lateral but becomes reverse-lateral at the proximal ends. The terminus of the raphe is thin, comma shaped, and the terminal raphe fissures are deflected toward the dorsal side. The valves lack a distinct central area. The stigmata are absent but the striae are fine with 16-19 in 10 µm.

(9) *Gomphonema auritum* A.Braun ex Kützing (Figures 24 and 72)

Basionym: *Gomphonema dichotomum* var. *auritum* (A.K.H.Braun) G.L.Rabenhorst

Gomphonema gracile var. *auritum* (A.K.H.Braun) H.F.Van Heurck

Length Range: 24-40 µm

Width Range: 3-4 µm

Striae in 10 µm: 13-14

Description: Valves have acutely rounded apices, with a possible pseudoseptum present at the apex of the headpole. Apical pore field is distinct at the footpole. Frustules are cuneated. Striae do not appear continuous around headpole. Axial area is narrow and expanded slightly to form a linear-elliptical central area. Raphe is lateral and weakly undulate. External proximal raphe ends are distinctly dilated. Striae appear costate and parallel.

(10) *Craticula vixnegligenda* Lange-Bertalot. (Figures 37 and 72)

Basionym -

Length Range: 22-32 µm

Width Range: 5-7 µm

Striae in 10 µm: 15-18

Description: Valves are linear-lanceolate with prolonged and rounded apices. The raphe is straight and filiform. Striae are punctate, parallel in the middle and becoming convergent at the apices. Axial area is narrow, straight and expanded to form a narrow shape. The central area is narrowly elliptical. There does not appear to be longitudinal striae formed in this taxon, which does occur in other members of the genus.

(11) *Encyonema gaeumannii* (Meister) Krammer (Figures 21 and 72)

Basionym: *Cymbella gaeumannii* Meister

Length Range: 11.4-20.7 µm

Width Range: 2.9-4.4 µm

Striae in 10 µm: 25-30

Description: Valves are narrowly lanceolate and moderately dorsiventral with rostrate apices that are deflected to the ventral area. The dorsal margin is curve and the ventral margin is straight with narowlly axial area. The central area is very small and continuous to the axial area. The raphe branches are filiform and concave to the dorsal margin. Proximal raphe ends are unexpanded and deflected dorsally. Distal raphe fissures are hooked toward the ventral margin. Striae are slightly radiate.

12 *Hippodonta pseudoacceptata* (H.Kobayasi) Lange-Bertalot, Metzeltin & Witkowski (Figures 42 and 72)

Basionym; *Navicula pseudoacceptata* H.Kobayasi

Length Range: 10-15 µm

Width Range: 3-5 µm

Striae in 10 µm: 15-21

Description: Valve outline is linear-elliptic with broadly rounded ends and a conspicuous hyaline apical area. Raphe is filiform and straight. Axial area is narrow and linear. Central area is transapically dilated, rectangular, and delimited by two shortened central striae. Transapical striae are slightly radiate at the center, becoming parallel toward the ends. Areolae are not obserbed in the LM.

13 *Hippodonta avittata* (Cholnoky) Lange-Bertalot, Metzeltin Witkowski (Figures 42 and 72)

Basionym: *Navicula subcostulata* var. *avittata* Cholnoky

Length Range: 10-15 µm

Width Range: 3-4 µm

Striae in 10 µm: 13-14

Description: Valves are rhombic with a convex outline shape and possess thickly rounded, non-prolonged apices. Axial area is linear and very narrow. Central area is distinct, forming a wedge-shaped subfascia with 1-2 shortened striae. Raphe is filiform, straight with very small, proximal pores and distally while appearing weakly deflected. Transapical striae are moderately radiated near the central area, becoming parallel and even weakly convergent towards the apices. Areolae are not obserbed in the LM.

(14) *Luticola terminata* (Hustedt) J.R.Johansen (Figures 32 and 72)

Basionym: *Navicula mutica* var. *tropica* Hustedt

Length Range: 23-35 µm

Width Range: 8-10 µm

Striae in 10 µm: 20-22

Description: Valves are lanceolate to elliptical-lanceolate with not protracted apices. Central ends of the raphe are turned into the same direction. Central area is larges, almost reaching the margins of the valves with large stigma present on one side. Striae are radiated throughout the valve; distinctly punctate.

(15) *Luticola simplex* Metzeltin, Lange-Bertalot & García-Rodríguez (Figures 31 and 72)

Basionym: *Luticola charlatii* cf. *simplex* Hustedt

Length Range: 12.5-26 µm

Width Range: 5.5-8 µm

Striae in 10 µm: 20-24

Description: Valves are rhombic to rhombic-elliptic with broadly rounded and non-produced apices. Central ends of raphe are distinct and deflected opposite to the stigma. The stigma appears circular standing rather close to the marginal areolae. Axial area is very narrow to almost linear. Central area is almost rectangular but not reaching the valve margin with radiatly striae.

(16) *Navicula cataracta-rheni* Lange-Bertalot (Figures 47 and 73)

Basionym: -

Length Range: 22-48 µm

Width Range: 6.3-8 µm

Striae in 10 µm: 12-13

Description: Valves are linear lanceolate or slightly lanceolate bluntly rounded apices. Axial area is narrowly linear. The central area is rhombic lanceolated shaped, and quite large. Striae are transapical radiate in the valve center and becoming convergent at the apices. The areolae are visible under the LM.

(17) *Navicula escambia* (Patrick) Metzeltin and Lange-Bertalot (Figures 43 and 73)

Basionym: *Navicula schroeteri* var. *escambia* Patrick

Length Range: 28.1-48.6 µm

Width Range: 6.3-9.1 µm

Striae in 10 µm: 10-13

Description: Valves are linear-elliptical with rounded apices. The central area is asymmetrically rounded with narrowly linear axial area and a distinctly central nodule is present. In the LM, the raphe is filiform with enlarged proximal raphe ends deflected towards the center. Striae are radiate. The space between the striae is equal to or less than the width of the striae. Areolae are lineate and apically aligned to form the appearance of continuous curving lines.

(18) *Navicula hintzii* Lange-Bertalot (Figures 45 and 73)

Basionym: -

Length Range: 30-38 µm

Width Range: 6.5-8.5 µm

Striae in 10 µm: 12-13

Description: Valves are linear-elliptic-lanceolate shape. Apices valves engaging with bluntly rounded ends. Raphe is straight, filiform, and central pores are distinct. Central area is small and widely lanceolate with narrowly axial area. Striae are strongly radiate in the two parts of the valve to the ends, scarcely convergent at the apices, and a little less elongated at the apical ends.

(19) *Navicula pseudostauropteroides* Fritsch (Figures 47 and 73)

Basionym: -

Length Range: 42-53 µm

Width Range: 9-10 µm

Striae in 10 µm: 14-16

Description: The valve apices are slightly produced, rounded, and capitated. The rather delicate ribs are very closely set and practically reach the median line; they are usually quite parallel except at the ends. In occasional individuals, they are slightly radiating in the centre. In some cases, there was no stauros and the ribs, though somewhat shorter, continued over the centre of the valve in a uniform manner.

(20) *Navicula vandamii* Schoeman & Archibald (Figures 45 and 73)

Basionym: *Navicula acephala* Schoeman

Length Range: 19.6-25 µm

Width Range: 4.1-5.5 µm

Striae in 10 µm: 16-19

Description: Valves are elliptical-lanceolate with protracted rostrate apices and a narrowly linear axial area. The central area is differentiated from the axial area. The raphe is filiform with enlarged proximal raphe ends that deflect toward one side of the valve. The striae are lineolate and radiate at the center to parallel or convergent at the apices. The space between the striae is wider or at least equal to the width of the striae. The central nodule is present on the same side as the deflected proximal fissures.

(21) *Navicula viridulacalcis* Lange-Bertalot in Rumrich *et al*. (Figures 45, and 73)

Basionym: *Navicula viridulacalcis* subsp. *viridulacalcis* Lange-Bertalot in Rumrich *et al.*

Length Range: 45-68 µm

Width Range: 10.0-12.2 µm

Striae in 10 µm: 8-9

Description: Valves are linear with pin-shaped apices and a narrowly and straight axial area. The central area is asymmetrical. The raphe is straight, with external proximal raphe ends slightly dilated and bent towards the primary side of the valve. The central nodule is asymmetrically expanded on the internal valve surface to the primary side. Striae are radiate in the valve center and convergent at the apices. The areolae are visible under the LM.

(22) *Navicula antonii* Lange-Bertalot (Figures 42 and 73)

Basionym: *Navicula menisculus* var. *grunowii* Lange-Bertalot

Length Range: 10-23.8 µm

Width Range: 4.2-7.3 µm

Striae in 10 µm: 16-22

Description: Valves are lanceolate shape. The raphe is filiform with linear and narrowly axial area. The central area is relatively small, oval to slightly asymmetrical shape. Striae are radiate and curved to the valve center. Striae become convergent at the valve apices with striae that are lineolate.

(23) *Nitzschia solgensis* Cleve-Euler, Kongl (Figures 54 and 73)

Basionym: *Nitzschia denticula* var. *delognei* Grunow in Van Heurck

Length Range: 10-30 µm

Width Range: 3-8 µm

Striae in 10 µm: 18-25

Description: Frustule is elongated and circular in shape, usually with a raphe or pseudo-raphe. Frustule raphe is provided with at least one valve, often very short and limited to the apices. The raphe extends along the face valve margin. Frustules are without keel, and possess a combination of different characters. Raphe appears interchangeable on both sides of the frustule, or central Fibulae is widespread transapical.

(24) *Nitzschia desertorum* Hustedt (Figures 60 and 73)

Basionym: -

Length Range: 13-22 µm

Width Range: 3-4 µm

Striae in 10 µm: 25-26

Description: Valves are elliptical-lanceolate with short, rostrate, narrowly round apices. Fibulae are small, but distinct, 14-16 in 10 µm. Striae are punctate and resolvable. The central two fibulae are equidistant from one another.

(25) *Nitzschia hantzschiana* Rabenhorst (Figures 61 and 73)

Basionym: *Nitzschia frustulum* var. *hantzschiana* (Rabenhorst) Grunow

Length Range: 8-20 µm

Width Range: 3-4 µm

Striae in 10 µm: 22-27

Description: Valves are linear to linear-lanceolate shaped with parallel margins. The distal valve is narrowly abrupt to form slightly protracted to rounded apices. Fibulae are distinct, numbering 11-13 in 10 µm. Striae are parallel and finely punctate.

(26) *Nitzschia sinuata* var. *tabellaria* Grunow (Figures 60 and 73)

Basionym: *Denticula tabellaria* Grunow

Length Range: 9-21 µm

Width Range: 4.5-8 µm

Striae in 10 µm: 18-23

Description: Valves are rhombic to lanceolate shaped and swollen at the center with slightly capitated to round apices. The fibulae of the raphe are distinct, expanded (crossing about half of the valve face), numbering 6-8 in 10 µm. Striae are distinctly punctate and radiate. A central nodule is commonly absent.

(27) *Placoneis witkowskii* Metzeltin, Lange-Bertalot & García-Rodríguez (Figures 24 and 73)

Basionym: -

Length Range: 14-24 µm

Width Range: 8-10 µm

Striae in 10 µm: 12-15

Description: Valves are simply elliptic shaped, but with broadly protracted subrostrate apices which are broadly rounded to truncate. The central pores of the raphe are closer to standing. Axial area is narrowly linear, less expanded towards the center. The central area is smaller, ill-defined and outlined by a single longer stria in the middle with two shorter striae on the other side.

(28) *Reimeria uniseriata* S.E.Sala, J.M.Guerrero & M.E.Ferrario (Figures 31 and 73)

Basionym: *Reimeria uniseriata* Sala, Guerrero and Ferrario

Length Range: 12.5-24 µm

Width Range: 4.0-7.0 µm

Striae in 10 µm: 8-10

Description: Valves are linear-lanceolated with subcapitate apices, dorsiventral with convex dorsal side. Ventral side of the valve has a pronounced medial expansion. Striae are uniseriate with areolae that are 17-20 in 10 µm and covered externally by silica flaps. The central area is expand in the middle of the ventral side. One stigma is present near the central nodule. The raphe is straight with the terminal raphe fissures that are curved to the ventral side.

(29) *Nitzschia commutata* Grunow (Figures 55 and 74)

Basionym: *Nitzschia pseudoamphyoxys* Hustedt

Length: 38.5-54.5 µm

Width: 4-6 µm (center valve)

Striae: 18-21 in 10 µm at the center; 20-23 in 10 µm at the ends

Description: Valves are linear-lanceolate shape with narrowing towards the produced, capitate endings. The ventral margin is concave and the dorsal margin is parallel to slightly concave. Raphe is strange, stretching along the valve margin; proximal raphe endings are simple; distal raphe endings are hooked toward the dorsal margin. Striae are parallel throughout. Fibulae are variable in size and spacing.

(30) *Nitzschia hoehnkii* Hustedt (Figures 55 and 74)

Basionym: *Nitzschia prolongata* var. *hoehnkii* (Hustedt) Lange-Bertalot

Length Range: 60-165 µm

Width Range: 2.9-6.5 µm

Striae in 10 µm: 22-25

Description: Frustule is linear with very little sigmoid shape. Valves are linear-lanceolate and gradually to moderate shape. The valve apices are acute to roundly capitate. The raphe is excentric with fibulae numbering 5-9 in 10 µm.

(31) *Nitzschia parvula* W.Smith (Figures 57, and 74)

Basionym: *Homoeocladia parvula* (W.Smith) Kuntze

Length Range: 35-100 µm

Width Range: 5-9 µm

Striae in 10 µm: 16-19

Description: Valves are linear and slightly concave in the middle. The poles of valves are protracted slightly and bluntly rounded. The raphe is excentric, with fibulae numbering 8-11 in 10 µm. The striae appear costated, rather than distinctly punctate. A longitudinal fold is present and extends the length of the valve.

(32) *Nitzschia salinicola* Aleem & Hustedt (Figures 54 and 74)

Basionym: -

Length Range: 20-70 µm

Width Range: 3.5-6.5 µm

Striae in 10 µm: 23-40

Description: Frustules are isopolar and bilaterally symmetrical with linear to linear-lanceolated features. The central part of the valve usually has slightly concave margins. Apices are usually rostrate, but sometimes cuneate in smaller specimens. Striae are easily visible to invisible in LM; stria pores are unresolvable. Fibulae are small, dot-like to ± square. Central pair of fibulae is more widely separated than the others. The central raphe endings are present and detectable with care by a tiny pimple-like thickening at the margin.

(33) *Plagiotropis lepidoptera* var. *proboscidea* (Cleve) Reimer in Patrick and Reime (Figures 52 and 74)

Basionym: *Tropidoneis lepidoptera* var. *proboscidea Cleve*

Length Range: 73-110 µm

Width Range: 17.1-20.4 µm

Striae in 10 µm: 17-19

Description: Valves are lanceolate with a curved valve face. The valve face has longitudinal folds and apiculate apices. The narrow axial area and raphe are both located on the apex of a raised keel that runs along the apical axis. The central area is asymmetrical and about one-half the width of the valve. The raphe is filiform with simple proximal and distal ends. Proximal raphe ends are straight, narrow and positioned close to one another. The striae are parallel at the center but become increasingly radiated towards the apices. Areolae are difficult to resolve in the LM.

(34) ***Sellaphora blackfordensis*** **D.G.Mann & S.Droop** (Figures 35 and 75)

Basionym: -

Length Range: 19-57µm

Width Range: 8-9.75 µm

Striae in 10 µm: 17-21

Description: Valves are linear-elliptical, with broadly and subcapitate apices. Axial area is narrow and central area is expanded somewhat irregularly and is mostly bow-tie–shaped. Raphe-sternum is often defined in the LM, through development of slight grooves alongside it, externally. Areolae are invisible in LM. Central external raphe endings are expanded but turned toward the primary side.

(35) ***Sellaphora capitata*** **D.G.Mann & McDonald, S.M.** (Figures 36 and 75)

Basionym: -

Length Range: 19-44 µm

Width Range: 7.0-9.3 µm

Striae in 10 µm: 18.2 -20.5

Description: Valves are linear-elliptical and possess broadly and subcapitate apices. Striae are radiated and curving and usually becoming angled near the apices. The axial area is narrow with expanded central area, somewhat irregular, mostly bow tie–shaped. No grooves are visible alongside the raphe-sternum in LM. The raphe is slightly sinuous, central external raphe endings expanded, turned towards the primary side.

(36) ***Sellaphora lanceolata*** **D.G.Mann & S.Droop** (Figures 35 and 75)

Basionym: -

Length Range: 24-30µm

Width Range: 7.1-8.1 µm

Striae in 10 µm: 17.7-21.8

Description: The valves are narrowly elliptical with rostrate apices. The axial area is narrow and straight. The central area is irregular in the outline and has the radiately striae at the center and then becomes convergent at the pole. The striae and transapical ribs are of approximately equal height, externally. The polar bars appear sharply angled toward the central area in the LM. The raphe appears simple, straight and thread-like. The external central raphe endings are expanded and scarcely deflected toward the primary side.

(37) *Sellaphora obesa* D.G.Mann & M.M.Bayer (Figures 35 and 75)

Basionym: -

Length Range: 20-53 µm

Width Range: 7.1-8.1 µm

Striae in 10 µm: 17.7-21.8

Description: The valves are elliptical with rostrated apices. The axial area is narrow and straight. The central area presents a rectangular outline and possesses short striae. The areolae are not observed in the LM. The polar silica bars appear perpendicular to the apical axis in the LM. The raphe-sternum is elevated externally, with well-marked grooves separating it from the remainder of the valve face. The raphe appears simple, straight and thread-like in the LM. The external central raphe endings are slightly expanded but deflected a little toward the primary side.

(38) *Sellaphora stroemii* (Hust.) H. Kobayasi in Mayama *et al.* (Figures 36 and 75)

Basionym: *Navicula stroemii* Hust.

Length Range: 8-18 µm

Width Range: 4-5 µm

Striae in 10 µm: 24-29

Description: Valves are linear with rounded apices and are sometimes slightly subcapitate in the bigger forms. The raphe is filiform, straight, with the external ends bent towards the primary side of the valve. The raphe sternum is flanked by parallel furrows, which are continuous or interrupted at the level of central area. The narrowly axial area is expanded in the middle with a bow tie–shaped central area. Striae are often visible in LM, but radiated and become sparser.

(39) *Sellaphora subbacillum* (Hust.) Falasco *et* Ector (Figures 34 and 75)

Basionym: *Navicula subbacillum* Hust.

Length Range: 10-24µm

Width Range: 3.5-5.0 µm

Striae in 10 µm: 24-28

Description: Valves are rather broadly linear with straight margins and have very broadly rounded apices. The raphe is both filiform and straight or slightly undulate, with long external ends bent toward one side of the valve. The parallel apical is located at the narrow axial area and is visibly observed under LM. The central area is absent or small and rounded. Striae are always visible, strongly radiate and becoming sparser in the centre.

(40) *Surirella ostentata* B.J.Cholnoky (Figures 66 and 75)

Basionym: -

Length Range: 11-16 µm

Width Range: 5-7 µm

Striae in 10 µm: 55

Description: The valves are heteropolar and have broadly rounded apices. The keel is low but slightly wider than the mantle face. The apical axial line is visible in the LM. The extremely abbreviated fibulae appear in a density of 8-10 in 10 µm and are visible in the LM arising from 2-4 costae. The portulae possess 2-4 costae entering them. The rows of areolae are interrupted between each fibulae before they enter the portulae.

(41) *Neidium binodeforme* Krammer in Krammer & Lange-Bertalot (Figures 33 and 75)

Basionym: *Neidiomorpha binodeformis* (K. Krammer in Krammer & Lange-Bertalot) M. Cantonati, H. Lange-Bertalot & N. Angeli

Length Range: 27-27.5 µm

Width Range: 5.5-7 µm

Striae in 10 µm: 26-28

Description: Valves are lanceolate with a central constriction and protracted and rostrate apices. Raphe is straight and filiform with straighly proximal ends. The axial area is straight, narrow and without a differentiated central area. Central nodule is distinct. Striae are radiate, punctate, and longitudinal lines are sub-marginal.

(42) *Puncticulata shanxiensis* Xie & Qi (Figures 10 and 75)

Basionym: *Cyclotella shanxiensis* Xie & Qi

Length Range: 9-27 µm

Striae in 10 µm: 10-17

Description: Valves are cylindrical and transversely undulatehe central area is of about half the valve diameter. One or two central portulaes are obviously visible in LM on the convex portion of the central area. The central area consisted of scattered nodules, or is unornamented. Striae are equal in length and multiseriate are near the valve margins. Striae are uniseriate nearest to the valve center. Putamen are disk-shaped, shallow, round and tray-like.

4.1.4 New taxa from Wang River (inpress)

From this studied, a new species of benthic diatoms were discovered as new taxa and being in publishing process. The informations of new species were show as below:

Basionym: *Cymbella bifurcumstigma* Nakkaew, Peerapornpisal and Mayama, sp. nov.

Length Range: 26–44 µm

Width Range: 11.0–13.5 µm

Striae in 10 µm: 14-16

Habitat:—Found only at lotic site in the Wang Kaew Water fall, Doi Luang National Park the upstream of Wang River, Thailand.

Other Information:—Collected 20 January 2012; growth on the cobble; collected by Surakit Nakkaew, Chiang Mai, Thailand; Environmental data: specific conductance = 280 µS/cm; pH = 8.51; total alkalinity = 162 mg/L; temperature = 18.8 Celsius; dissolved oxygen = 8.40 mg/L; total phosphorus = 0.01 mg/L; nitrate = 0.1 mg/L, ammonium=0.05 mg/L

Description: The live cell has a single plastid, which is X-shaped in dorsal girdle view (Figure 76 left) and H-shape in valve view (Figure 76 right). There is a large pyrenoid in the dorsal portion of the plastid (Figure 76). Valves are moderately dorsiventral elliptic-lanceolate with rostrate to subcapitate apices (Figure 77). Axial area narrow with slightly elongated central area. In dorsal side of the valve face, one stigma is present between central two striae. Striae slightly radiate in the center becoming radiate toward the ends. Valves are 26–44 µm long, 11.0–13.5 µm wide. In the valve center, striae on dorsal side 9–10 in 10 µm, on ventral side 11–13 in 10 µm, while near ends striae 14–16 in 10 µm on both sides. Areolar density 24–26 in 10 µm. Raphe is lateral and becomes filiform near the central endings, which are deflected slightly towards the ventral margin. External distal raphe endings slightly curved to the dorsal side.

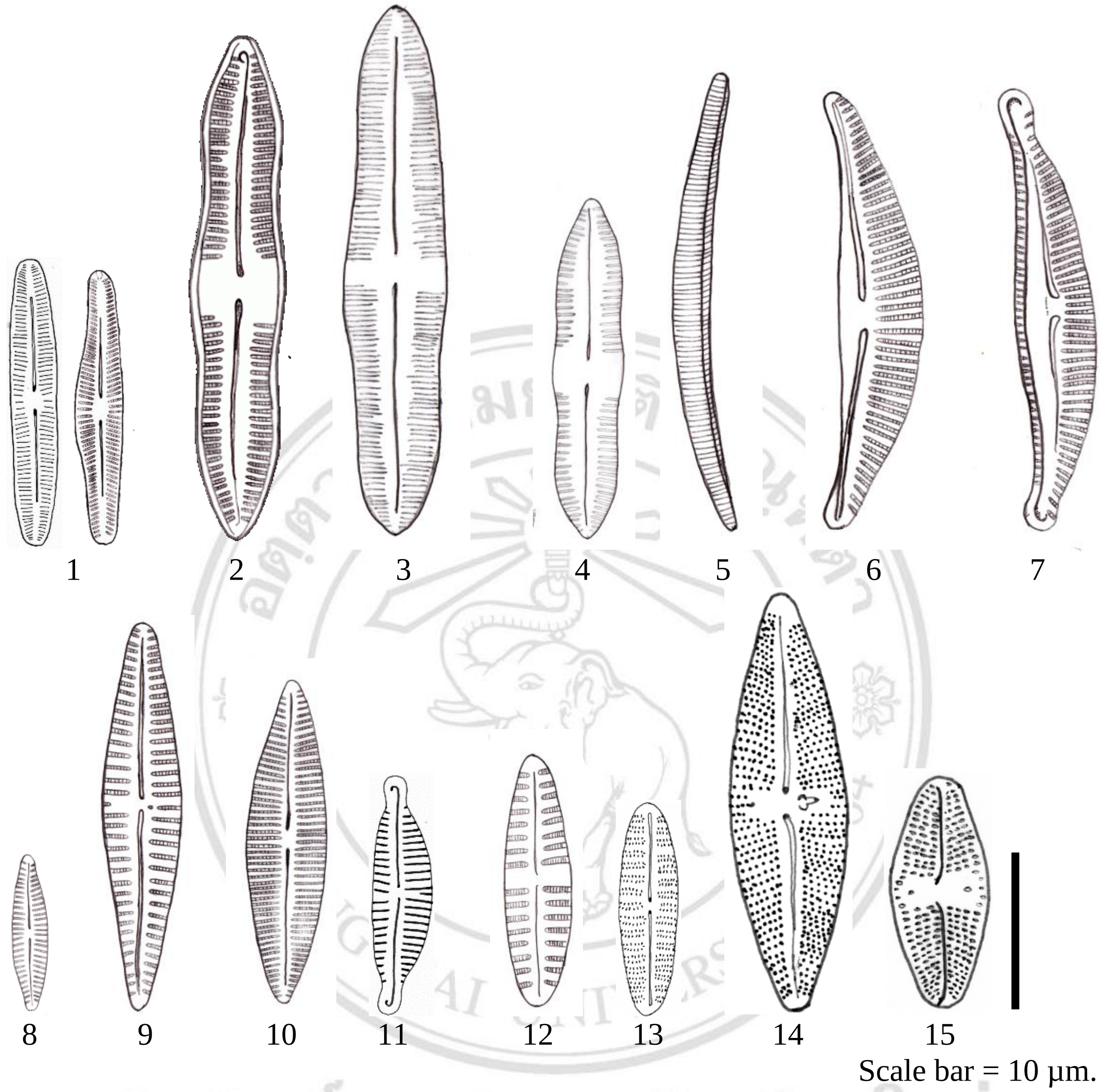


Figure 72 Illustration of new record benthic diatoms of Thailand in the Wang River during October 2011 to September 2012

(1) *Achnanthidium exile* (Kützing) Round & Bukhtiyarova, (2) *Caloneis silicula* var. *alpina* Cleve, (3) *C. silicula* var. *peisonis* Husted, (4) *C. ventricosa* (Ehrenberg) Meister, (5) *Eunotia curvata* (Kützing) Lagerstedt, (6) *Halamphora veneta* (Kützing) Levkov, (7) *H. bullatoides* (Hohn&Hellerman) Levkov, (8) *Delicata delicatula* (Kützing) Krammer, (9) *Gomphonema auritum* A.Braun ex Kützing, (10) *Craticula vixnegligenda* Lange-Bert., (11) *Encyonema gaeumannii* (Meister) Krammer, (12) *Hippodonta pseudoacceptata* (H.Kobayasi) Lange-Bertalot, Metzeltin & Witkowski, (13) *H. avittata* (Cholnoky) Lange-Bertalot, Metzeltin & Witkowski, (14) *Luticola terminata* (Hustedt) Johansen, (15) *L. simplex* Metzeltin, Lange-Bertalot & García-Rodríguez

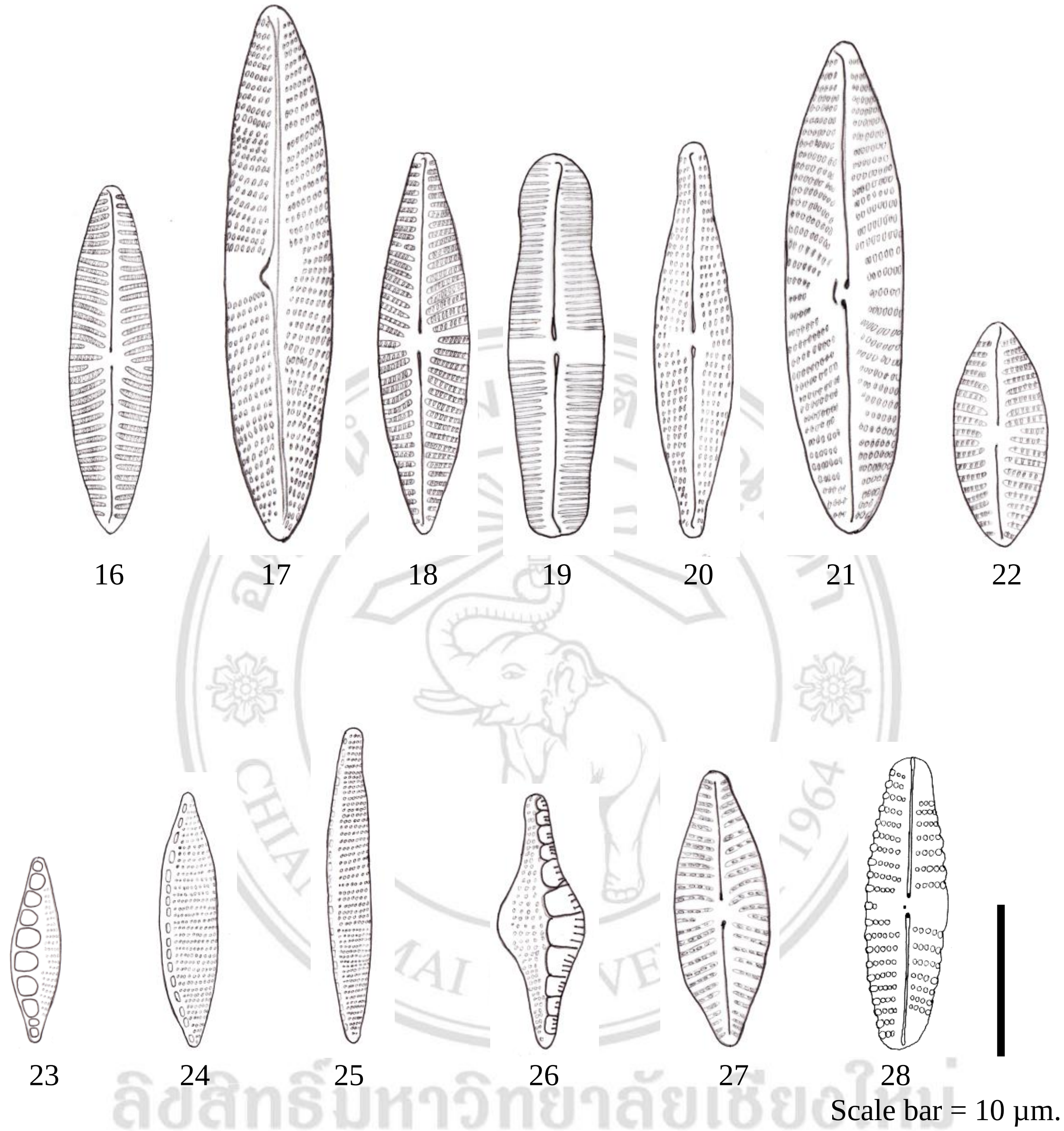


Figure 73 Illustration of new record benthic diatoms of Thailand in the Wang River during October 2011 to September 2012

(16) *Navicula cataracta-rheni* Lange-Bertalot, (17) *N. escambia* (Patrick) Metzeltin and Lange-Bertalot, (18) *N. hintzii* Lange-Bertalot, (19) *N. pseudostauropteroides* Fritsch, (20) *N. vandamii* Schoeman & Archibald, (21) *N. viridulacalcis* Lange-Bertalot in Rumrich *et al*., (22) *N. antonii* Lange-Bertalot, (23) *Nitzschia solgensis* Cleve-Euler, (24) *N. desertorum* Hustedt, (25) *N. hantzschiana* Rabenhorst, (2) *N. sinuata* var. *tabellaria* Grunow, (27) *Placoneis witkowskii* Metzeltin, Lange-Bertalot & García-Rodríguez, (28) *Reimeria uniseriata* Sala, Guerrero & Ferrario

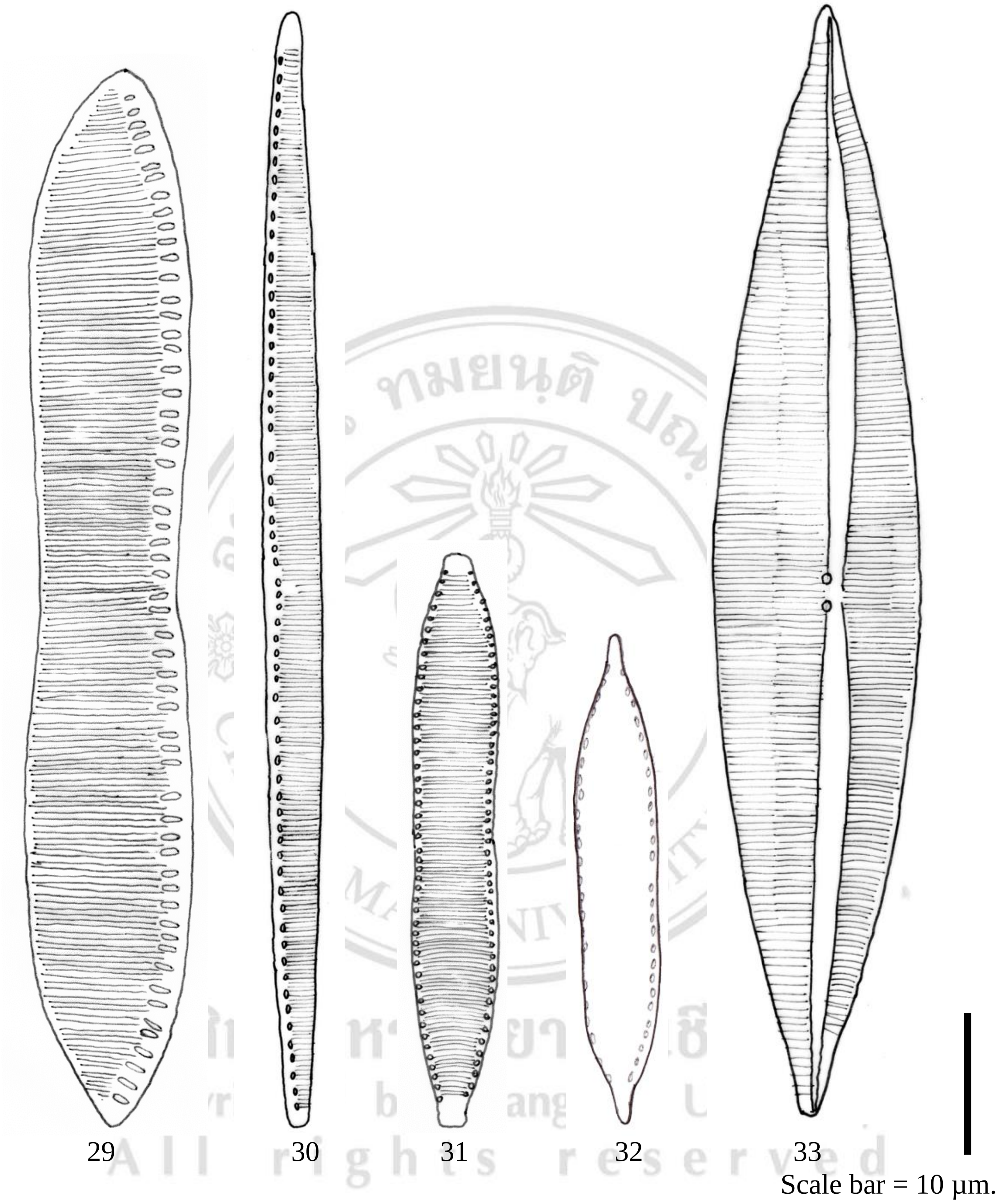


Figure 74 Illustration of new record benthic diatoms of Thailand in the Wang River during October 2011 to September 2012

(29) *Nitzschia commutata* Grunow, (30) *N. hoehnkii* Hustedt, (31) *N. parvula* Smith, (32) *N. salinicola* Aleem & Hustedt, (33) *Plagiotropis lepidoptera* var. *proboscidea* (Cleve) Reimer in Patrick and Reime

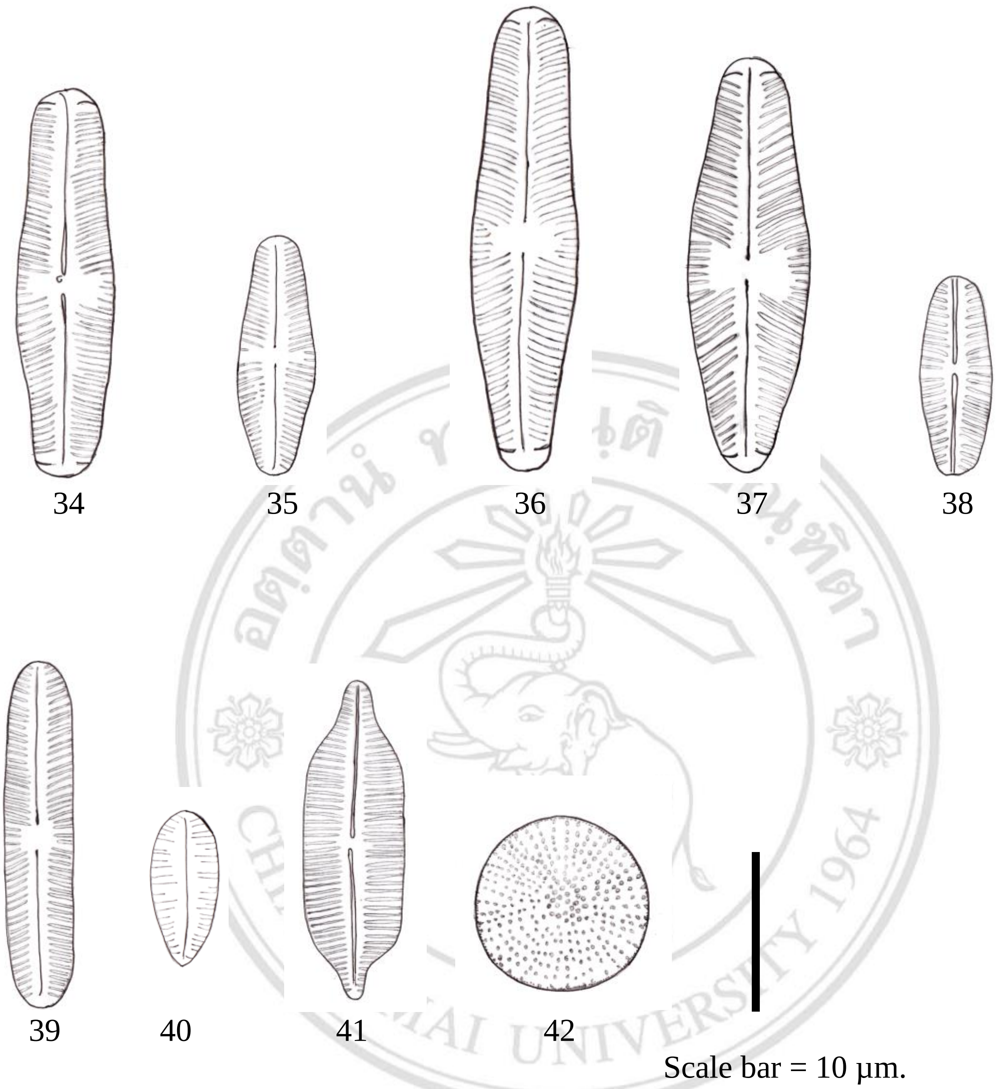


Figure 75 Illustration of new record benthic diatoms of Thailand in the Wang River during October 2011 to September 2012

(34) *Sellaphora blackfordensis* Mann & Droop, (35) *S.capitata* Mann & McDonald, (36) *S. lanceolata* Mann & Droop, (37) *S.obesa* Mann & Bayer, (38) *S.stroemii* (Hustedt) H. Kobayasi in Mayama *et al*., (39) *S.subbacillum* (Hustedt) Falasco *et* Ector, (40) *Surirella ostentata* Cholnoky, (41) *Neidium binodeforme* Krammer in Krammer & Lange-Bertalot, (42) *Puncticulata shanxiensis* Xie & Qi

SEM observation: Externally, valve is planar with shorter ventral and taller dorsal mantles (Figure 78). Outer fissure of the raphe runs almost straight throughout valve length. Proximal endings of the raphe form a small hook curving to ventral side. Terminal fissures are hook-like and curve to dorsal side. Uniseriate striae continue from the valve face to the mantle without interruption on both ventral and dorsal valve shoulders. Outer openings of the areolae are elongated along the apical axis except for those located in the margin of central area and in apical mantle; they are transapically elongated in the center and rounded in the ends of the valve. The numbers of areola are 24–26 in 10 µm. The outer opening of stigma is oval to circular, showing internally convoluted bifurcation of pore; the stigmal hole is divided into two branches by a ridge fusing with dorsal portion of the outer opening.

Internally, the dorsal mantle is almost threefold taller than ventral mantle and both sides of the raphe sternum are equally thick except for central nodule, in which only ventral side thickened (Figure 79). Inner fissure of the raphe runs continuously between both poles without interruption at the center. Inner distal fissures were terminate as helictoglossae. Each helictoglossa is placed slightly toward dorsal side from apical axis. Between helictoglossa and apical mantle margin, narrowly curved hyaline area is formed in both apices; it corresponds to underside of the distal fissure. Striae are formed in troughs between developed virgae. The areolae are loculate and have mushroom-like inner occlusion, papilla. At the valve center, there are elongated grooves in the two central striae, which are united near the outer opening of the stigma.

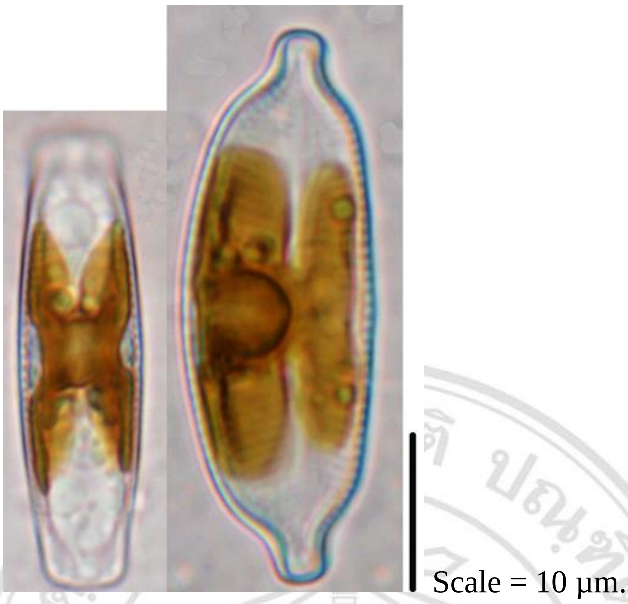


Figure 76 *Cymbella bifurcumstigma*, live cells. Left: girdle view, right: valve view

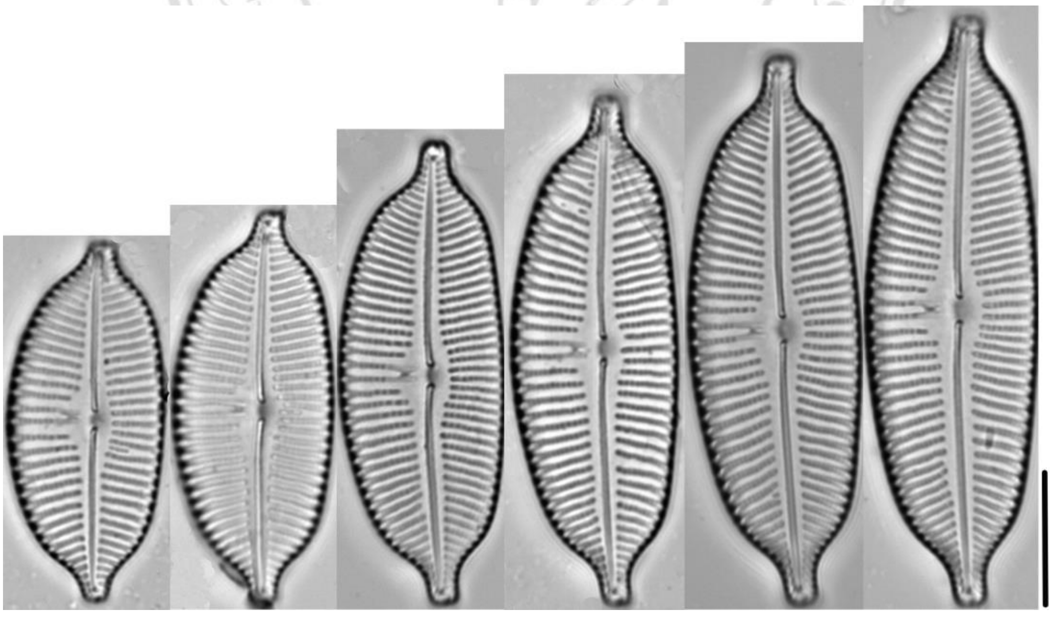


Figure 77 *Cymbella bifurcumstigma*, cleaned valves

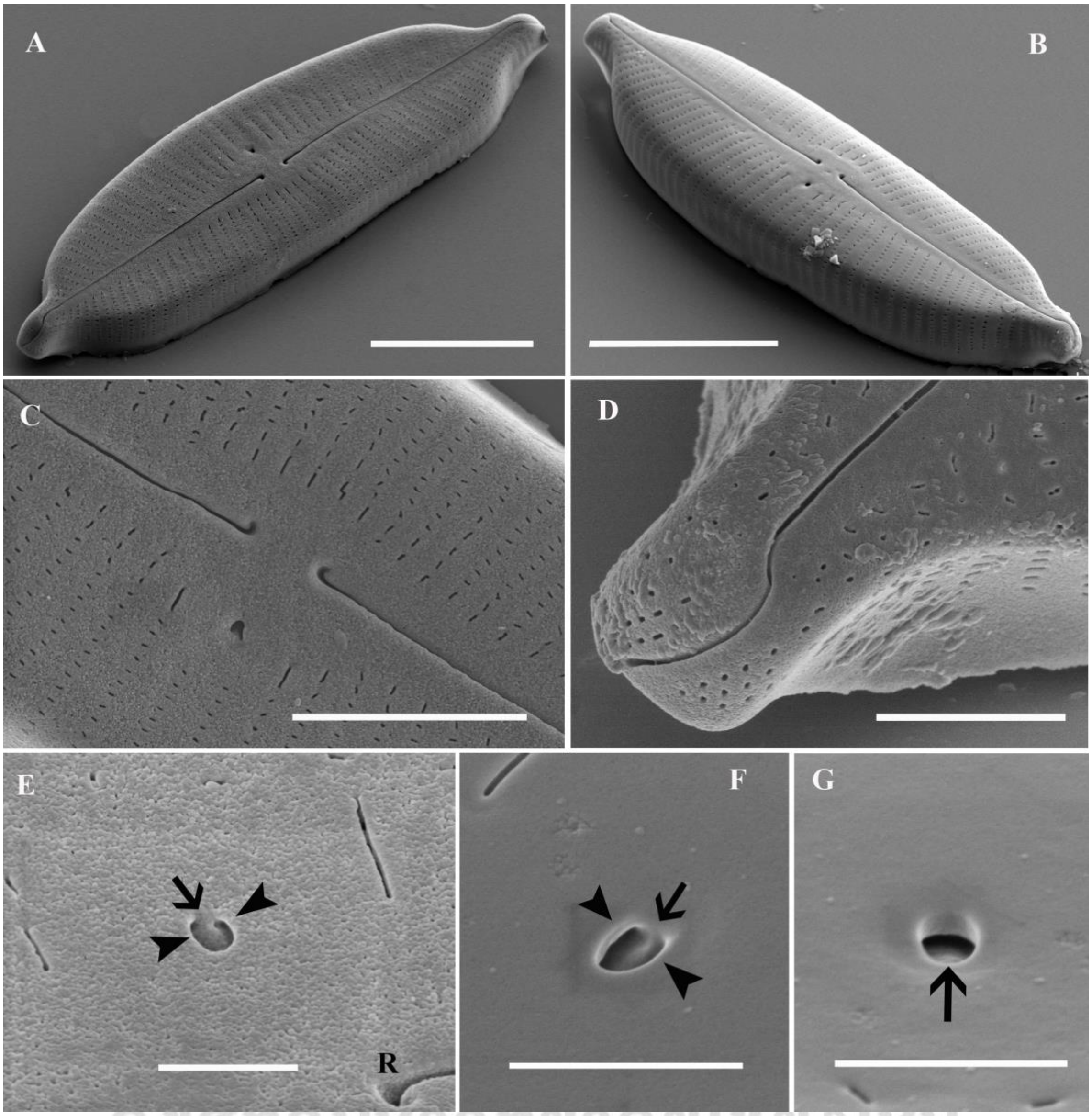


Figure 78 SEM of external valve views of *Cymbella bifurcumstigma*: (A, B) showing external surface from ventral and dorsal sides, respectively. (C) showing central endings of the raphe with a small hook curving to ventral side and a stigma opening located on dorsal side. (D) showing hook-like terminal fissures that curve to dorsal side.(E–G) showing characteristic of bifurcated stigma on external view (arrow heads:each branched hole penetrating to inner opening. arrows: ridge fusing with dorsal portion of the outer opening of stigma. R: central raphe ending. Scale bars = 10 μm (A, B); 5 μm (C); 2 μm (D); 1 μm (E–G)

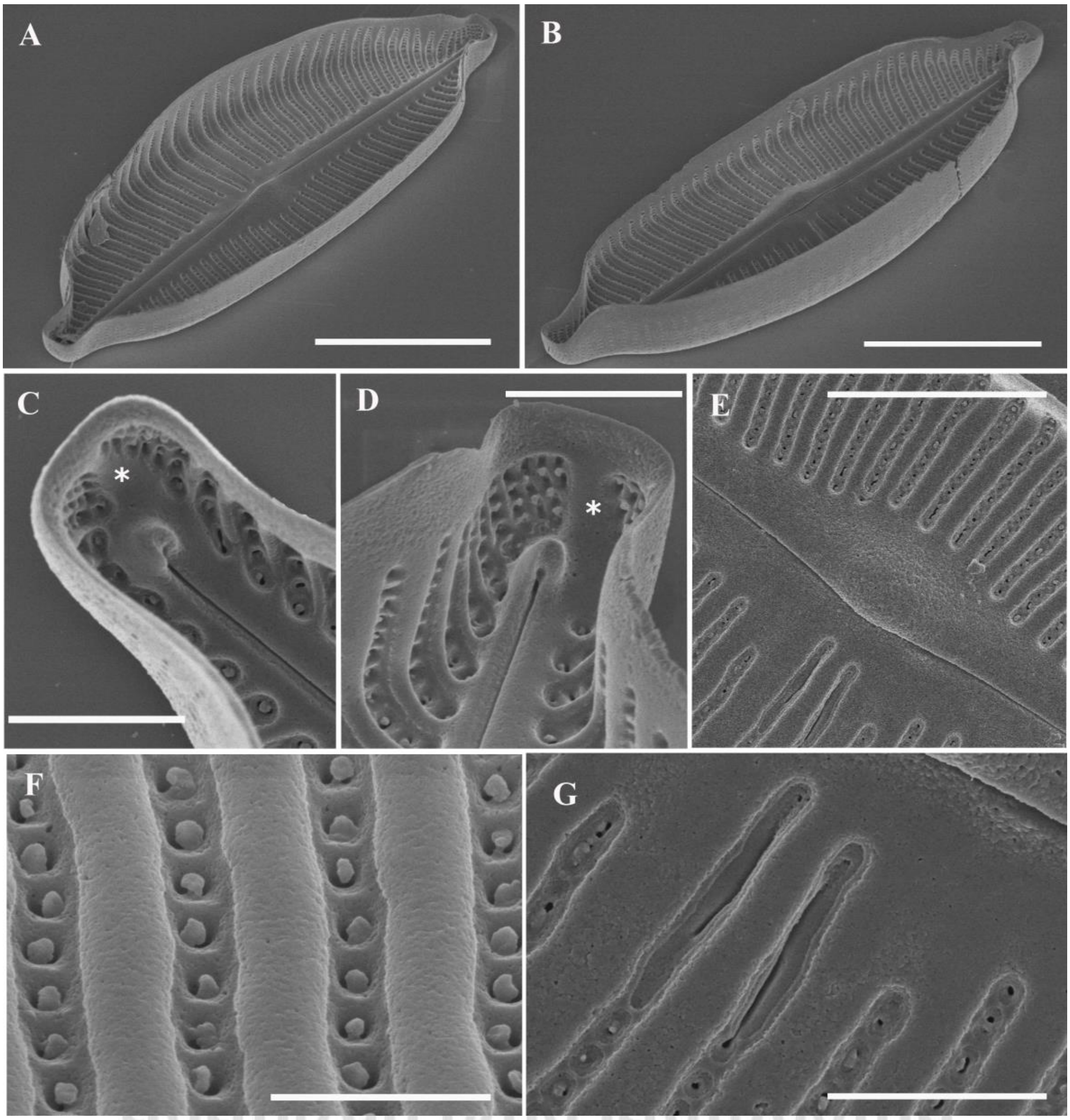


Figure 79 SEM of internal valve views of *Cymbella bifurcumstigma*: (A, B) showing internal surface from ventral and dorsal sides, respectively. (C, D) showing an inner fissure terminated in a helictoglossa and a narrowly curved hyaline area formed in both apices (asterisk). (E) showing inner fissure of the raphe running continuously between both poles without interruption at the center.(F) showing loculate areolae with mushroom-like inner occlusion, papilla. (G) showing the elongated grooves in the two central striae which are united near the outer opening of the stigma on the external side**.** Scale bars = 10 μm (A, B); 2 μm (C, D, E); 5 μm (F); 1 μm (G)

4.1.3 Relative abundance

A total of 129,600 benthic diatom cells were counted and identified from 12 samplings sites in the Wang River of Thailand. The percentages of relative abundance of 28 common species (relative abundance of more than 1%) are shown in Table 12. The highest number of benthic diatoms were identified as *Nitzschia palea* (15.53%), *Achnanthidium minutissimum* (10.00%), *Seminavis strigosa* (7.13%) *Achnanthidium exile* (4.79%), *Planotudium frequentissimum* (2.48%), *Gomphonema parvulum* (2.39%), *Cymbella affinis* (2.38%), *Navicula simulata* (2.25%) and *Cocconeis placentula* (1.76%), respectively.

Table 12 Twenty-eight common species of benthic diatoms in the Wang River and their percentages of relative abundance * = present

TAXA	% relative abundant	Site											
		1	2	3	4	5	6	7	8	9	10	11	12
Auracoseira granulate	1.35	-	-	*	*	*	*	*	*	*	-	*	*
Discostella stelligeroides	1.59	-	-	*	*	*	*	*	*	*	-	*	*
Achnanthidium exile	4.79	*	-	*	*	*	-	*	*	*	-	*	-
Achnanthidium minutissimum	10.00	*	*	*	*	*	*	*	-	*	*	*	*
Cocconeis placentula	1.76	*	*	*	*	*	-	*	*	*	*	*	*
Cymbella affinis	2.38	-	*	*	*	*	*	*	-	-	-	*	*
Cymbella parva	1.09	-	-	*	*	*	*	*	-	-	-	-	-
Cymbella turgidula	1.34	*	*	-	*	-	-	-	*	*	*	*	-
Cymbella bifurcumstigma	1.67	*	-	*	-	-	-	-	-	-	-	-	-
Delicata spartistriata	1.06	*	-	-	*	-	*	-	-	-	-	-	-
Encyonema malaysianum	1.22	*	-	-	-	-	-	-	-	*	-	-	-
Encyonopsis microcephala	1.58	*	*	*	*	*	-	-	-	-	-	-	-
Hippodonta pseudoacceptata	1.00	-	*	-	-	-	-	-	*	*	*	*	*
Gomphonema pumilum	1.77	*	*	*	*	-	*	-	*	-	-	-	-
Gomphonema auritum	1.61	*	-	*	*	*	*	*	-	-	*	-	*
Gomphonema parvulum	2.39	-	*	-	*	*	*	*	*	*	*	*	*
Navicula suprinii	1.01	*	-	-	-	*	*	*	-	-	-	-	*
Navicula simulata	2.25	-	-	-	*	*	*	*	*	*	*	*	*
Navicula cf. *leistikowii*	1.22	*	-	-	*	*	*	*	-	-	*	*	-
Navicula cf. *parablis*	1.28	-	*	*	*	-	-	*	*	*	*	*	-
Nitzschia recta	1.58	*	-	*	*	*	*	*	-	-	-	*	*
Nitzschia cf. *ruttneri*	1.51	-	*	-	-	*	*	*	*	-	*	*	*
Nitzschia gracilis	1.21	-	*	-	-	*	*	*	*	*	*	*	*
Nitzschia palea	15.53	-	*	*	*	*	*	*	*	*	*	*	*
Planotudium frequentissimum	2.48	-	*	*	*	*	*	*	*	*	*	*	*
Seminavis strigosa	7.13	-	*	*	*	*	*	*	*	*	*	*	*
Ulnaria lanceolata	1.01	*	-	*	*	*	*	*	-	-	-	*	*
Ulnaria ulna	1.68	*	*	*	*	*	*	*	*	*	*	*	-

4.1.5 Diversity index

Shannon's diversity index, evenness and the species number of benthic diatoms in the Wang River are shown in Tables 13-15. The diversity index of benthic diatoms ranged from 0.46-3.14 and the evenness ranged from 0.201-0.877, while the number of species was ranged from 10-47. The lowest values of the diversity index were observed at sampling site 8 in August 2012 and the highest values were observed at sampling site 3 in April 2012. The evenness values were lowest at sampling site 8 in August 2012 and the highest values were revealed in sampling site 12 in April 2012. The highest numbers of species were recorded at sampling site 7 in October 2011, while the lowest value was recorded at sampling site 10 in September 2012.

The data of Shannon's diversity index, evenness and the species number of benthic diatoms in the Wang River were considered by each site (Table 14), while the highest value of the diversity index was 3.4 and was found at site 12 where the Wang River joined with the Ping River. Conversely, the lowest value of the diversity index was 2.32 and was found at site 8, which was located in the urban area and had more polluted water. The higest evenness value was 0.79 and was also found at site 12, while the lowest value was 0.56 and was found at site 8. The highest species number was 87 species that was recorded at site 9 which contained polluted water and the minimum value of water velocity, while the lowest value in terms of species number was reported as 60 species at site 10.

While the data of Shannon's diversity index, the evenness and the species number of benthic diatoms in the Wang River was considered by the month and are shown in Table 15. The highest value of the diversity index was 3.85 in April 2012 and the lowest value was 3.26 in August 2012. The highest recorded value of the evenness index was 0.807 in April 2012 and lowest recorded value was 0.707 in August 2012. And the highest number of species was found in October 2011, where a total of 141 species was found, and the lowest number was recorded in June 2012 with a tatal of 104 diatoms species found.

Table 13 Shannon's diversity index, evenness and the species number of benthic diatoms in the Wang River during the period of October 2011 to September 2012

Sampling site	Diversity Index	Evenness	Number of species
site1-Oct	1.871	0.581	25
site 2-Oct	2.409	0.739	26
site3-Oct	2.05	0.696	19
site4-Oct	2.287	0.777	19
site5-Oct	2.405	0.832	18
site6-Oct	1.767	0.52	30
site7-Oct	3.097	0.804	47
site8-Oct	1.339	0.507	14
site9-Oct	2.101	0.573	39
site10-Oct	1.758	0.587	20
site11-Oct	2.686	0.845	24
site12-Oct	2.683	0.868	22
site1-Nov	2.007	0.616	26
site2-Nov	2.098	0.689	21
site3-Nov	2.178	0.647	29
site4-Nov	1.973	0.613	25
site5-Nov	2.558	0.854	20
site6-Nov	2.09	0.687	21
site7-Nov	2.313	0.702	27
site8-Nov	1.08	0.469	10
site9-Nov	1.706	0.552	22
site10-Nov	1.861	0.571	26
site11-Nov	1.973	0.648	21
site12-Nov	2.907	0.839	32
site1-Dec	2.272	0.689	27
site2-Dec	2.391	0.752	24
site3-Dec	2.027	0.656	22
site4-Dec	1.685	0.511	27
site5-Dec	2.753	0.794	32
site6-Dec	2.7	0.861	23
site7-Dec	2.538	0.762	28
site8-Dec	2.501	0.751	28
site9-Dec	2.351	0.713	27
site10-Dec	1.898	0.614	22
site11-Dec	1.366	0.493	16
site12-Dec	2.549	0.735	32
site1-Jan	2.371	0.728	26
site2-Jan	2.61	0.767	30
site3-Jan	1.434	0.451	24
site4-Jan	2.452	0.866	17
site5-Jan	2.495	0.833	20

Table 13 (continued)

Sampling site	Diversity Index	Evenness	Number of species
site6-Jan	1.803	0.541	28
site7-Jan	2.45	0.771	24
site8-Jan	2.031	0.657	22
site9-Jan	2.323	0.705	27
site10-Jan	2.181	0.641	30
site11-Jan	2.297	0.705	26
site12-Jan	2.859	0.867	27
site1-Feb	1.882	0.6	23
site2-Feb	2.137	0.622	31
site3-Feb	2.027	0.602	29
site4-Feb	2.788	0.802	22
site5-Feb	2.279	0.717	24
site6-Feb	2.165	0.764	17
site7-Feb	2.398	0.83	18
site8-Feb	1.145	0.497	10
site9-Feb	1.913	0.662	18
site10-Feb	1.295	0.505	13
site11-Feb	2.413	0.781	22
site12-Feb	2.567	0.831	22
site1-Mar	2.22	0.682	26
site2-Mar	1.919	0.652	19
site3-Mar	2.762	0.848	26
site4-Mar	1.638	0.547	20
site5-Mar	1.524	0.55	16
site6-Mar	2.431	0.738	27
site7-Mar	1.216	0.421	18
site8-Mar	2.397	0.736	26
site9-Mar	2.407	0.715	29
site10-Mar	2.33	0.778	20
site11-Mar	2.449	0.832	19
site12-Mar	2.774	0.858	22
site1-Apr	2.237	0.664	29
site2-Apr	1.069	0.351	21
site3-Apr	3.142	0.841	42
site4-Apr	2.445	0.719	30
site5-Apr	1.519	0.548	16
site6-Apr	2.652	0.787	29
site7-Apr	2.318	0.72	25
site8-Apr	1.69	0.659	13
site9-Apr	2.422	0.762	24
site10-Apr	2.986	0.827	37
site11-Apr	2.978	0.867	31

Table 13 (continued)

Sampling site	Diversity Index	Evenness	Number of species
site12-Apr	3.04	0.877	32
site1-May	2.403	0.729	27
site2-May	3.013	0.841	36
site3-May	2.296	0.651	34
site4-May	2.138	0.714	20
site5-May	2.456	0.834	19
site6-May	0.912	0.329	16
site7-May	2.077	0.637	26
site8-May	2.295	0.794	18
site9-May	2.669	0.871	20
site10-May	2.814	0.865	24
site11-May	2.479	0.875	17
site12-May	2.808	0.852	27
site1-Jun	2.321	0.74	23
site2-Jun	2.389	0.852	15
site3-Jun	2.269	0.696	26
site4-Jun	2.594	0.861	19
site5-Jun	2.152	0.731	19
site6-Jun	2.608	0.767	30
site7-Jun	2.166	0.821	14
site8-Jun	1.48	0.494	20
site9-Jun	2.327	0.764	21
site10-Jun	2.391	0.812	19
site11-Jun	1.965	0.645	21
site12-Jun	2.641	0.862	20
site1-Jul	2.472	0.742	28
site2-Jul	2.335	0.725	25
site3-Jul	2.94	0.827	35
site4-Jul	1.161	0.402	18
site5-Jul	2.477	0.841	19
site6-Jul	2.418	0.821	19
site7-Jul	1.771	0.625	17
site8-Jul	1.94	0.648	20
site9-Jul	2.013	0.672	20
site10-Jul	2.358	0.851	16
site11-Jul	0.8	0.277	18
site12-Jul	2.169	0.683	24
site1-Aug	2.444	0.667	39
site2-Aug	3.047	0.864	34
site3-Aug	2.974	0.837	35
site4-Aug	2.617	0.748	33
site5-Aug	3.066	0.853	41
site6-Aug	1.466	0.572	13

Table 13 (continued)

Sampling site	Diversity Index	Evenness	Number of species
site7-Aug	2.577	0.834	22
site8-Aug	0.464	0.201	10
site9-Aug	1.99	0.664	20
site10-Aug	1.694	0.736	10
site11-Aug	1.621	0.55	19
site12-Aug	2.283	0.75	21
site1-Sep	2.632	0.818	25
site2-Sep	2.778	0.827	20
site3-Sep	2.841	0.872	26
site4-Sep	2.767	0.84	27
site5-Sep	2.833	0.833	30
site6-Sep	1.501	0.569	14
site7-Sep	2.274	0.787	18
site8-Sep	1.386	0.479	18
site9-Sep	3.059	0.829	40
site10-Sep	1.904	0.766	12
site11-Sep	1.306	0.545	11
site12-Sep	1.981	0.826	11

Table 14 Shannon's diversity index, evenness and the species number of benthic diatoms in the Wang River considered by sampling site

Sampling site	Diversity Index	Eveness	Number of species
S1	2.758	0.654	68
S2	3.127	0.72	77
S3	3.147	0.716	81
S4	3.032	0.7	76
S5	2.929	0.674	77
S6	2.932	0.681	74
S7	3.233	0.728	85
S8	2.324	0.555	66
S9	3.057	0.684	87
S10	2.762	0.674	60
S11	2.794	0.672	64
S12	3.4	0.79	74

Table 15 Shannon's diversity index, evenness and the species number of benthic diatoms in the Wang River considered by month

Sampling month	Diversity Index	Eveness	Number of species
m1	3.693	0.746	141
m2	3.469	0.722	116
m3	3.492	0.726	123
m4	3.434	0.715	122
m5	3.456	0.727	116
m6	3.508	0.728	124
m7	3.694	0.759	130
m8	3.85	0.807	118
m9	3.629	0.781	104
m10	3.599	0.76	114
m11	3.255	0.707	112
m12	3.646	0.764	118

4.2 Physico - chemical properties of the Wang River

The environmental parameters measured in the Wang River and its reservoirs between October 2011 and September 2012 are shown in Tables 16-17. It was found that wide differences were apparent between the sampling sites. The water properties observed results are shown as follows.

4.2.1 Water and air temperatures

The water temperature in the Wang River and its reservoir was measured between October 2011 and September 2012 and ranged from 18.4 – 35.5 °C (Tables 16-17, Figure 80 and Appendix 1). The lowest water temperature was recorded in December 2011 at site 1. The highest temperature was observed in April 2012 at site 8. The mean average water temperature between all sampling sites and months of record revealed significant differences ($p < 0.001$) (Appendix 3), where the lowest water temperature was recorded in site 1, which is an upstream and mountainous area, at 20.9 °C while the higest temperature was recorded at site 9, which is an urban area, at 29.8 °C. And the results of study also showed that the month of December was the in the cool-dry season and was the month which showed the lowest average water temperature at 25.2 °C. Additionally, April, which falls in the hot-dry season, presented the highest average water temperature of about 30.9 °C.

Air temperature followed a similar pattern as water temperature and ranged from 17.5- 39 °C (Tables 16-17, Figure 81, and Appendix 1). The lowest air temperature was recorded in January 2012 at site 1 and the highest temperature was observed in March 2012 at site 8. The mean average air temperature of all sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3), the lowest average air temperature was recorded at site 1 as 23.4 °C, while the higest average air temperature was recorded at site 10 at 32.9 °C. December revealed the lowest average air temperature at about 27 °C, while May reported the higest average air temperature at about 36 °C.

4.2.2 Velocity

The velocity of the water in the Wang River depended on slope, water discharge, seasons and dam operations. The range of velocity was 0.00-0.70 m/s with the highest value at site 4 in May 2012 and the lowest value being recorded at site 3 and site 6, which were decared as standing water sites. For the study of velocity in the main river, the mean average velocity of all sampling sites revealed significant differences ($p < 0.001$) (Appendix 3), the higest was recorded at 0.37 m/s and was reported at site 4 and the lowest was reported as 0.03 m/s and occurred at site 9. In addition, site 4 showed a high current of velocity because this site was located below the Kiew Kor Ma Dam, where the water was discharged from the dam gate when it was in operation (Tables 16-17, Figure 82 and Appendix 1). Site 9 reported the low current level of this property due to the fact that at this location, the main river was blocked by a concrete weir causingthe water current to slow down. Nevertheless, the velocity data in site 3 and site 6 were not investigated because both these sites were comprised of standing water.

4.2.3 Conductivity

Conductivity is the measure of the ability of an aqueous solution to induce an electric current. This ability depends on the dissolved ions including the total component concentration and temperature. The conductivity level of the Wang River in both running and standing water were found to be different. In the standing water sites or at the reservoirs sites, the conductivity levels were lower than in the running water or main river sites. Moreover, the seasonal period also affected to this property by amount concentration. The conductivity in the Wang River and its reservoirs ranged from 128.7 – 523.3 $\mu S.cm^{-1}$. The lowest values were detected in September 2012 at site 6 and the highest values were detected at site 8 in April 2012 (Tables 16-17, Figure 83, and Appendix 1). The mean average conductivity of all sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3), whereas the higest values occurred at site 11 as 334.3 $\mu S.cm^{-1}$ and in December at 307.0 $\mu S.cm^{-1,}$ while the lowest values were presented at site 5 at 195.8 $\mu S.cm^{-1}$ and in August at 221.0 $\mu S.cm^{-1}$. In addition, the prevailing trend of the conductivity value at the downstream sites (sites 8-12) was higher than at the upstream site (sites 1-7) by the amount of ion that was released from the household and agricultural activities.

4.2.4 Dissolved oxygen (DO)

The amount of DO in the standing water is a result of the process of photosynthesis. However, in the running water, the DO is influenced by many factors such as water movement dynamics and other physical factors. Light, temperature and the nutrient level of the water as well as other environmental conditions influenced the DO. Normally, the dissolved oxygen level of running water revealed higher values than standing water as a result of the movement of the water. The dissolved oxygen concentrations in the Wang River and its reservoirs ranged from 4.0 – 10.7 $mg.l^{-1}$

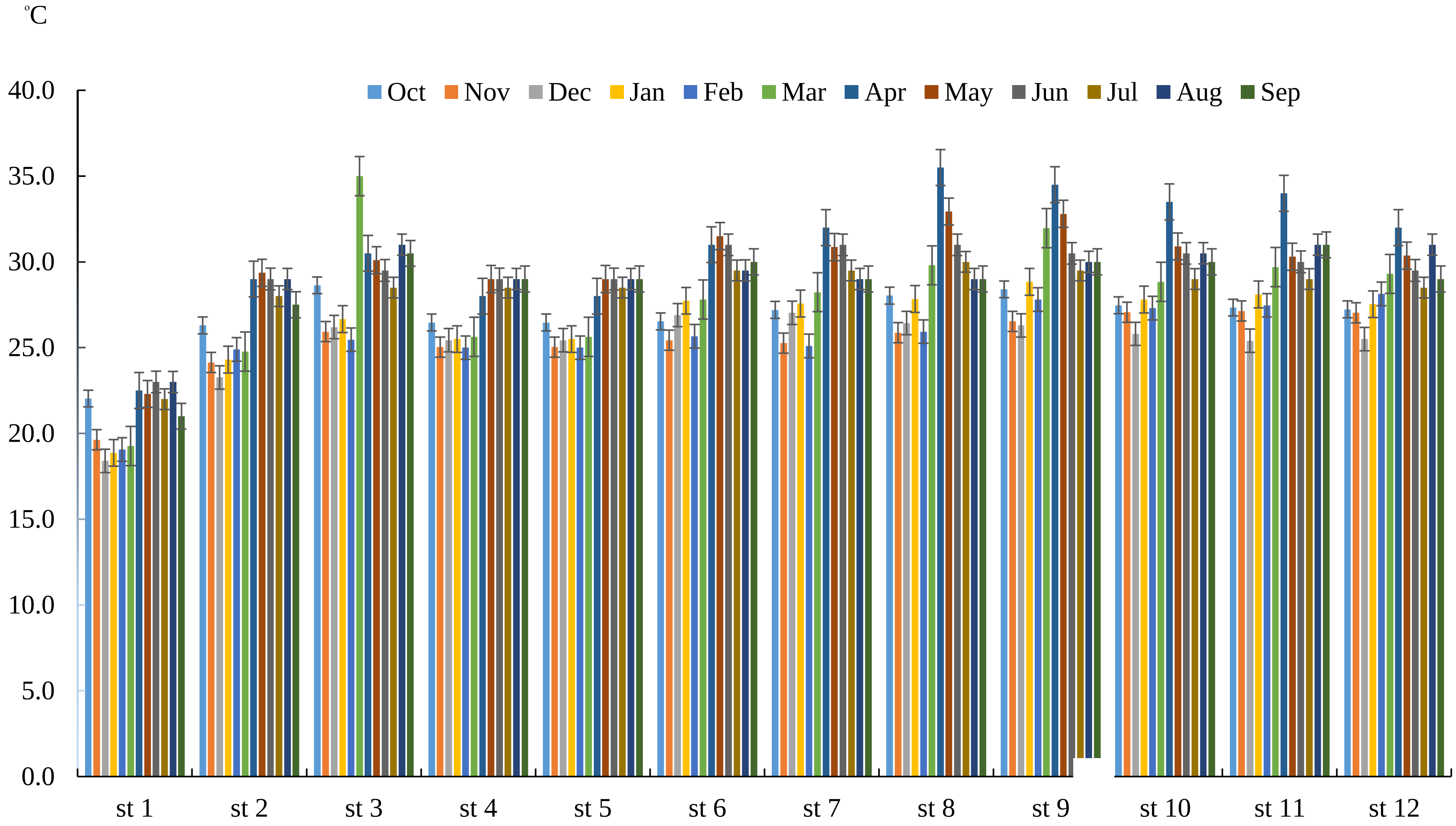


Figure 80 Water temperature in each sampling site of the Wang River from October 2011 to September 2012

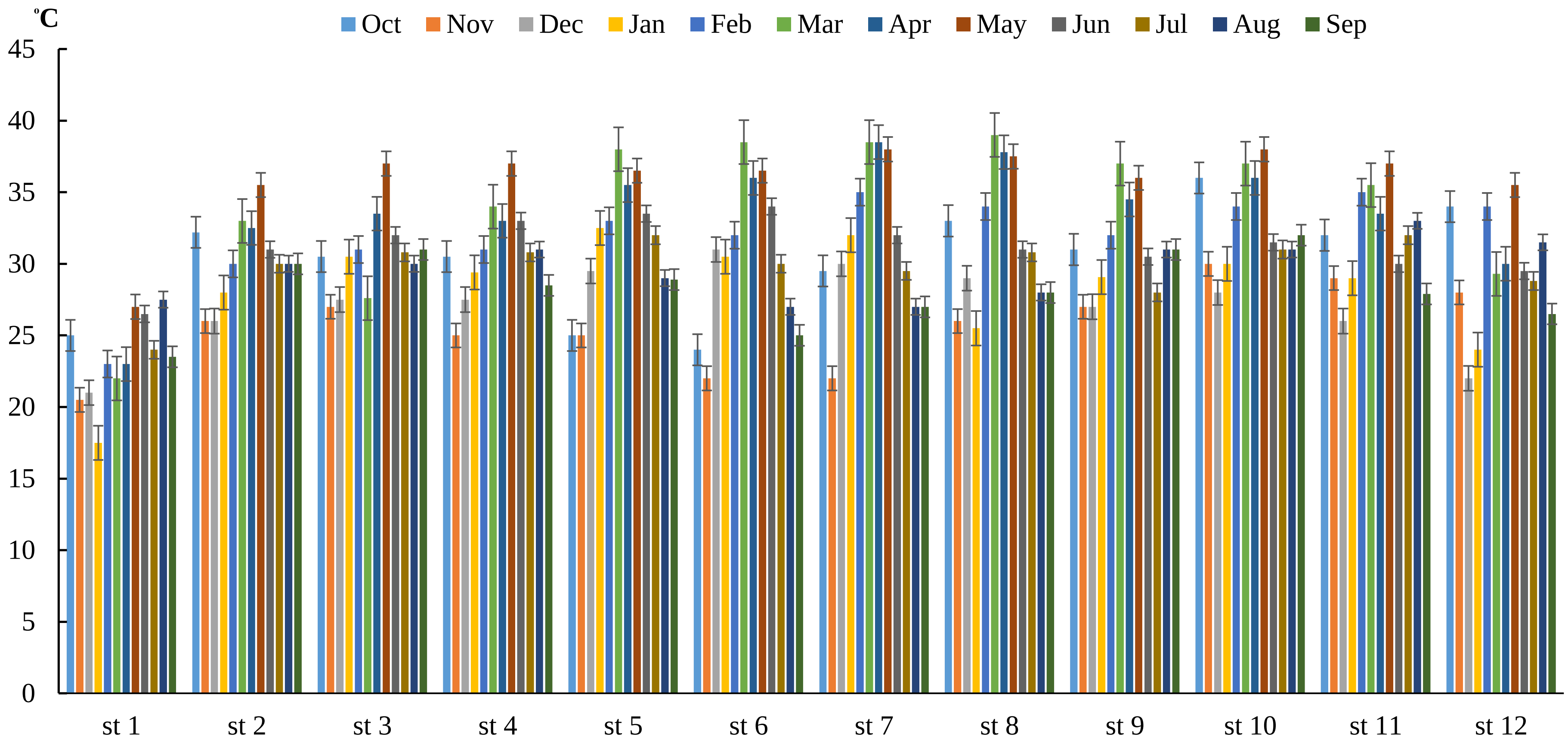


Figure 81 Air temperature in each sampling site of the Wang River from October 2011 to September 2012

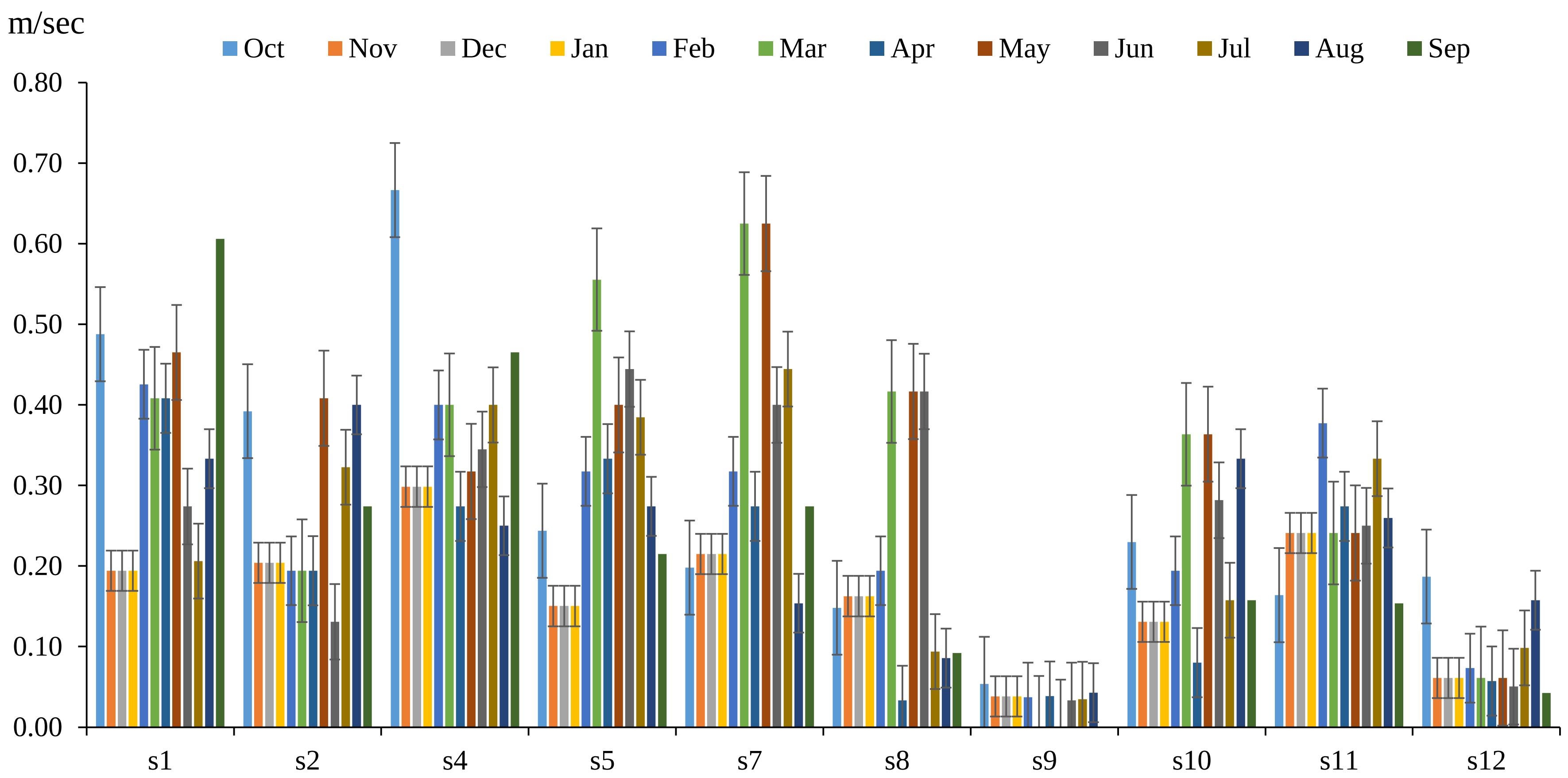


Figure 82 Velocity in each sampling site of the Wang River from October 2011 to September 2012

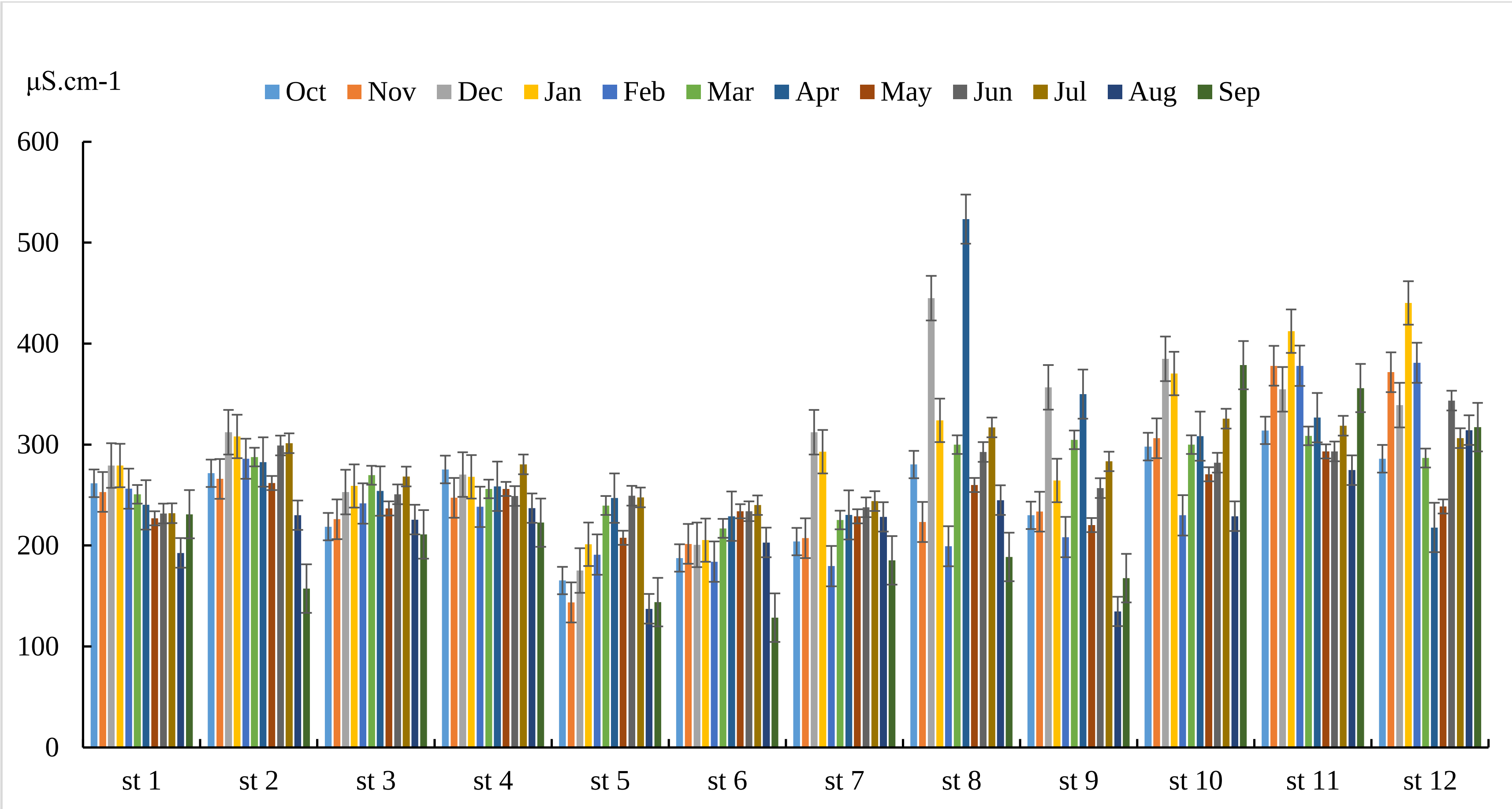


Figure 83 Conductivity in each sampling site of the Wang River from October 2011 to September 2012

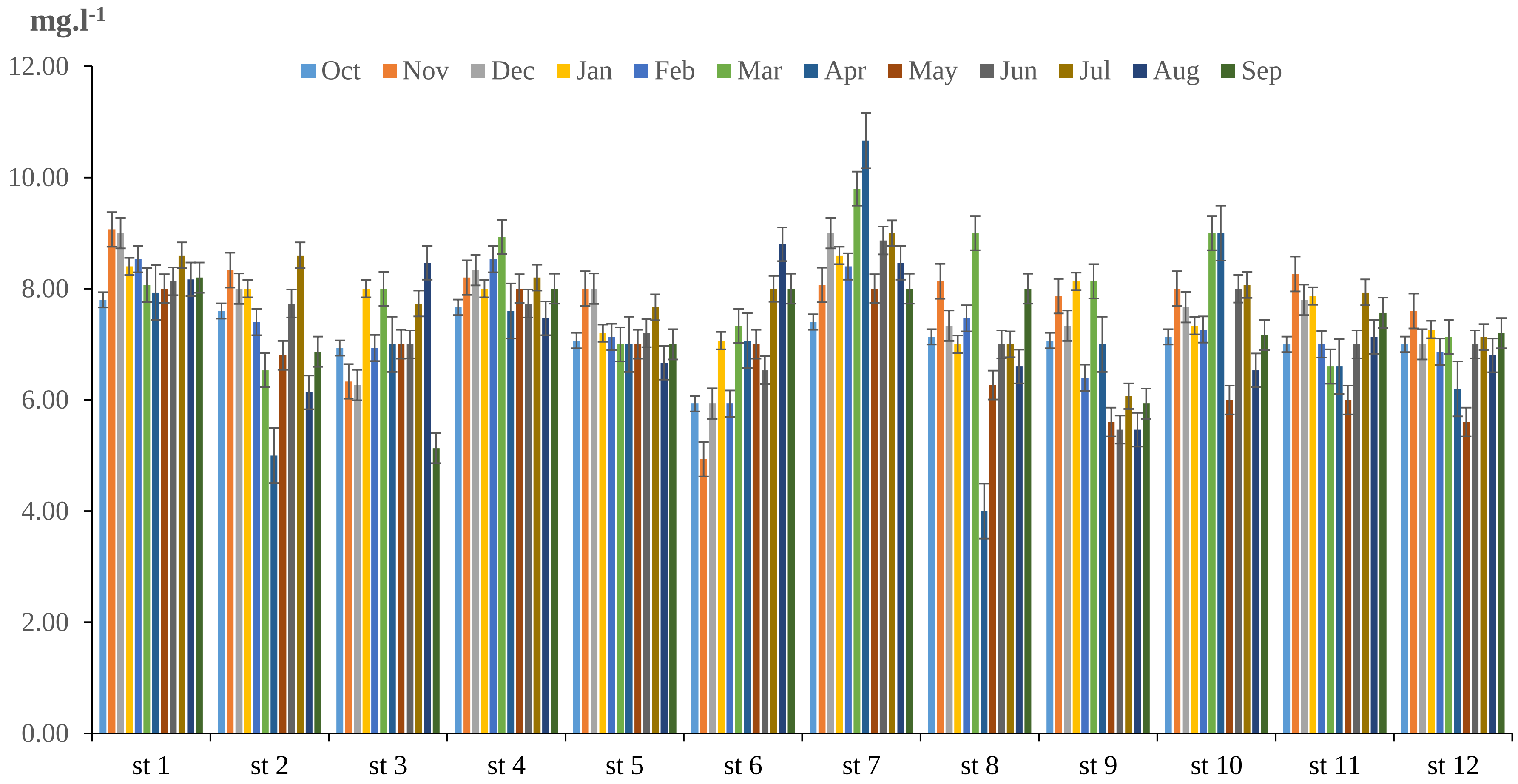


Figure 84 Dissolve oxygen in each sampling site of the Wang River from October 2011 to September 2012

(Tables 16-17, Figure 84, and Appendix 1). The lowest value was recorded at site 8 in April and the highest value was presented at site 7 in April, respectively. The average DO value of the sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3). The lowest average of DO was recorded at site 9 about 6.7 $mg.l^{-1}$. This was due to the fact that this site was affected by the waste discharge that was released from the urban area, while the highest average of DO value was presented at site 7 as 8.7 $mg.l^{-1}$. This was believed to have occurred because of the high water current that originated from the dam gate when it was in operation, because this site was situated below the dam. The results of the study of the sampling months revealed that the average DO value was lowest in May at about 6.8 $mg.l^{-1}$ and was highest in March at about 8.0 $mg.l^{-1}$, respectively.

4.2.5 pH

The pH of the water is a measure of hydrogen ion concentration with 7.0 being neutral. The pH value in the Wang River ranged from 6.02- 9.30 (Tables 16-17, Figure 85, and Appendix 1). The lowest pH values were observed at site 6 in October and the highest value was recorded at site 3 in April, respectively. The average pH value of the sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3). The lowest pH value was recorded at site 2 at about 7.75 while the higest value was presented at site 1 as 8.41. In terms of the results of the study of the time period, it was found that the average pH value was lowest in October at about 6.96 and highest in April at about 8.47, respectively.

4.2.6 Alkalinity

The alkalinity of the water is its acid-neutralizing capacity. The alkalinity of many surface waters is primarily a function of the carbonate, bicarbonate and hydroxide content and therefore, it is indicated from both the discharge and the geological dissolved substances. The alkalinity in the Wang River and its reservoirs was quite high, as it ranged from 65 - 210 $mg.l^{-1}$ (Tables16-17, Figure 86, and Appendix 1). The lowest value was recorded at site 7 in October and the highest value was presented at site 1 in May, respectively.

The average alkalinity value of the sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3). The lowest average alkalinity value was recorded at site 5 at about 120.8 $mg.l^{-1}$, while the higest alkalinity value was presented at site 1 as 162.5 $mg.l^{-1}$. For the results of the study of the sampling months, it was found that the average alkalinity value was lowest in October at about 91.7 $mg.l^{-1}$ and highest in March at about 160.6 $mg.l^{-1}$, respectively.

4.2.7 Turbidity

Turbidity is the condition that results from the presence of suspended solids in the water, including silt, clay, industrial waste, sewage and plankton. Normally, the turbidity level in running water is higher than in standing water, and the rainy season period resulted in the turbidity level of the river being higher than the dry season. The turbidity in the Wang River and its reservoirs from October 2011 to September 2012 ranged from 0 – 789 NTU (Tables 16-17, Figure 87, and Appendix 1). The lowest values were recorded at site 6 in March 2012, at site 6 in March 2012 and the highest turbidity levels were observed in September 2012 at site 8.

Turbidity level of the sampling sites and months revealed significant differences ($p < 0.001$) (Appendix 3). The lowest turbidity level was recorded in site 1, which had the waterfall and was in the upstream area of the river, the observed data revealed a value of 14.2 NTU. The higest turbidity level was recorded at site 12, which is the river mount area and was as 130 NTU. The results of the study also showed the lowest average of turbidity level at 20 NTU in March, which was during the dry season, while the highest average turbidity level presented about 160 NTU in September, which was in the rainy season.

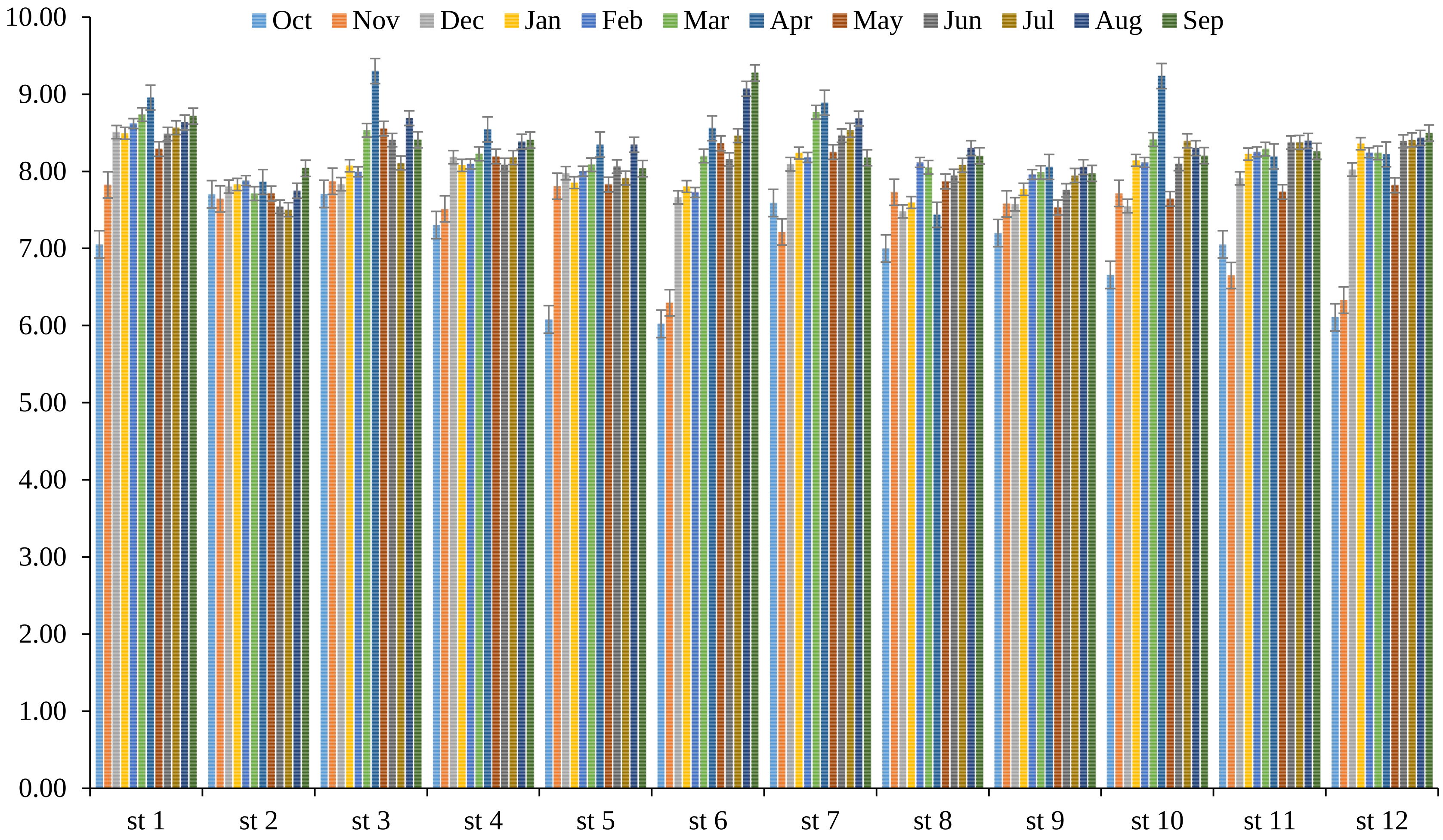


Figure 85 pH in each sampling site of the Wang River from October 2011 to September 2012

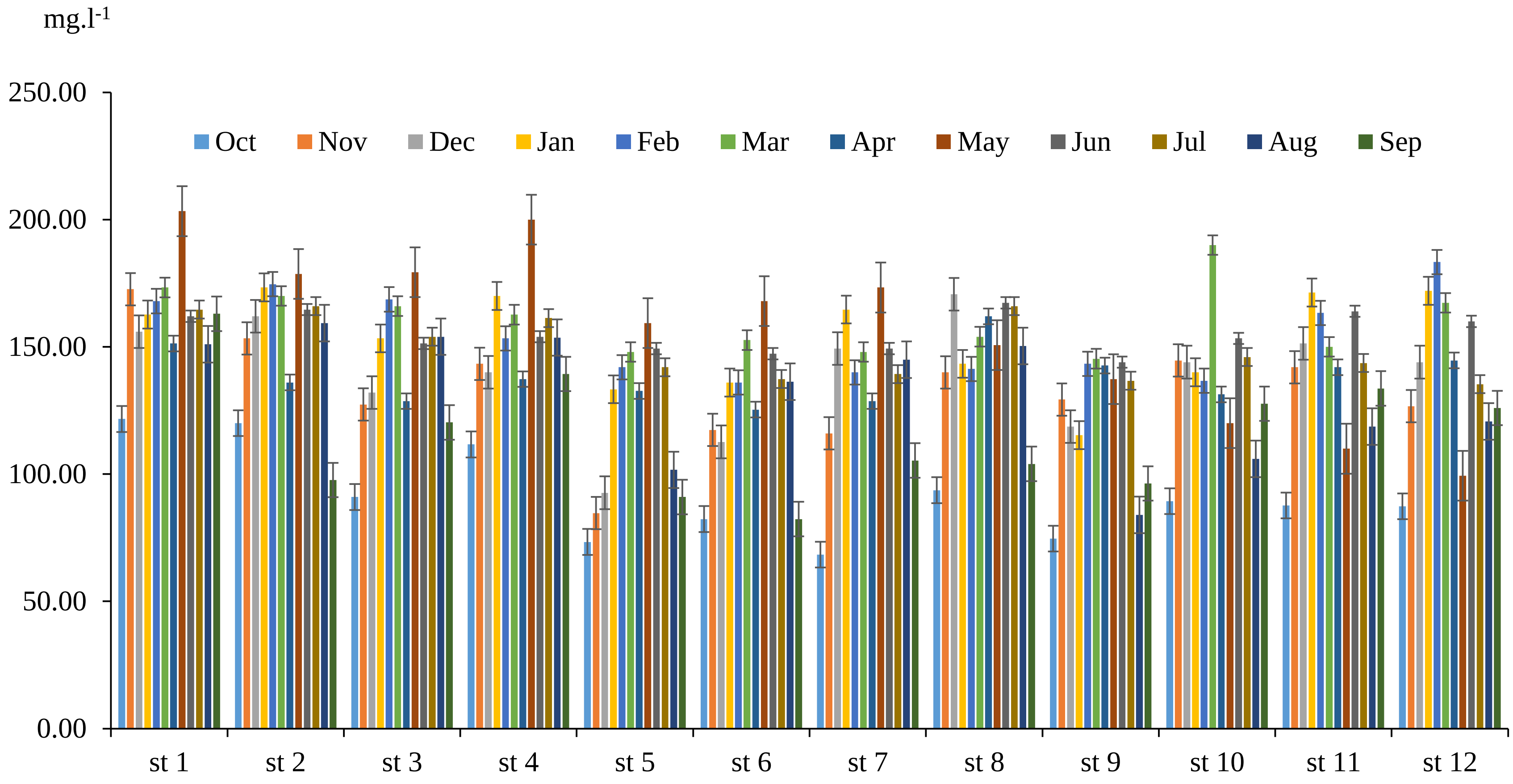


Figure 86 Alkalinity in each sampling site of the Wang River from October 2011 to September 2012

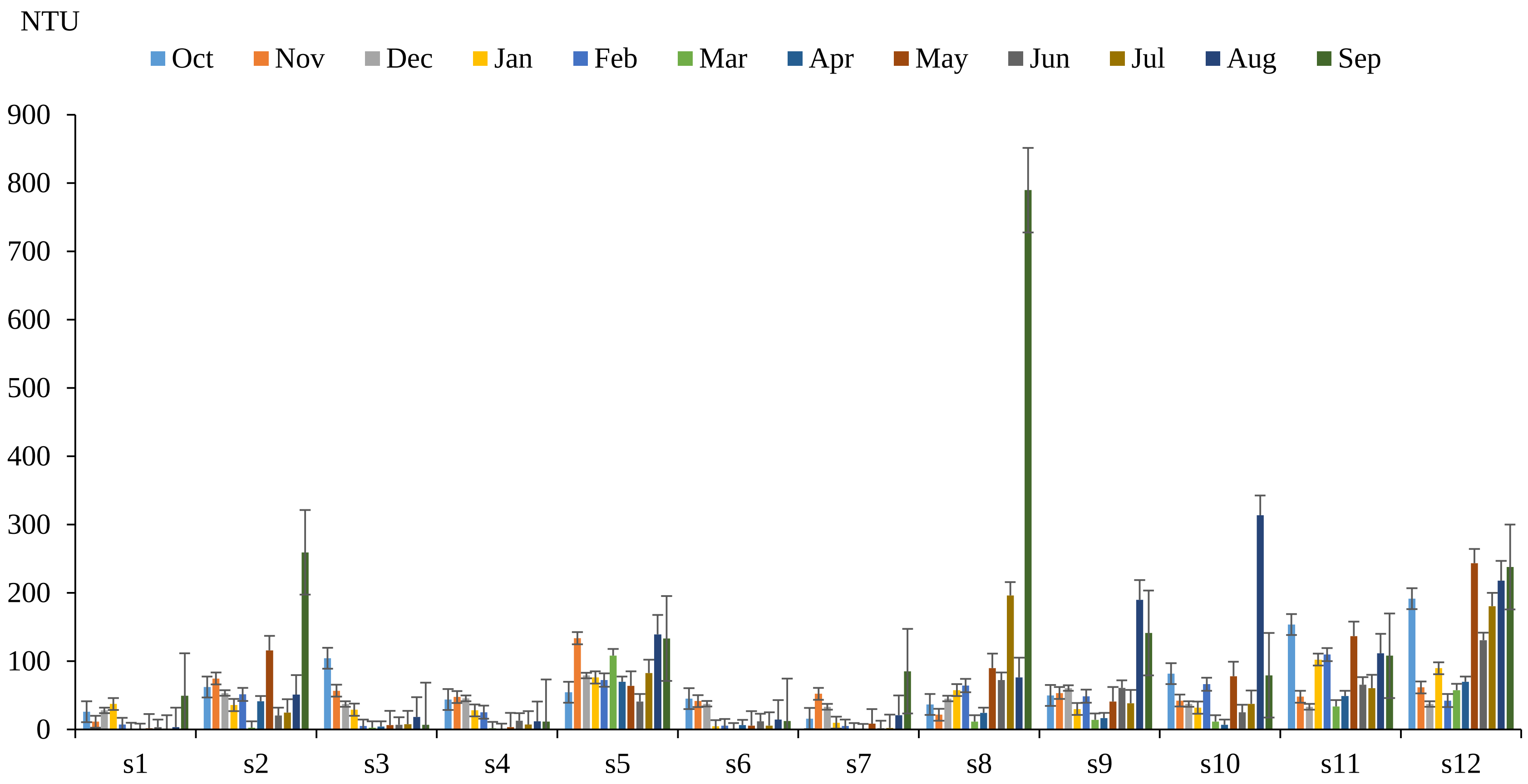


Figure 87 Turbidity in each sampling site of the Wang River from October 2011 to September 2012

4.2.8 Biochemical Oxygen Demand (BOD)

The BOD determination is relative to the oxygen requirements of the organic matter digestion by microorganisms. The BOD could reveal the waste loading or organic and inorganic contamination in the river. In this study, BOD showed high contamination at the urban and agricultural sampling sites. The biochemical oxygen demand in the Wang River and its reservoirs ranged from 0.00 – 3.70 $mg.l^{-1}$ over 5 days (Tables 16-17, Figure 88, and Appendix 1). The highest BOD value was observed at site 8 in April and lowest at site 6 in January, respectively. The average BOD value of the sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3), the lowest average of BOD was recorded at site 1 at about 0.64 $mg.l^{-1}$. While the highest average of BOD value was recorded at site 8 as 2.02 $mg.l^{-1}$. In terms of the results of the study of the sampling time period, the average BOD value was lowest in October at about 0.59 $mg.l^{-1}$ and highest in September at about 1.79 $mg.l^{-1}$, respectively.

4.2.9 Soluble Reactive Phosphorus (SRP)

Phosphorus is one of the main elements necessary for the growth of algae and plants in rivers. The run off by rain, erosion and detergents are the major sources of contamination that are found in rivers. In this study, SRP showed high concentration levels in the rainy season and at the sites located near agricultural and urban areas. The SRP concentration in the Wang River and its reservoirs between October 2011 and September 2012 ranged from 0.01 – 0.86 $mg.l^{-1}$ (Tables 16-17, Figure 89, and Appendix 1). The lowest values were recorded in January at sites 1, 2, 3, 4, 6 and 7. The highest concentrations were observed at site 4 in April.

The average SRP concentration value of the sampling sites and sampling months revealed significant differences ($p < 0.001$) (Appendix 3). The lowest average concentration level was recorded at site 4 at about 0.07 $mg.l^{-1}$, while the highest average value was presented at site 9 at 0.37 $mg.l^{-1}$ respectively. According to the results of the study of the sampling months showed that the average level of SRP was lowest in January at about 0.07 $mg.l^{-1}$ and highest in August at about 0.49 $mg.l^{-1}$, respectively.

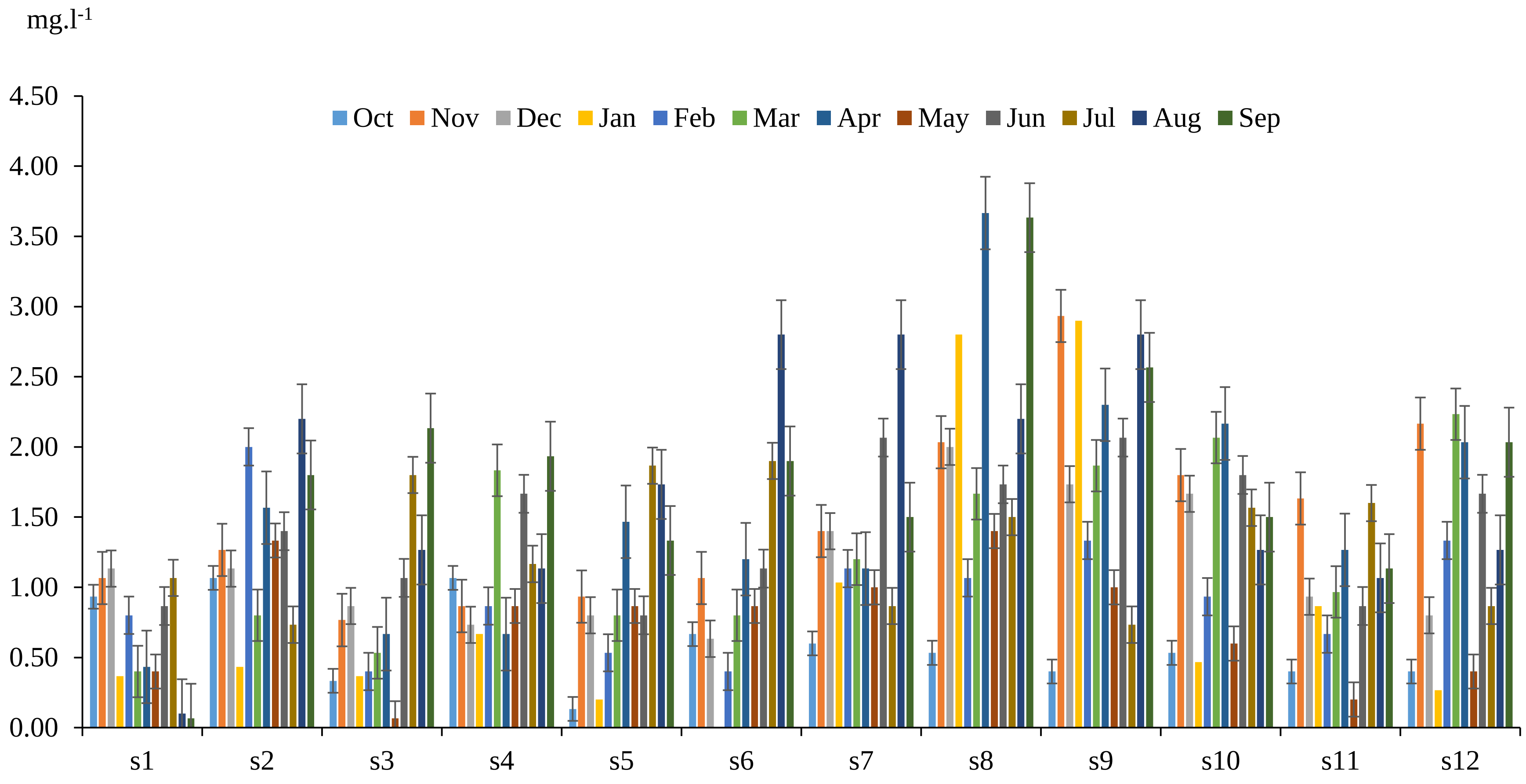


Figure 88 BOD in each sampling site of the Wang River from October 2011 to September 2012

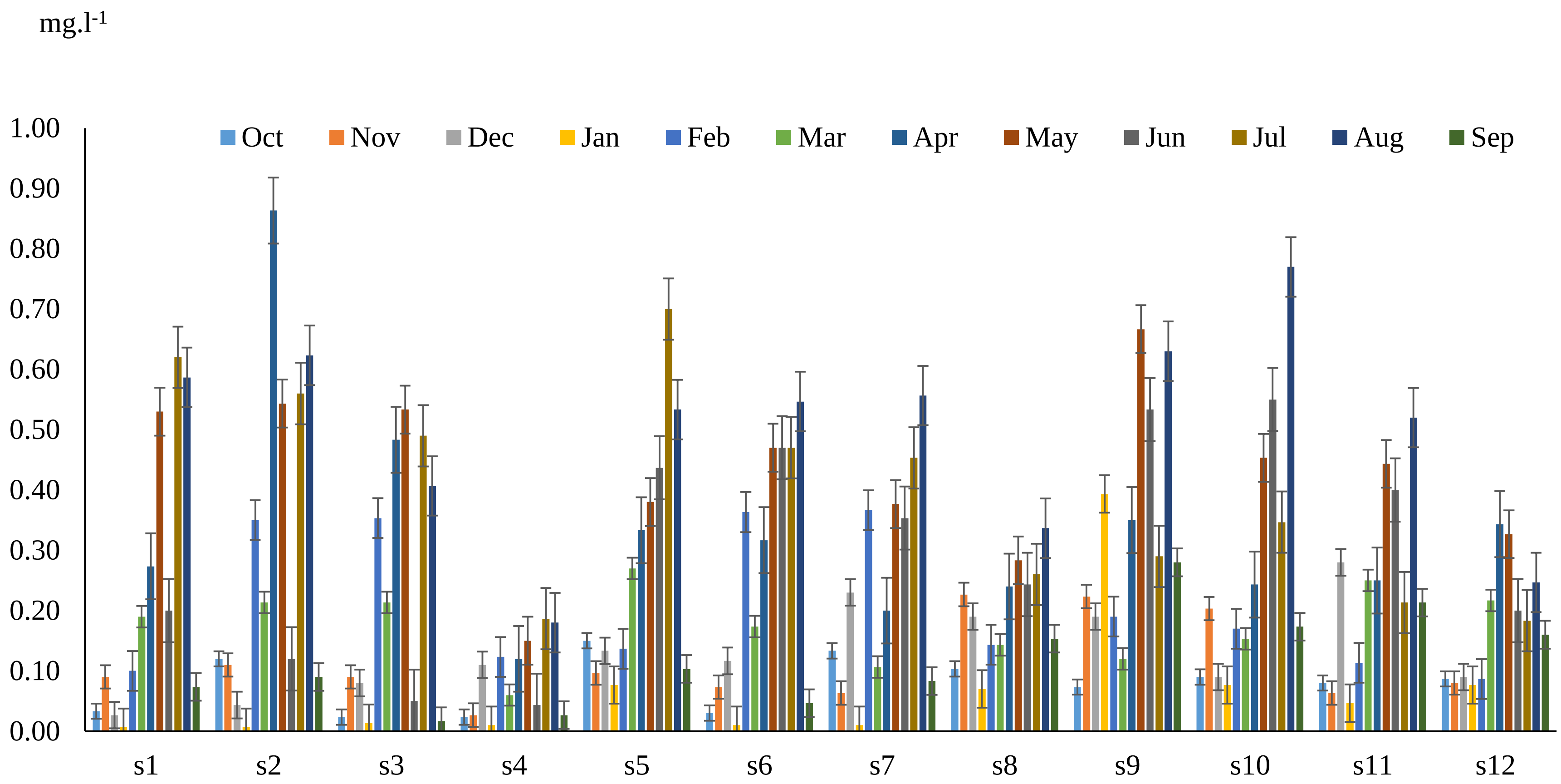


Figure 89 Soluble Reactive Phosphorus (SRP) in each sampling site of the Wang River from October 2011 to September 2012

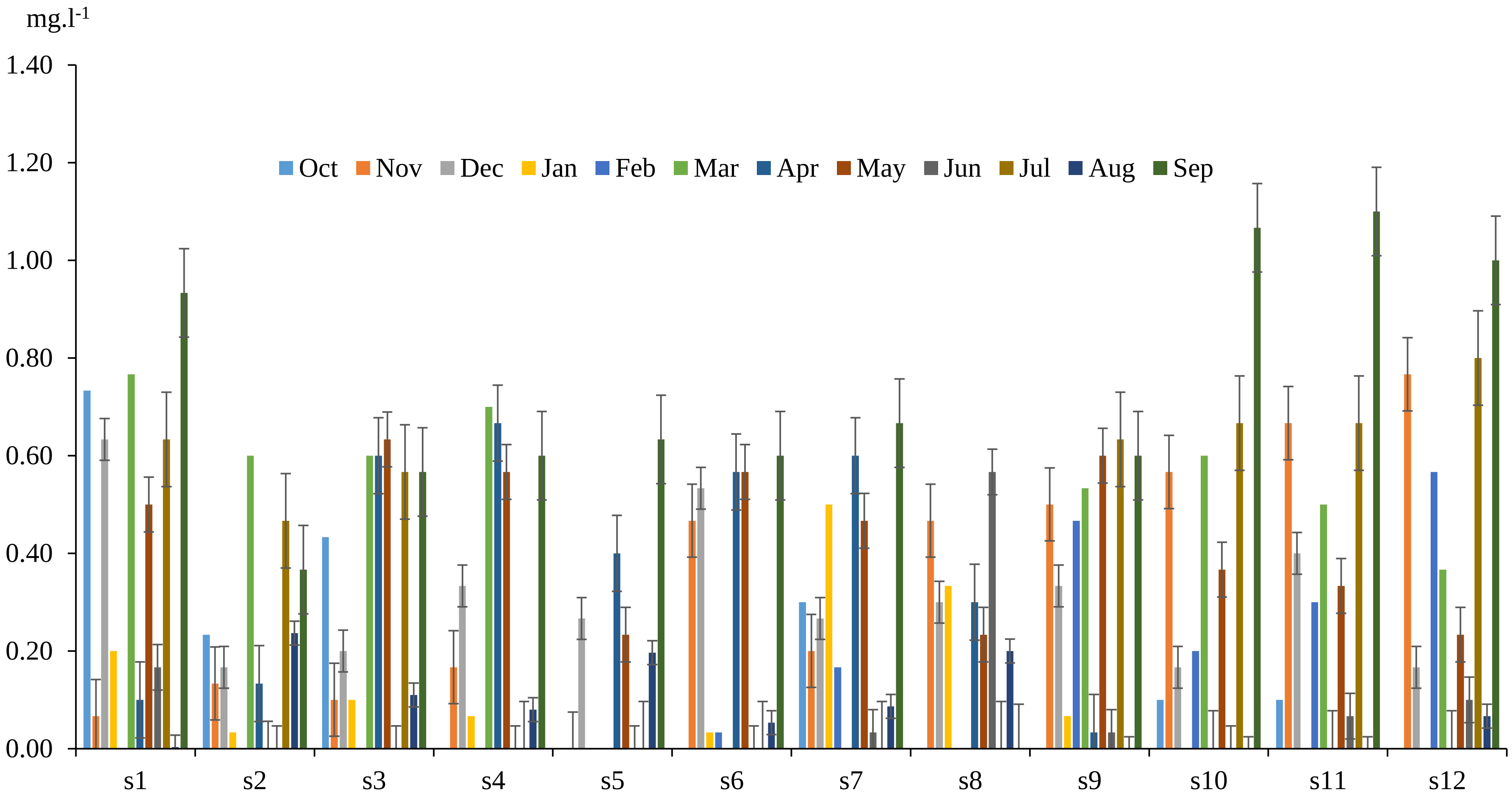


Figure 90 Nitrate nitrogen in each sampling site of the Wang River from October 2011 to September 2012

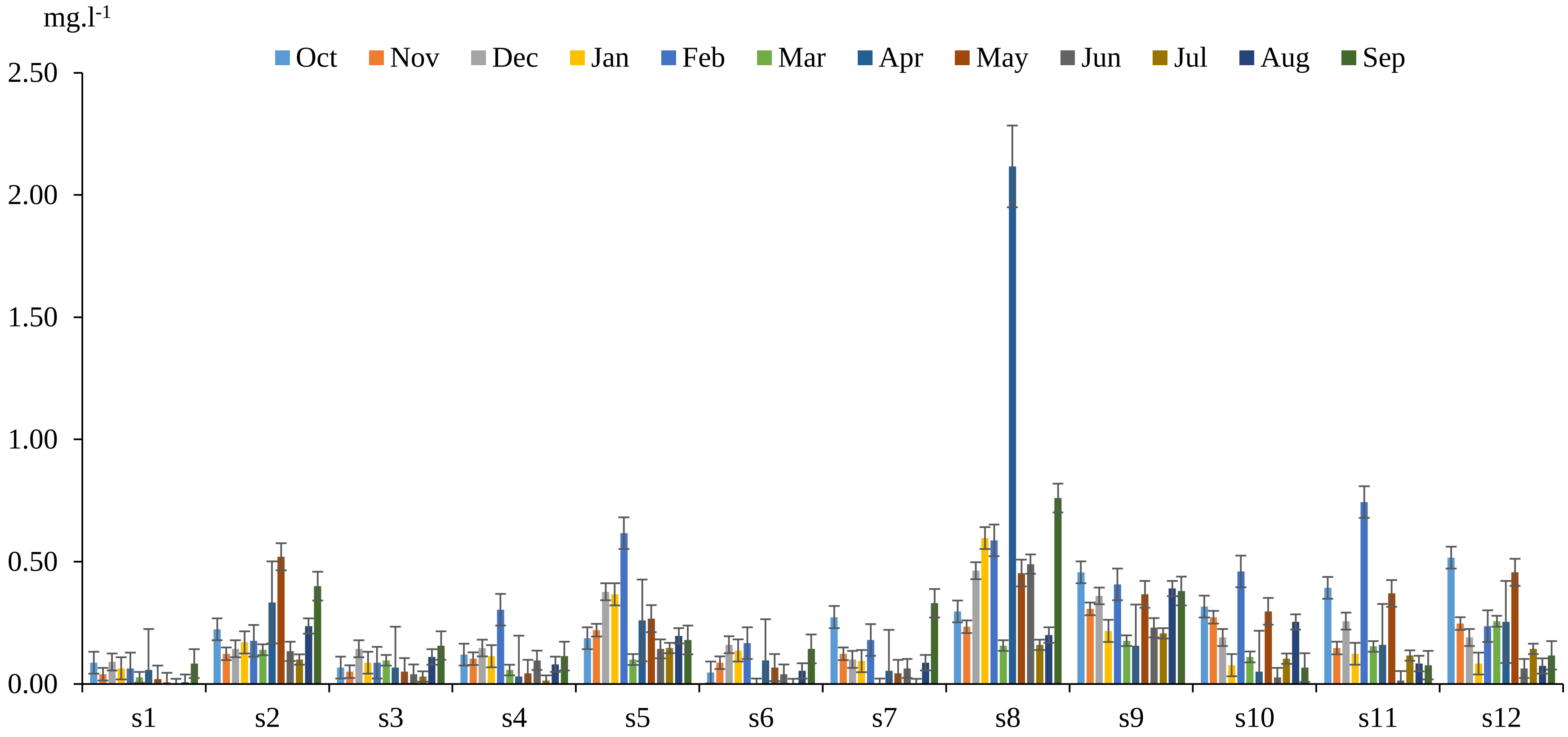


Figure 91 Ammonium nitrogen in each sampling site of the Wang River from October 2011 to September 2012

4.2.10 Nitrate nitrogen

The nitrate concentration in the Wang River was related to the season. During the rainy season, a high amount of nitrate nitrogen occurred. The main source of nitrate nitrogen came from the run off by rain and erosion. The nitrate nitrogen concentrations in the Wang River and their reservoirs ranged from 0.00-1.10 $mg.l^{-1}$ (Tables 16-17, Figure 90 and Appendix 1) with the highest values found at site 10 in May. The lowest concentrations were observed at site 1 in Febuary and August, at site 2 in Febuary, May and June, at site 3 in Febuary and June, at site 4 in October, Febuary, June and July, at site 5 in October, November, January, Febuary, March, June and July, at site 6 in October, March, June and July, at site 7 in March and July, at site 8 in October, March, June, July and September, at site 9 in October and August, at site 10 in January, April, June and August, at site 11 in January, April and August and at site 12 in October, January and April.

The average nitrate nitrogen concentration of the month revealed significant differences ($p < 0.001$) (Appendix 3), while a comparison of the concentration levels at all sampling sites did not reveal significant differences. The lowest average of nitrate concentration was recorded in June at about 0.08 $mg.l^{-1}$, and highest was recorded in September at about 0.68 $mg.l^{-1}$, respectively.

4.2.11 Ammonium nitrogen

Ammonium nitrogen is discharged by sewage and domestic waste from urban areas and by agricultural run off, especially as run from animal waste and silage. However, the form of the ammonium depends on the level of oxygen present. Under the aerobic conditions, ammonium is easily converted into nitrite and subsequently to nitrate by nitrifying bacteria; however, ammonium nitrogen is induced by pollution. The concentration levels of ammonium nitrogen in the Wang River and its reservoirs was high in the sites located near urban and agricultural areas, while at the reservoirs and upstream sites, this parameter was found to reveal lower concentration levels. The concentration ranged from 0.00 – 2.12 $mg.l^{-1}$ (Tables 16-17, Figure 91, and Appendix 1) The lowest values were recorded at site 1 in July, at site 6 in March and July and at site 7 in March and July. Additionally, the highest values were observed in April at site 8. The average ammonium nitrogen value of the sampling sites and the months revealed significant differences ($p < 0.001$) (Appendix 3), the lowest average of ammonium nitrogen was recorded at site 1 at about 0.04 $mg.l^{-1}$, while the highest average of ammonium nitrogen value was presented at site 8 at 0.54 $mg.l^{-1,}$ respectively. In terms of the results of the study of the sampling months, it revealed that the average ammonium nitrogen level was lowest in July at about 0.09 $mg.l^{-1}$ and the highest was recorded in Febuary at about 0.34 $mg.l^{-1}$, respectively.

4.3 The assessment of water quality and trophic status by AARL-PC score

The water quality and trophic status of the water in the Wang River was evaluated from five parameters, which were: conductivity, DO, BOD, ammonium-nitrogen, nitrate-nitrogen and soluble reactive phosphorus by the Applied Algal Research Laboratory Physical and Chemical score (AARL-PC score) (Peerapornpisal *et al*., 2004 and was modified from Lorraine and Vollenweider, 1981; Wetzel, 2001; the Pollution Control Department, 2010). In the mainstream area of the river, the trophic status was calculated by the running water method of the AARL-PC score, while in the reservoirs, the water status was estimated by the standing water method of the AARL-PC score (Peerapornpisal *et al*., 2004).

The AARL-PC scores of the water at the running sampling site are shown in Figure 90, the range of the score was between 0.9 -2.7 mean, as the trophic status was between oligo trophic (clean water quality) and meso trophic status (moderate water quality), for which the lowest score was presented at site 1 in November 2011 and the higest score was presented at site 8 in April 2012. The water quality at most sampling sites of the main river was classified in the oligotrophic-mesotrophic status (clean – moderate water quality), except at sites 1, 4 and 7, for which most of the month presented a trophic status as oligotrophic (clean water quality), while most of the month of sites 8

Table 16 Environmental parameters of the Wang River and its reservoirs in each sampling site from October 2011 to September 2012 (average values and min – max values, n=36)

Site	Water Temp(°C)	Air Temp(°C)	Velocity (m/s)	Conduct (µS.cm^{-1})	Alk (mg.l^{-1})	Turbid (NTU)	pH	DO (mg.l^{-1})	BOD mg.l^{-1}	SRP mg.l^{-1}	NO_3-N mg.l^{-1}	NH_3-N mg.l^{-1}
1	20.9	23.4	0.35	244.6	162.5	14.2	8.41	8.3	0.64	0.16	0.38	0.04
	(18.4 - 23)	(17.5 - 27.5)	(0.2-0.6)	(193- 279)	(120-210)	(0.3- 49.3)	(7.05-8.96)	(7.8-9.1)	(0.1-1.1)	(0.01-0.62)	(0- 0.93)	(0-0.09)
2	26.6	30.4	0.26	272.0	154.6	66.1	7.75	7.3	1.31	0.29	0.18	0.23
	(23.3 - 29.4)	(26.0 - 35.5)	(0.1-0.4)	(157 - 313)	(95-180)	(2.7 – 259)	(7.50-8.04)	(5.0-8.6)	(0.4-2.2)	(0.01-0.86)	(0- 0.60)	(0.10- 0.52)
3	29.0	30.7	0.0	242.9	143.8	23.8	8.29	7.1	0.86	0.15	0.32	0.07
	(25.5 - 35.0)	(27.0 - 37.0)	0.0	(208 - 291)	(88-180)	(2.7 – 104)	(7.71-9.30)	(5.1-8.5)	(0.1-2.1)	(0.01-0.53)	(0- 0.63)	(0.03- 0.16)
4	27.1	30.9	0.37	254.9	152.2	20.0	8.10	8.1	1.12	0.07	0.26	0.06
	(25.0- 29.0)	(25.0 - 37.0)	(0.3-0.7)	(220 - 285)	(109-200)	(0.7-48)	(7.30-8.54)	(7.5-8.9)	(0.7- 1.9)	(0.01-0.19)	(0-0.70)	(0.01-0.30)
5	26.8	31.5	0.30	195.8	120.8	87.8	7.86	7.2	0.96	0.29	0.13	0.25
	(25.0-29.0)	(25.0-38.0)	(0.2-0.6)	(135-252)	(70-166)	(41-139)	(6.08-8.35)	(6.7-8.0)	(0.1 – 1.9)	(0.08-0.70)	(0-0.63)	(0.10-0.62)
6	28.5	30.5	0.0	205.4	127.8	15.9	7.97	6.9	1.11	0.21	0.23	0.07
	(25.4-31.5)	(22-38.5)	0.0	(128-242)	(78-170)	(0-45)	(6.02-9.28)	(4.9-8.8)	(0 – 2.8)	(0.01-0.55)	(0-0.60)	(0-0.17)
7	28.5	31.6	0.33	231.4	135.6	19.6	8.26	8.7	1.34	0.17	0.21	0.08
	(25.1-32.0)	(22.0-38.5)	(0.2-0.6)	(176-315)	(65-180)	(0-99)	(7.21-8.89)	(7.4-10.7)	(0.6-2.8)	(0.01-0.56)	(0-0.67)	(0-0.33)
8	29.3	31.6	0.20	299.9	145.3	123.8	7.82	7.1	2.02	0.22	0.20	0.54
	(25.9-35.5)	(25.5-39.0)	(0.0-0.4)	(187-562)	(93-178)	(11.3-789)	(7.00-8.30)	(4.0-9.0)	(0.5-3.7)	(0.07-0.30)	(0-0.57)	(0.16-2.12)
9	29.8	31.2	0.03	250.9	122.3	62.1	7.78	6.7	1.89	0.37	0.32	0.30
	(26.3-34.5)	(27.0-37.0)	(0.0-0.1)	(133-360)	(73-150)	(14-190)	(7.20-8.06)	(5.5-8.10)	(0.4-2.9)	(0.07-0.67)	(0-0.63)	(0.16-0.46)
10	29.1	32.9	0.21	334.5	135.8	67.6	8.04	7.6	1.36	0.28	0.31	0.19
	(25.8-33.5)	(28.0-38.0)	(0.1-0.4)	(229-385)	(88-196)	(6.7-313)	(6.66-9.24)	(6.0-9.0)	(0.5-2.2)	(0.08-0.77)	(0-1.07)	(0.03-0.46)
11	29.2	31.7	0.25	334.0	139.8	84.3	7.98	7.2	0.97	0.23	0.34	0.22
	(25.4-34.0)	(26.0-37.0)	(0.2-04)	(274-413)	(87-180)	(33-153)	(6.65-8.44)	(6.0-8.3)	(0.2-1.6)	(0.05-0.52)	(0-1.10)	(0.01-0.74)
12	28.8	29.4	0.08	320.2	138.9	130.0	7.92	6.9	1.29	0.17	0.34	0.22
	(25.5-32.0)	(22.0-35.5)	(0.0-0.2)	(286-441)	(86-190)	(37.3-243)	(6.11-8.50)	(5.6-7.6)	(0.3-2.2)	(0.08-0.34)	(0-1.00)	(0.06-0.52)

Table 17 Environmental parameters of the Wang River and its reservoirs in each month from October 2011 to September 2012 (average values and min – max values, n=36).

Month	Water Temp(ºC)	Air Temp(ºC)	Velocity (m/s)	Conduct (µS.cm^{-1})	Alk (mg.l^{-1})	Turbid (NTU)	pH	DO (mg.l^{-1})	BOD mg.l^{-1}	SRP mg.l^{-1}	NO_3-N mg.l^{-1}	NH_3-N mg.l^{-1}
Oct	26.8	30.2	0.23	249.4	91.7	72	6.96	7.1	0.59	0.08	0.16	0.25
	(22.0-28.6)	(24.0-36.0)	(0-0.7)	(165.3-314)	(68.3-121.7)	(16-191.7)	(6.02-7.71)	(5.9-7.8)	(0.1-1.1)	(0.02-0.15)	(0- 0.73)	(0.05-0.52)
Nov	25.3	25.6	0.14	254.8	133.1	54	7.35	7.7	1.49	0.11	0.34	0.16
	(19.6-27.1)	(20.5-30.0)	(0-0.3)	(143.7-313)	(84.7-172.7)	(11.3–133.7)	(6.30-7.87)	(4.9-9.1)	(0.8-2.9)	(0.03-0.23)	(0- 0.77)	(0.04- 0.31)
Dec	25.2	27.0	0.14	307	139.4	44	7.88	7.6	1.15	0.13	0.31	0.22
	(18.4-27.0)	(21.0 - 31.0)	(0-0.3)	(175-445)	(92.7-170.7)	(28 – 79)	(7.48-8.51)	(5.9-9.0)	(0.6-2.0)	(0.03-0.28)	(0.17- 0.63)	(0.09-0.46)
Jan	26.4	28.2	0.14	302.1	152.9	44	8.04	7.7	0.86	0.07	0.11	0.18
	(18.9-28.8)	(17.5-32.5)	(0-0.3)	(201.3-440)	(115.3-173.3)	(4.7-102.3)	(7.60-8.49)	(7.0-8.6)	(0- 2.9)	(0.01-0.39)	(0-0.5)	(0.06-0.60)
Feb	25.6	32.0	0.21	247.8	154.2	42	8.10	7.3	0.96	0.21	0.14	0.34
	(19.1-28.1)	(23.0-35.0)	(0-0.4)	(180-381)	(136-183.3)	(5-109.7)	(7.73-8.62)	(5.9-8.5)	(0.4 – 2.0)	(0.09-0.37)	(0-0.57)	(0.06-0.74)
Mar	28.0	34.1	0.27	297.9	160.6	20	8.27	8.0	1.26	0.18	0.39	0.11
	(19.3-35.0)	(22.0-39.0)	(0-0.6)	(217-308.7)	(145.3-190)	(0-108.3)	(7.71-8.77)	(6.5-9.8)	(0.4 –2.2)	(0.06-0.27)	(0-0.77)	(0-0.26)
Apr	30.9	33.7	0.16	289.0	138.6	24	8.47	7.1	1.55	0.33	0.28	0.30
	(22.5-35.5)	(23.0-38.5)	(0-0.4)	(217.8-523)	(125.3-162)	(0.3-70)	(7.44-9.30)	(4.0-10.7)	(0.4 – 3.7)	(0.12-0.86)	(0-0.67)	(0.03-2.12)
May	30.0	36.0	0.27	244.6	156.6	66	7.98	6.8	0.75	0.43	0.39	0.25
	(22.3-32.9)	(27.0-38.0)	(0-0.6)	(207.7-293)	(99.3-203)	(1.7-243)	(7.53-8.55)	(5.6-8.0)	(0.1-1.4)	(0.15-0.67)	(0-0.63)	(0.02-0.52)
Jun	29.4	31.2	0.22	268.3	155.6	38	8.15	7.3	1.43	0.30	0.08	0.11
	(23.0-31.0)	(26.5-34.0)	(0-0.4)	(231-343)	(144-167.3)	(1.7-130.7)	(7.54-8.48)	(5.5-8.9)	(0.8-2.1)	(0.04-0.55)	(0-0.57)	(0.01-0.49)
Jul	28.4	29.8	0.21	280.3	149.4	54	8.21	7.8	1.31	0.40	0.37	0.09
	(22.0-30.0)	(24.0-32.0)	(0-0.4)	(232-325.7)	(135.3-166)	(1.3-196.3)	(7.50-8.57)	(6.1-9.0)	(0.7-1.9)	(0.18-0.70)	(0-0.80)	(0-0.21)
Aug	29.3	29.7	0.19	221.0	131.7	97	8.42	7.2	1.72	0.49	0.09	0.15
	(23.0-31.0)	(27.0-33.0)	(0-0.4)	(134.7-314)	(84-159.3)	(3.3-313.7)	(7.75-9.07)	(5.5-8.8)	(0.1-2.8)	(0.18-0.77)	(0-0.24)	(0.01-0.39)
Sep	28.8	28.3	0.19	224	115.6	160	8.35	7.3	1.79	0.12	0.68	0.23
	(21.0-31.0)	(23.5-32.0)	(0-0.6)	(128.7-378)	(82.3-163)	(6.7-789.7)	(7.97-9}}.28)	(5.1-8.2)	(0.1-3.6)	(0.02-0.28)	(0-1.00)	(0.07-0.76)

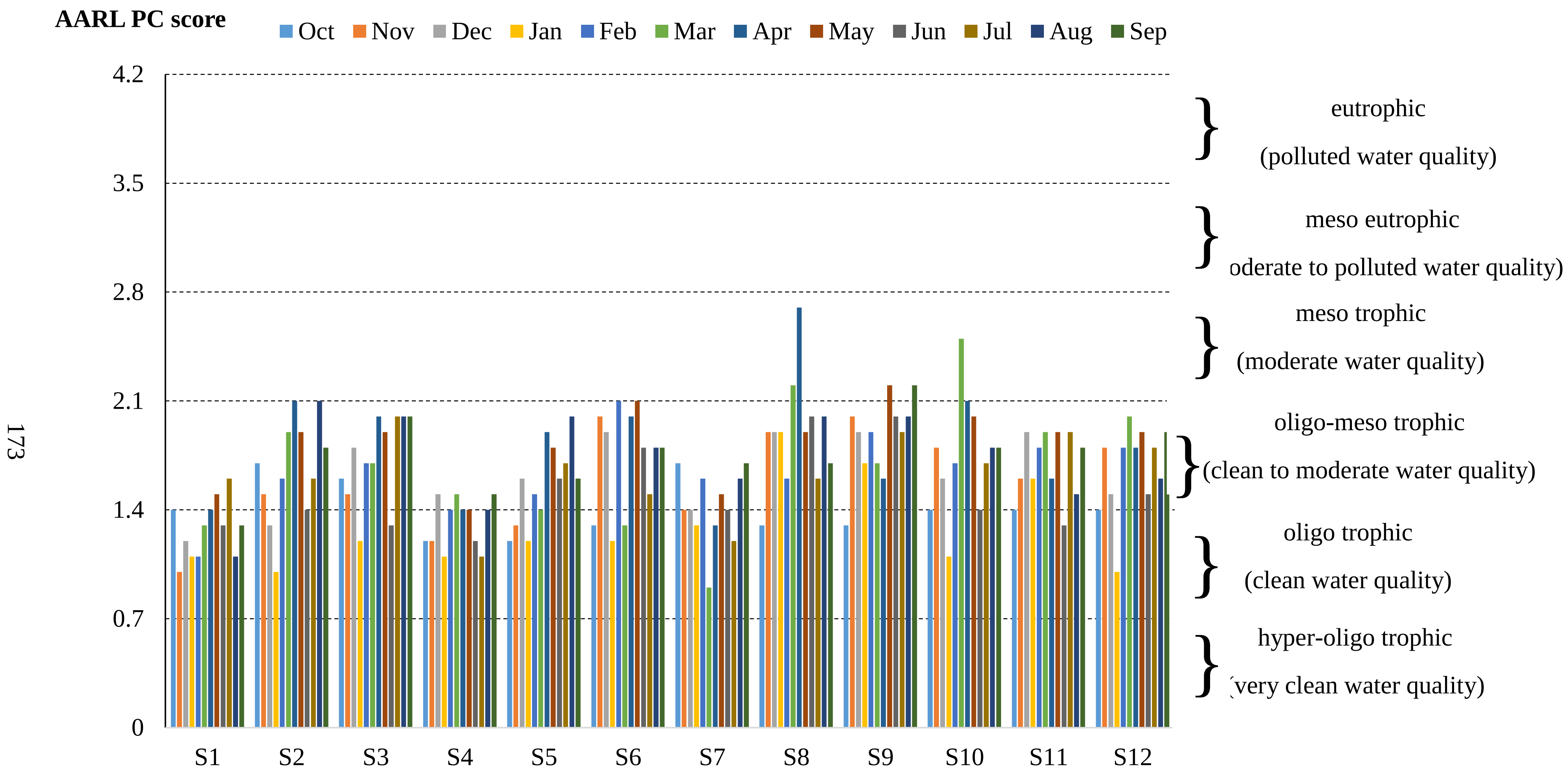


Figure 92 Genaral water quality and trophic status of 12 sampling sites in the Wang River from October 2011 to September 2012.

and 9 tended to reveal higher scores and were classiflied in mesotrophic status (moderated water quality).

The AARL-PC scores in the sampling sites of standing water are also shown in Figure 90. At sites 3 and 6, the range of scores was between 1.2 -2.1 mean and the trophic status was between oligotrophic (clean water quality) and oligo-mesotrophic status (clean to moderate water quality). The lowest score was presented at site 3 in November 2011 and site 6 in January 2012, while the higest score was shown at site 6 in February 2012 and site 6 in May 2012. The trophic status of most sampling sites in the reservoirs was classified in the oligotrophic-mesotrophic status (clean to moderate water quality), except at site 3 in January 2012, site 3 in June 2012, site 6 in October 2011, site 6 in January 2012 and site 6 in March 2012, all of which were reported the trophic as oligotrophic status (clean water quality).

4.4 Principle component analysis (PCA) of the physico-chemical parameters

Principle component analysis (PCA) was done to describe the correlation between the sampling sites and the physico-chemical parameters, which showed both a positive and negative correlation.

The relationship between sampling sites of the mainstream area with the water quality is shown in Figure 93, the samples of sites 1, 4 and 7 were affected by strong water currents, so they had a positive correlation with DO, velocity, nitrate- nitrogen and pH. While the sites which were disturbed by agricultural activities such as sites 10, 11 and 12 and the sites which were contaminated by the domestic waste from household or communities such as at sites 8 and 9, tended to have a positive correlation with ammonium-nitrogen, BOD, conductivity, reactive soluble phosphorus (SRP) and alkalinity.

The relationship between the sampling sites of the reservoir with the water quality is presented in Figure 94. The sampling sites made up of standing water were site 3 and site 6, DO had a positive correlation with pH, soluble phosphorus and temperature. While, turbidity had a positive correlation with ammonium-nitrogen and alkalinity and had a negative correlation with DO and pH.

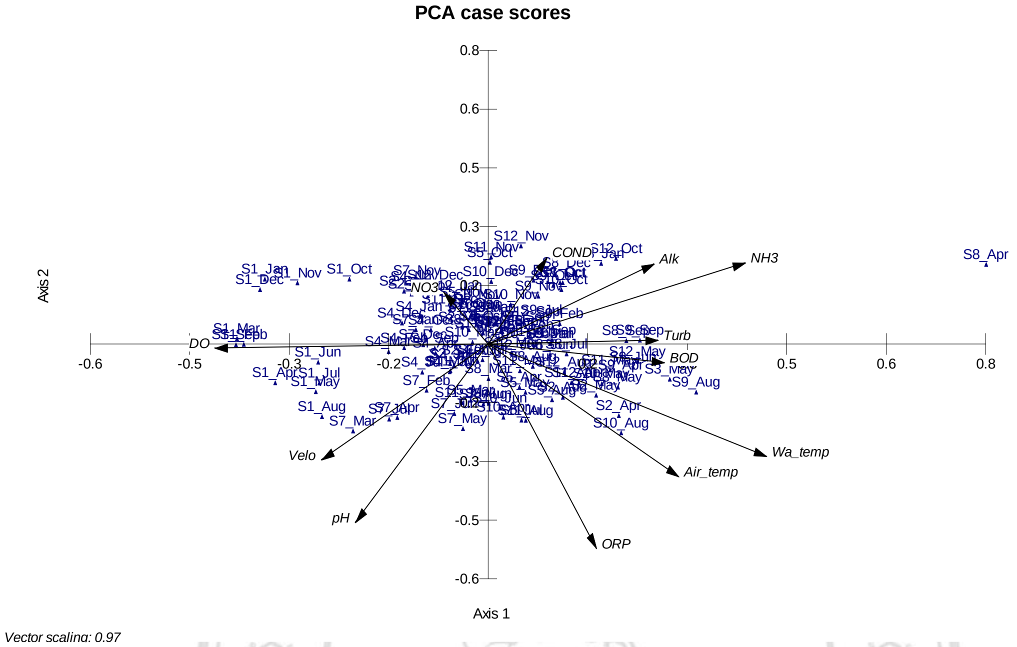


Figure 93 PCA plot graph showing the relationship between sampling sites of mainstream area including various water quality in the Wang River between October 2011 and September 2012

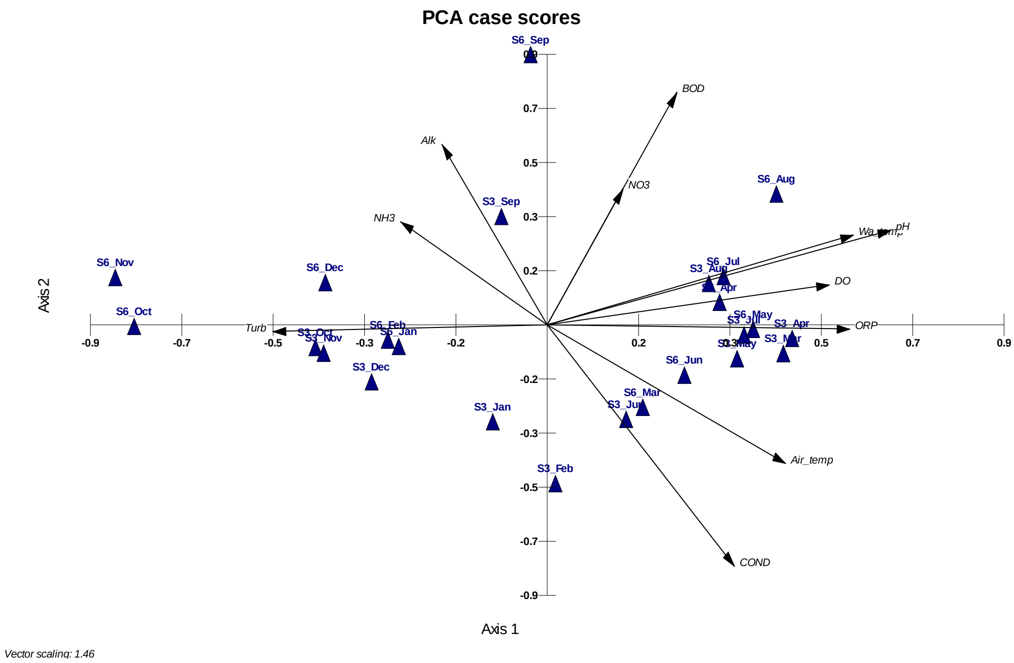


Figure 94 PCA plot graph showing the relationship betaween sampling sites of the reservoirs including various water quality in the Wang River between October 2011 and September 2012

4.5 Canonical correspondence analysis (CCA) between water quality and benthic diatoms

The canonical correspondence analysis (CCA) was used for studying the relationship between the water quality of this study with the benthic diatoms which had high relative abundance (>1%). The results of the CCA of some physico-chemical parameters and benthic diatoms are shown in a CCA plot (Figure 95). It was found that the CCA plot graph indicated 3 groups of correlation:

Firstly, the presence of *Navicula leistikowii, Encyonopsis microcephala, Navicula suprinii, Cymbella bifurcumstigma, Delicata sparsistriata* and *Encyonema malaysianum* had a positive correlation with DO, velocity and pH and had a negative correlation with BOD, SRP conductivity, alkalinity, ammonium-nitrogen and turabidity; thus, the species were found in high abundance when the water conditions displayed a high DO level and low conductivity, alkalinity, ammonium-nitrogen and turbidity and BOD levels, and could be used to monitor the clean water quality.

Secondly, the presence of *Gomphonema auritum, Gomphonema pumilum, Achnanthidium minutissimun, Auracoseira granulata, Discostella stelligeroides, Cymbella affinis and Cocconeis placentula had* a positive correlation with SRP, alkalinity, temperature and pH, and the species were found to be in high abundance when the water conditions displayed high alkalinity, temperatures, SRP, and pH.

Thirdly, the presence of *Cymbella turgidula, Nitzschia gracilis, Hippodonta pseudoacceptata, Planotudium frequentissimum, Nitzschia palea, Gomphonema parvulum, Seminavis strigosa, Navicula simulata* had a positive correlation with BOD, Ammonium-nitrogen, turbidity, conductivity and alkalinity and had a negative correlation with DO; thus, the species were found to be in high abundance when the water conditions included high BOD levels, ammonium-nitrogen conductivity, alkalinity and a low DO level, and could be used to indicate the polluted water quality.

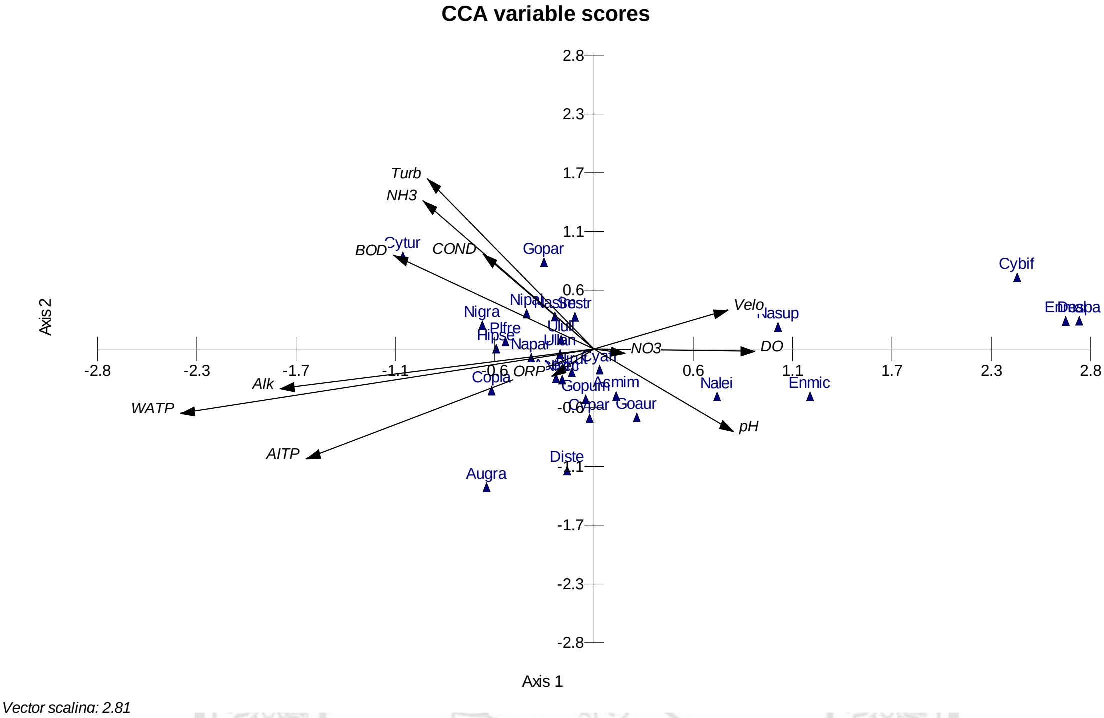


Figure 95 CCA plot graph presenting the relationship between benthic diatoms and the water quality of the Wang River between October 2011 and September 2012

4.6 Establishment of the Wang diatoms index

The benthic diatoms of the Wang River, which revealed a high relative abundance (>1%) at each site, were selected to establish a benthic diatom index for the Wang River. A total of 100 species of benthic diatoms were used to develop the index by indicator values and the weighted averages approach (WAs).

4.6.1 Indicator value by clusters method

Indicator values were applied using the cluster method (Dufrene and Legendre, 1977) to divide the abundance of the species of 12 sampling sites with 12 time periods between October 2011 and September 2012. The cluster analysis with percent similarity method was used to calculate and separate the samples into 9 groups (Table 18, Figure 94). The results are shown as folows:

Group 1 was composed by 12 samplings from site 1. The main species of this group were *Cymbella* cf. *bifurcumstigma, Delicata* cf. *sparsistriata, Encyonema malaysianum, Encyonopsis leei* and *Navicula* cf. *leistikowii.*

Group 2 was composed by 12 samplings from site 2. The main species of group 2 were *Navicula* cf. *aquaedurae, Navicula escambia* and *Nitzschia palea*.

Group 3 was the biggest group and was composed of 53 samplings collected from various sites such as 4, 5, 6, 7, 9, 10, 11 and 12, respectively. The key species of this group were *Achnanthidium minutissimum, Cymbella affinis, Gomphonema parvulum, Navicula simulata* and *Seminavis strigosa.*

Group 4 was composed of 23 samplings collected from sites 8 and 9, respectively. The key species of this group were *Cymbella turgidula, Navicula* cf. *parablis, Nitzschia palea* and *Planotudium frequentissimum.*

Group 5 was composed of 1 sampling collected from site 10 in the month of October. The main species were *Navicula germainii* and *Nitzschia palea* var. *deblis*.

Group 6 was composed of 3 samplings collected from sites 8 and 9, respectively. The key species of this group were *Nitzschia gracilis* and *Nitzschia* cf. *ruttneri*.

Group 7 was composed of 22 samplings collected from sites 3 and 4. The key species of this group were *Achnanthidium exile*, *Discostella stelligeroides* and *Cymbella parva.*

Group 8 was composed of 17 samplings collected from sites 6 and 7. The key species of this group were *Achnanthidium minutissimum, Gomphonema auritum* and *Auracoseira granulata.*

Group 9 was composed of 1 samplings collected from site 12 in the month of September. The main species were *Hantzschia amphioxys* and *Nitzschia recta*.

Table 18 Groups of sampling sites of the Wang River between October 2011 and September 2012 separated by cluster analysis of diatom assemblage

Group	Sampling
1	s1m1, s1m2, s1m3, s1m4, s1m4, s1m5, s1m6, s1m7, s1m8, s1m9, s1m10, s1m11, s1m12
2	s2m1, s2m2, s2m3, s2m4, s2m5, s2m6, s2m7, s2m8, s2m9, s2m10, s2m11, s2m12,
3	s4m1, s5m1, s5m2, s5m3, s5m4, s5m5, s5m6, s5m7, s5m8, s5m9, s5m10, s5m11, s5m12, s6m1, s7m1, s7m2, s7m5, s7m10, s7m11,s7m12, s9m7, s10m2, s10m3, s10m4, s10m5, s10m6, s10m7, s10m8, s10m9, s10m10, s10m11, s11m1, s11m2, s11m3, s11m4, s11m5, s11m6, s11m7, s11m8, s11m9, s11m10, s11m11, s12m1, s12m2, s12m3, s12m4, s12m5, s12m6, s12m7, s12m8, s12m9, s12m10, s12m11
4	s8m1, s8m2, s8m3, s8m4, s8m5, s8m6, s8m7, s8m8, s8m9, s8m10, s8m11, s8m12, s9m1, s9m2, s9m3, s9m4, s9m5, s9m6, s9m8, s9m11, s9m1, s9m9, s9m10
5	s10m1
6	s10m12, s11m12, s12m12
7	s3m1, s3m2, s3m3, s3m4, s3m5, s3m6, s3m7, s3m8, s3m9, s3m10, s3m11, s4m2, s4m3, s4m4, s4m5, s4m6, s4m7, s4m8, s4m9, s4m10, s4m11, s4m12
8	s6m2, s6m3, s6m4, s6m5, s6m6, s6m7, s6m8, s6m9, s6m10, s6m11, s6m12, s7m3, s7m4, s7m6, s7m7, s7m8, s7m9
9	s3m12

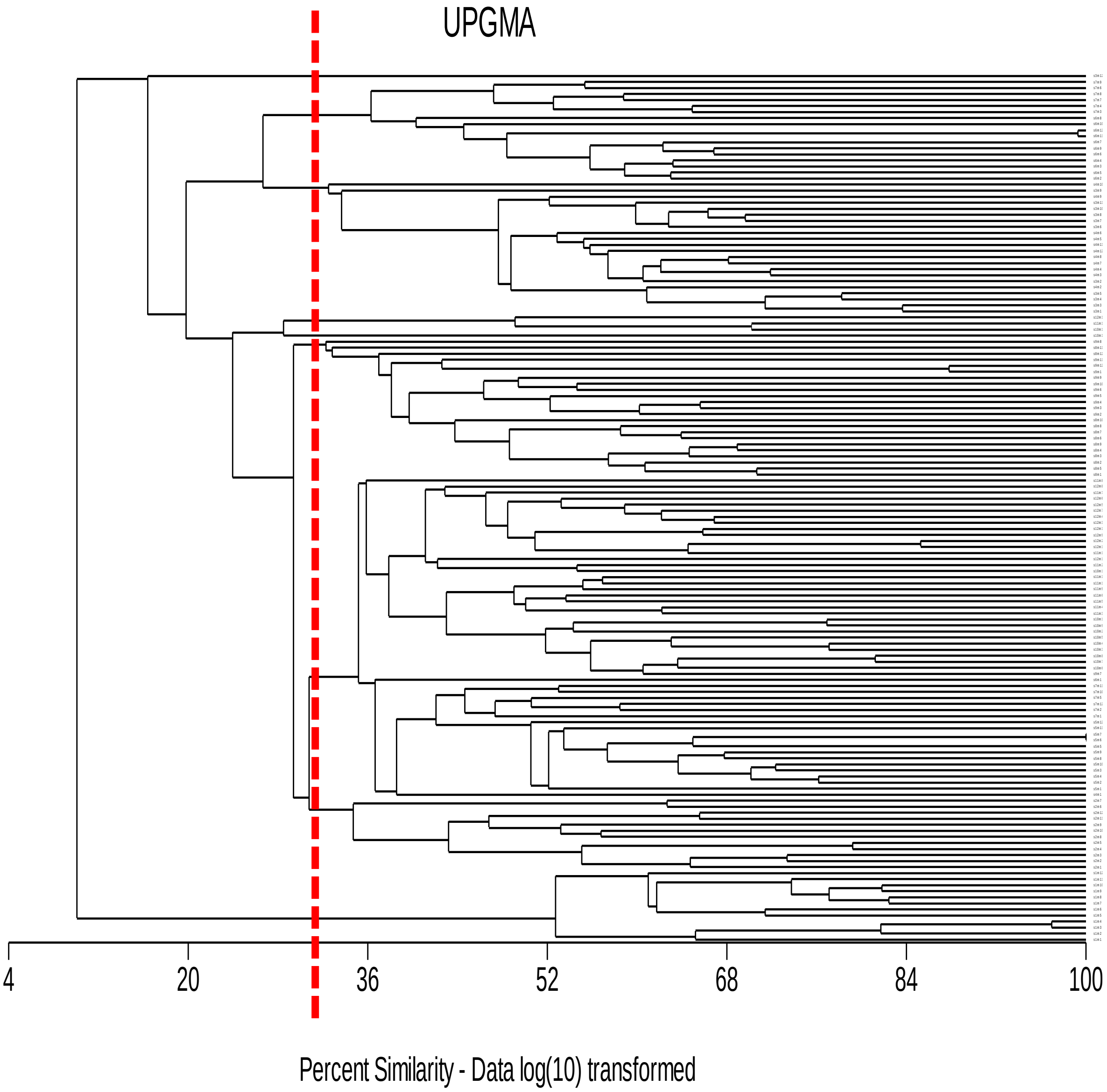


Figure 96 Percent similarity (data log (10) transformed) of investigated sampling sites of the Wang River and its reservoirs according to diatom assemblages

Each cluster was examined for an evaluation of the relationship between the species from specific sampling sites without water properties reported at that sampling site. The equation of this method was presented in Chapter 3. An example of the calculation is presented in an example (1)

Example (1) Calculation of indicator values for *Navicula suprinii* in cluster 1

Sampling	Nasup (A_{ij})	$RA_{ij(nasup)}$	$RF_{ij(nasup)}$	$IV_{(nasup)}$
s1m1	35	0.19	0.92	0.17
s1m2	26	0.14	0.92	0.13
s1m3	18	0.09	0.92	0.09
s1m4	21	0.11	0.92	0.10
s1m5	6	0.03	0.92	0.03
s1m6	2	0.01	0.92	0.01
s1m7	5	0.03	0.92	0.02
s1m8	4	0.02	0.92	0.02
s1m9	1	0.00	0.92	0.00
s1m10	0	0.00	0.92	0.00
s1m11	3	0.02	0.92	0.02
s1m12	67	0.36	0.92	0.33
Sum(Ai)	188			
S_{ij}	11			
S_j	12			

$$RA_{ij} = A_{ij}/A_i \qquad (1)$$

Where RA_{ij} = Relative abundant of species i at sampling j in a cluster

A_{ij} = the mean abundance of species i at sampling j in a cluster

A_i = the sum of the mean abundance of specie i in a cluster

$$RA_{(Nasup,\ s1m1)} = 35/188$$
$$= 0.19$$

$$RF_{ij} = S_{ij}/S_j \qquad (2)$$

Where RF_{ij} = Relative frequency of species i in a cluster

S_{ij} = the number of sites in cluster where species i is present

S_j = the total number of sites in that group

$RF_{(nasup)} = 11/12$

$= 0.92$

$IV_{ij} = RA_{ij} \times RF_{ij}$

Where IV_{ij} = indicator Value of species i at sampling j in a cluster 1

$IV_{(Nasup, s1m1)} = 0.19 \times 0.92$

$= 0.17$

4.6.2 Weighted averages

The estimation of the index values of each benthic diatom species was based on a weighted average approach (WAs). WAs values were calculated based on the abundance of benthic diatoms found at each site and the relevant water quality variables. The major environmental factors of BOD, nitrate nitrogen ammonium nitrogen and SRP levels were classified into seven classes (Table 19) according to the AARL PC score (Peerapornpisal *et al.*, 2004) and the guidelines of the Pollution Control Department (2010). Nevertheless, an estimation of the weighted averages of this study was applied by multiplying them with the indicator value for assurance of the relationship of each species at the sampling in each cluster. An example of the calculation is presented in example 2.

4.6.3 Index values (IV)

The weighted average value of each species were compared with the water quality scores which were composed of four main parameters, namely BOD, nitrate-nitrogen, ammonium-nitrogen and SRP, in order to calculate the index values (Table 20). The seven classes of water qualities were modified from Lorraine and Vollenweider (1981), Wetzel (2001) Peerapornpisal *et al.* (2004), the Pollution Control Department (2010) and Wojtal (2013). As a result, the index values were averaged from the scores of BOD, nitrate nitrogen, ammonium nitrogen and SRP and compared with the trophic status in Table 19. The index values (IV) of each species with each parameter were then averaged according to the number of parameters. In this investigation, the range of the indicator values was 2.5-4.4 (Table 20). The highest index value was found with *Geissleria decussis*, *Gomphonema lanceolatum*, *Gomphonema pseudoaugur* and *Nitzschia palea*. The lowest values were of *Craticula molestiformis*, *Cymbella* cf. *bifurcumtigma*, *Cymbella* cf.

geddiana and *Nitzschia linearis*. The weighted averages and the index values of 100 species of benthic diatoms are presented in Table 20. An example of the average index values is shown in example 3.

Table 19 The seven categories of BOD, ammonium-nitrogen, nitrate-nitrogen and SRP for index calculation

Scores	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BOD ($mg.l^{-1}$)	0.5	0.5-1.0	1.0-2.0	2.0-4.0	4.0-10.0	10.0-20.0	>20
Nitrate -N ($mg.l^{-1}$)	<0.01	0.01-0.19	0.20-0.39	0.40-0.79	0.80-1.90	2.0-10.0	>10.0
Ammonium-N ($mg.l^{-1}$)	<0.01	0.01-0.19	0.20-0.39	0.40-0.59	0.60-0.99	1.0-5.0	>5.0
SRP ($mg.l^{-1}$)	<0.01	0.02-0.04	0.05-0.06	0.07-0.19	0.20-0.99	1.0-3.0	>3.0
Trophic Status	hyper-oligo trophic	oligo trophic	oligo-meso trophic	meso trophic	meso-eutrophic	eutrophic	hyper-eutrophic

4.6.4 Calculation of Wang River sample index

The average of the index value of each species (which had more than 1 percent of the relative abundance at each site) in each month was used to calculate the percentage of relative abundance. The results of the sample index were compared with the 7 categories of trophic status (Table 19). The example of the sample index is presented in example 4 and the formula for estimating the sample index is presented below:

$$\text{Sample index} = \frac{\sum (\%\text{Relative Abundant X Index values})}{\sum \text{Relative Abundant}}$$

Example (2) Weighted averages of *Navicula suprinii* with BOD

$$WA_{(Nasup,\ BOD)} = \frac{(X_{s1m1} \times Y_{Nasup,s1m1} \times Z_{Nasup,s1m1}) + (X_{s1m2} \times Y_{Nasup,s1m2} \times Z_{Nasup,s1m2}) \ldots\ldots + (X_{s12m12} \times Y_{Nasup,\ s12m12} \times Z_{Nasup,s12m12})}{(Y_{Nasup,\ s1m1} \times Z_{Nasup,\ s1m1}) + (Y_{Nasup,\ s1m2} \times Z_{Nasup,\ s1m2}) \ldots\ldots + (Y_{Nasup,\ s12m12} \times Z_{Nasup,\ s12m12})}$$

$$WA_{(Nasup,\ BOD)} = \frac{(0.93 \times 12.34 \times 0.17) + (1.07 \times 8.92 \times 0.126) + \ldots\ldots + (2.03 \times 0 \times 0)}{(12.34 \times 0.17) + (8.92 \times 0.126) + \ldots\ldots + (0 \times 0)}$$

$$WA_{(Nasup,\ BOD)} = 0.486$$

Examples (3) Calculation of index values for the *Navicula suprinii*

$$\text{Index values} = \frac{IV_{WA(Nasup,\ BOD)} + IV_{WA(Nasup,\ NO3)} + IV_{WA(Nasup,\ NH3)} + IV_{WA(Nasup,\ SRP)}}{N \text{ (number of parameters)}}$$

$$\text{Index values} = \frac{IV_{(0.49)} + IV_{(0.65)} + IV_{(0.11)} + IV_{(0.10)}}{N \text{ (number of parameters)}}$$

$$\text{Index values} = \frac{1 + 4 + 3 + 4}{4} = 3$$

Table 20 Weighted averages (WA) and index values (IV) used for calculating the trophic status in the Wang River

Diatoms species	$WA_{(BOD)}$	$IV_{(BOD)}$	$WA_{(nitrate)}$	$IV_{(nitrate)}$	$WA_{(ammonium)}$	$IV_{(ammonium)}$	$WA_{(SRP)}$	$IV_{(SRP)}$	Averaged IV
Auracoseira granulata	1.02	3	0.52	4	0.10	3	0.44	5	3.8
Discostella stelligeroides	1.75	3	0.49	4	0.15	3	0.10	4	3.5
Achnanthidium exiguum	1.15	3	0.18	2	0.25	4	0.19	4	3.3
Achnanthidium exile	0.82	2	0.34	3	0.09	2	0.15	4	2.8
Achnanthidium latecephalum	0.88	2	0.28	3	0.13	3	0.26	5	3.3
Achnanthidium minutissimum	1.05	3	0.20	2	0.18	3	0.36	5	3.3
Adlafia bryophila	0.65	2	0.48	4	0.09	2	0.23	5	3.3
Amphora liriope	1.40	3	0.17	2	0.28	4	0.30	5	3.5
Bacillaria paxillifera	1.14	3	0.29	3	0.26	4	0.35	5	3.8
Branchysira neoexilis	1.46	3	0.45	4	0.14	3	0.07	3	3.3
Caloneis sp.2	1.59	3	0.28	3	0.23	4	0.22	5	3.8
Cocconeis placentula	1.52	3	0.25	3	0.12	3	0.23	5	3.5
Craticula molestiformis	0.92	2	0.14	2	0.09	2	0.10	4	2.5
Cymbella affinis	1.11	3	0.06	2	0.09	2	0.20	5	3.0
Cymbella cf.*bifurcumstigma*	0.90	2	0.33	3	0.06	2	0.07	3	2.5
Cymbella parva	1.11	3	0.37	3	0.09	2	0.13	4	3.0
Cymbella tumidula	0.79	2	0.25	3	0.15	3	0.16	4	3.0
Cymbella turgidula	1.04	3	0.13	2	0.87	5	0.25	5	3.8
Cymbella cf. *geddiana*	0.43	1	0.05	2	0.09	2	0.30	5	2.5
Cymbella cf. *subleptoceros*	1.23	3	0.28	3	0.08	2	0.30	5	3.3
Diadesmis confervacea	0.69	2	0.13	2	0.33	4	0.10	4	3.0
Delicata cf. *sparsistriata*	0.50	1	0.50	4	0.04	2	0.26	5	3.0
Diploneis oblongella	1.38	3	0.51	4	0.11	3	0.26	5	3.8

Table 20 (continued)

Diatoms species	$WA_{(BOD)}$	$IV_{(BOD)}$	$WA_{(nitrate)}$	$IV_{(nitrate)}$	$WA_{(ammonium)}$	$IV_{(ammonium)}$	$WA_{(SRP)}$	$IV_{(SRP)}$	Averaged IV
Encyonema malaysianum	0.61	2	0.23	3	0.04	2	0.26	5	3.0
Encyonema gaeumannii	1.36	3	0.38	3	0.08	2	0.15	4	3.0
Encyonema mesianum	1.48	3	0.22	3	0.34	4	0.39	5	3.8
Encyonema sp.1	0.87	2	0.53	4	0.18	3	0.12	4	3.3
Encyonopsis leei	0.53	2	0.34	3	0.03	2	0.12	4	2.8
Encyonopsis microcephala	0.51	2	0.28	3	0.05	2	0.17	4	2.8
Eolimna minima	1.56	3	0.21	3	0.28	4	0.24	5	3.8
Halamphora montana	0.98	2	0.30	3	0.19	3	0.22	5	3.5
Hippodonta pseudoacceptata	1.55	3	0.20	2	0.20	4	0.33	5	3.5
Geissleria decussis	2.04	4	0.48	4	0.25	4	0.51	5	4.4
Geissleria punctiferera	1.01	3	0.23	3	0.11	3	0.45	5	3.5
Gomphonema auritum	0.83	2	0.34	3	0.11	3	0.14	4	3.0
Gomphonema gracile	1.15	3	0.37	3	0.09	2	0.10	4	3.0
Gomphonema javanicum	1.80	3	0.02	2	0.01	1	0.45	5	2.8
Gomphonema lanceolatum	2.39	4	0.56	4	0.29	4	0.49	5	4.4
Gomphonema micropus	1.62	3	0.21	3	0.21	4	0.34	5	3.8
Gomphonema minutum	1.27	3	0.23	3	0.23	4	0.16	4	3.5
Gomphonema parvulum	1.47	3	0.48	4	0.33	4	0.16	4	3.8
Gomphonema parvulum var. *lagenulum*	1.54	3	0.26	3	0.27	4	0.20	5	3.8
Gomphonema productum	1.07	3	0.23	3	0.22	4	0.12	4	3.5
Gomphonema pseudoaugur	2.14	4	0.60	4	0.22	4	0.28	5	4.4
Gomphonema pumilum	1.11	3	0.13	2	0.10	2	0.20	5	3.0

Table 20 (continued)

Diatoms species	$WA_{(BOD)}$	$IV_{(BOD)}$	$WA_{(nitrate)}$	$IV_{(nitrate)}$	$WA_{(ammonium)}$	$IV_{(ammonium)}$	$WA_{(SRP)}$	$IV_{(SRP)}$	Averaged IV
Gyrosigma spencerii	1.49	3	0.33	3	0.28	4	0.31	5	3.8
Gyrosigma scalproides	1.24	3	0.24	3	0.38	4	0.11	4	3.5
Luticola simplex	1.00	2	0.24	3	0.20	4	0.07	3	3.0
Luticola terminata (tropica)	0.81	2	0.03	2	0.25	4	0.30	5	3.3
Luticola cf. *pseudokotschyi*	1.70	3	0.78	4	0.21	4	0.18	4	3.8
Luticola sp.1	1.68	3	0.42	4	0.30	4	0.29	5	4.0
Navicula amphiceropsis	1.01	3	0.33	3	0.36	4	0.17	4	3.5
Navicula antonii	1.32	3	0.17	2	0.25	4	0.40	5	3.5
Navicula capitatoradiata	0.77	2	0.38	3	0.01	1	0.41	5	2.8
Navicula cryptotenella	1.60	3	0.23	3	0.31	4	0.23	5	3.8
Navicula escambia	1.09	3	0.18	2	0.19	3	0.10	4	3.0
Navicula germainii	0.88	2	0.23	3	0.30	4	0.19	4	3.3
Navicula heimansioides	0.86	2	0.58	4	0.08	2	0.15	4	3.0
Navicula hintzii	0.98	2	0.28	3	0.08	2	0.17	4	2.8
Navicula radiosafallax	0.93	2	0.28	3	0.10	3	0.17	4	3.0
Navicula rostellata	1.16	3	0.40	3	0.23	4	0.35	5	3.8
Navicula simulata	1.10	3	0.33	3	0.22	4	0.19	4	3.5
Navicula suprinii	0.49	1	0.65	4	0.11	3	0.10	4	3.0
Navicula vandamii var *mertensiae*	1.10	3	0.64	4	0.17	3	0.18	4	3.5
Navicula vandamii	1.21	3	0.30	3	0.26	4	0.28	5	3.8
Navicula cf. *aquaedurae*	1.36	3	0.08	2	0.22	4	0.22	5	3.5
Navicula cf. *leistikowii*	1.04	3	0.20	2	0.06	2	0.23	5	3.0
Navicula cf. *parablis*	1.16	3	0.22	3	0.26	4	0.26	5	3.8

Table 20 (continued)

Diatoms species	$WA_{(BOD)}$	$IV_{(BOD)}$	$WA_{(nitrate)}$	$IV_{(nitrate)}$	$WA_{(ammonium)}$	$IV_{(ammonium)}$	$WA_{(SRP)}$	$IV_{(SRP)}$	Averaged IV
Nitzschia clausii	1.21	3	0.46	4	0.25	4	0.15	4	3.8
Nitzschia angustata	1.50	3	0.53	4	0.14	2	0.08	3	3.0
Nitzschia dissipata	1.19	3	0.37	3	0.26	4	0.21	5	3.8
Nitzschia linearis	0.82	2	0.30	3	0.06	2	0.06	3	2.5
Nitzschia frequens	0.88	2	0.21	3	0.09	2	0.14	4	2.8
Nitzschia frustulum	1.06	3	0.16	2	0.28	4	0.25	5	3.5
Nitzschia gracilis	1.45	3	0.87	5	0.11	3	0.20	5	4.0
Nitzschia hoehnkii	0.77	2	0.21	3	0.17	3	0.12	4	3.0
Nitzschia intermedia	1.78	3	0.34	3	0.37	4	0.16	4	3.5
Nitzschia palea	1.11	3	0.83	5	0.24	4	0.19	5	4.4
Nitzschia palea var. *deblis*	0.58	2	0.10	2	0.32	4	0.10	4	3.0
Nitzschia persuadens	1.12	3	0.40	4	0.23	4	0.20	5	4.0
Nitzschia recta	1.83	3	0.62	4	0.14	3	0.10	4	3.5
Nitzschia reversa	1.40	3	0.85	5	0.14	3	0.20	5	4.0
Nitzschia scalpelliformis	0.94	2	0.74	4	0.16	3	0.17	4	3.3
Nitzschia cf. *ruttneri*	1.40	3	0.82	5	0.10	3	0.24	5	4.0
Hantzschia amphioxys	2.11	4	0.56	4	0.16	3	0.03	2	3.3
Pinnularia acidojaponica	1.76	3	0.60	4	0.15	3	0.24	5	3.8
Pinnularia cf. *interrupta*	1.19	3	0.25	3	0.31	4	0.25	5	3.8
Planotudium frequentissimum	1.08	3	0.21	3	0.26	4	0.24	5	3.8
Planotudium rostratum	1.06	3	0.19	2	0.30	4	0.24	5	3.5
Pleurosigma negoroi	1.20	3	0.39	3	0.47	4	0.23	5	3.8

Table 20 (continued)

Diatoms species	$WA_{(BOD)}$	$IV_{(BOD)}$	$WA_{(nitrate)}$	$IV_{(nitrate)}$	$WA_{(ammonium)}$	$IV_{(ammonium)}$	$WA_{(SRP)}$	$IV_{(SRP)}$	Averaged IV
Seminavis strigosa	1.16	3	0.31	3	0.22	4	0.22	5	3.8
Rhopalodia musculus	1.05	3	0.09	2	0.14	3	0.33	5	3.3
Surirella fonticola	1.14	3	0.34	3	0.13	3	0.25	5	3.5
Ulnaria arcus	1.09	3	0.32	3	0.18	3	0.14	4	3.3
Ulnaria lanceolata	1.22	3	0.34	3	0.12	3	0.23	5	3.5
Ulnaria ullna	1.05	3	0.32	3	0.14	3	0.41	5	3.5

Example 4 The satisfication rate of the sample index calculation

Taxa	% relative abundance (1)	Index Value (2)	(1)x(2)
Auracoseira granulata	1.8	3.8	6.885
Discostella stelligeroides	2.1	3.5	7.491
Achnanthidium exile	6.4	2.8	18.02
Achnanthidium minutissimun	13.4	3.3	44.32
Cocconeis placentula	2.4	3.5	8.263
Cymbella affinis	3.2	3	9.581
Cymbella parva	1.5	3	4.397
Cymbella turgidula	1.8	3.8	6.832
Cymbella bifurcumstigma	2.2	2.5	5.594
Delicata cf. *sparsistriata*	1.4	3	4.234
Encyonema malaysianum	1.6	3	4.898
Encyonopsis microcephala	2.1	2.8	5.93
Hippodonta pseudoacceptata	1.3	3.5	4.656
Gomphonema pumilum	2.4	3	7.126
Gomphonema auritum	2.2	3	6.489
Gomphonema parvulum	3.2	3.8	12.2
Navicula suprinii	1.4	3	4.077
Navicula simulata	3.0	3.5	10.6
Navicula cf. *leistikowii*	1.6	3	4.91
Navicula cf. *parablis*	1.7	3.8	6.555
Nitzschia recta	2.1	3.5	7.407
Nitzschia ruttneri	2.0	4	8.109
Nitzschia gracilis	1.6	4	6.475
Nitzschia palea	20.9	4.3	89.68
Planotudium frequentissimum	3.3	3.8	12.65
Seminavis strigosa	9.6	3.8	36.39
Ulnaria lanceolata	1.4	3.5	4.765
Ulnaria ullna	2.3	3.5	7.886
Sum	100		356.4
Wang River sample index		3.56	
Trophic status	**oligo-mesotrophic to mesotrophic status**		

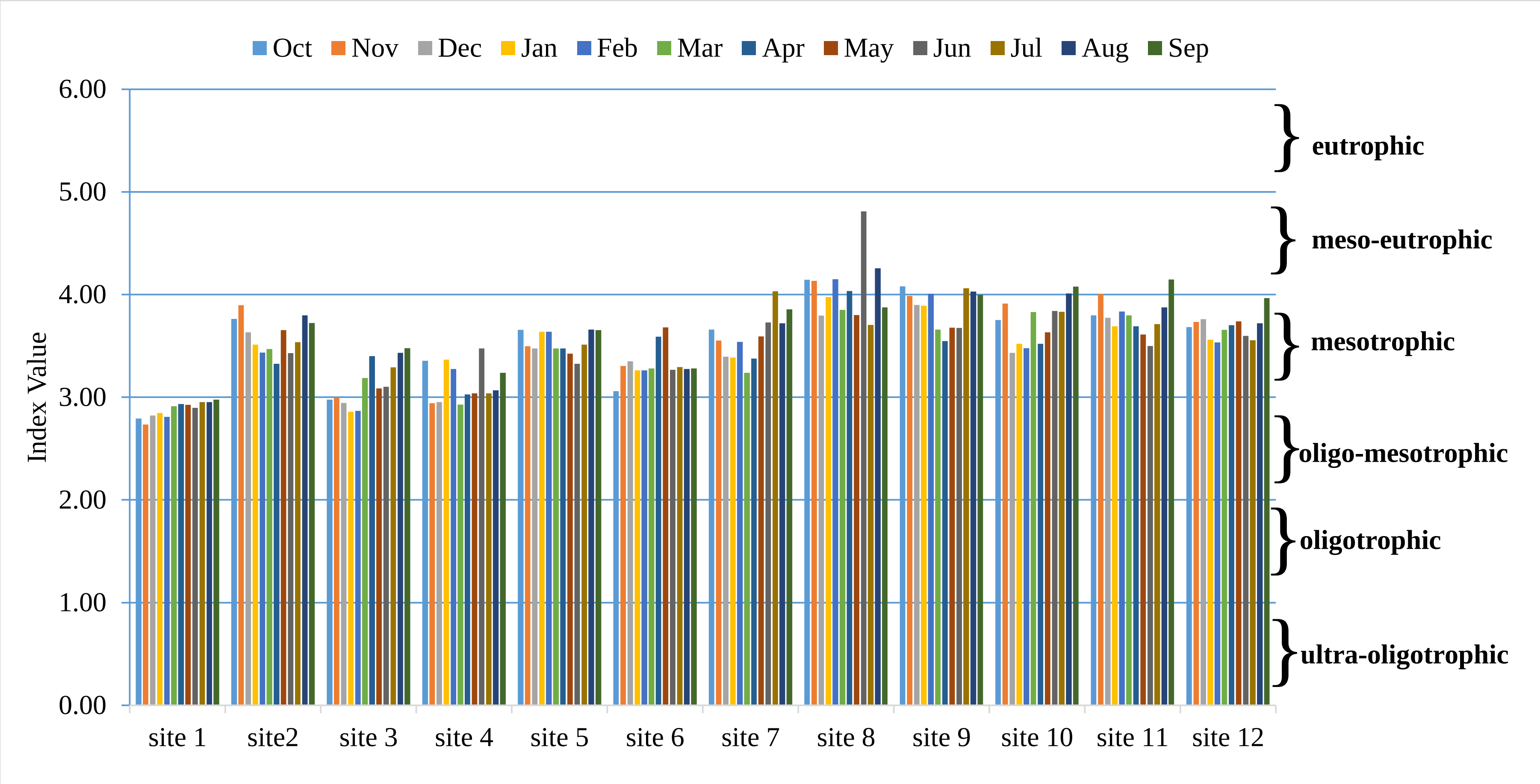


Figure 97 The trophic status of Wang River during October 2011- September 2012 calculated by using Wang Diatom Index

4.7 Comparison of trophic status in the Wang River using the Wang Diatom Index along with other indexes

The comparison of the indicator values of the Wang Diatoms Index with other indices, such as AARL-PC score, Thailand Diatom Index (Leelahakriengkrai, 2010) the Mekong Diatom Index (Suphan, 2009), the Ping and Nan Diatom Index (Kunpradid, 2005), the Mea Sa Diatom Index (Pekthong, 2002), the Rott Index (Rott *et al*., 1997) and the Van Dam Index (Van Dam, 1994) is shown in Table 21.

A comparison of the trophic status between the Wang Diatom Index with the AARL-PC score from each sampling site of the Wang River recorded from October 2011 to September 2012 is presented. The trophic status of the AARL-PC score, which used some physicochemical factors, was classified as oligotrophic to mesotrophic staus (Table 22). The Wang Diatom Index was classified as oligo-mesotrophic to meso-eutrophic staus (Table 22 and Figure 95). Most results of the Wang Diatom Index presented a trophic status that was higher than the AARL-PC score.

The comparison of the trophic status recorded between the Wang Diatom Index was done with 4 indices from Thailand, namely, the Mea Sa Diatom Index (Pekthong, 2002), the Mekong Diatom Index (Suphan, 2009), the Ping and Nan Diatom Index (Kunpradid, 2005) and Thailand Diatom Index (Leelahakriengkrai, 2010). The trophic status showed specific differences in each index (Table 22). The trophic status of the Wang River was arrived at by using the Mae Sa Diatom Index and was found to be oligo-mesotrophic to eutrophic status, and was slightly different at some sampling sites when compared with the Wang Diatom Index. In the same way, the Ping and Nan Diatom Index also revealed classifications of beta-mesosaprobic to alfa-mesosaprobic but most of them were alfa-mesosaprobic status. Additionally, the trophic status of the Wang River was arrived at by using the Thailand Diatom Index and the Mekong Diatom Index, and revealed the mesotrophic to meso-eutrophic status and this result was higher than that of the Wang Diatom Index, especaially at site 1. This site was in the upstream area of the river and for which the Wang Diatom Index revealed the oligo-mesotrophic trophic status, while the Thailand Diatom Index and the Mekong Diatom Index indicated that the water was of mesotrophic status.

Table 21 Comparison of the index value between the Wang Diatom Index with the other indexes

Taxa	Wang Index	Mae Sa Index	Ping and Nan Index	Mekong Index	Thailand Index	Van Dam Index	Rott Index
Achnanthidium exiguum	3.3	3			4	7	
Achnanthidium minutissimum	3.3		3	4	4	7	1.7
Halamphora montana	3.5				3.8		
Aulacoseira granulata	3.8				4.5	5	
Branchysira neoexilis	3.3				3.3		
Cocconeis placentula	3.5	4	4	3		5	2
Craticula molestiformis	2.5				4		
Cymbella affinis	3				3.3	5	4
Cymbella tumidula	3	4	4		3.3	4	4
Cymbella turgidula	3.8	4	5		3.8		
Diadesmis confervacea	3				4.8		
Diploneis oblongella	3.8						5
Discostella stelligeroides	3.5				4		
Encyonema mesianum	3.8				4		
Encyonopsis microcephala	2.8				3.3		
Geissleria decussis	4.3			4			
Gomphonema gracile	3				3.5	3	4
Gomphonema lagenula	3.8			4	3.8		
Gomphonema micropus	3.8					3	
Gomphonema minutum	3.5					5	
Gomphonema parvulum	3.8		4		3.5		
Gomphonema pumilum	3	2				7	3
Gyrosigma scalproides	3.5	5	5				
Hantzschia amphioxys	3.3					7	1
Navicula cryptotenella	3.8	4		4	3.5	7	2
Navicula germainii	3.3				3.8		
Navicula rostellata	3.8			4	4	5	4
Navicula radiosalfalax	3				3.5		
Navicula simulata	3.5		3	5	3.8		
Nitzschia clausii	3.8			4	3.8		

Table 21 (continued)

Taxa	Wang Index	Mae Sa Index	Ping and Nan Index	Mekong Index	Thailand Index	Van Dam Index	Rott Index
Nitzschia dissipata	3.8		3	5	3.5	4	3
Nitzschia intermedia	3.5				3.3		
Nitzschia palea	4.3	5	5	5	4.5	6	0
Planothidium frequentissimum	3.8			4			
Seminavis strigosa	3.8				4		
Ulnaria arcus	3.3				2.8		
Ulnaria lanceolata	3.5	4					
Ulnaria ulna	3.5	4	3	4	3	7	0

The trophic status of the Wang River was arrived at by using the Wang Diatom Index and was compared with foreign indices, such as the Van Dam index (Van Dam, 1994) and the Rott Index (Rott *et al.*, 1997). The results of the comparison presented the differences in the trophic status of the Wang River. The Van Dam Index showed a eutrophic to hypereutrophic status at most sampling sites. On the other hand, the results of the Rott Index classified the trophic status of the Wang River as being oligo saprobic to beta to alfamesosaprobic, and these results were slightly lower than those arrived at from the Wang Diatom Index (Table 22).

Table 22 The comparison of trophic status between Wang Diatom Index and other indexes in each sampling during October 2011 to September 2012

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site1-Oct	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	alfa- mesosaprobic	meso- eutrophic	mesotrophic	beta to alfamesosaprobic
site1-Nov	oligotrophic	oligo-mesotrophic	mesotrophic	no diatom	alfa- mesosaprobic	meso- eutrophic	mesotrophic	beta to alfamesosaprobic
site1-Dec	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site1-Jan	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site1-Feb	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	meso- eutrophic	beta to alfamesosaprobic
site1-Mar	oligotrophic	oligo-mesotrophic	mesotrophic	no diatom	alfa- mesosaprobic	mesotrophic	mesotrophic	beta to alfamesosaprobic
site1-Apr	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	betamesosaprobic
site1-May	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	oligo-mesotrophic	Hyper eutrophic	betamesosaprobic
site1-Jun	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site1-Jul	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site1-Aug	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligosaprobic
site1-Sep	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	eutrophic	betamesosaprobic
site 2-Oct	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	oligo to metamesosaprobic
site2-Nov	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	betamesosaprobic
site2-Dec	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site2-Jan	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site2-Feb	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site2-Mar	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site2-Apr	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site2-May	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site2-Jun	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site2-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	betamesosaprobic
site2-Aug	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	betamesosaprobic
site2-Sep	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site3-Oct	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site3-Nov	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	oligo-mesotrophic	Hyper eutrophic	betamesosaprobic
site3-Dec	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site3-Jan	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site3-Feb	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site3-Mar	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	eutrophic	betamesosaprobic
site3-Apr	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	oligo-mesotrophic	Hyper eutrophic	betamesosaprobic
site3-May	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	oligo-mesotrophic	eutrophic	betamesosaprobic
site3-Jun	oligotrophic	mesotrophic	mesotrophic	mesotrophic	no diatom	oligo-mesotrophic	eutrophic	beta to alfamesosaprobic
site3-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	oligo-mesotrophic	eutrophic	beta to alfamesosaprobic
site3-Aug	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site3-Sep	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site4-Oct	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	betamesosaprobic
site4-Nov	oligotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	mesotrophic	eutrophic	oligo to metamesosaprobic
site4-Dec	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-Jan	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-Feb	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-Mar	oligo-mesotrophic	oligo-mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	oligo to metamesosaprobic
site4-Apr	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-May	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-Jun	oligotrophic	mesotrophic	mesotrophic	mesotrophic	no diatom	oligo-mesotrophic	meso- eutrophic	betamesosaprobic
site4-Jul	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	betamesosaprobic
site4-Aug	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site4-Sep	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	oligo-mesotrophic	eutrophic	betamesosaprobic
site5-Oct	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site5-Nov	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site5-Dec	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site5-Jan	oligotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site5-Feb	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site5-Mar	oligotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site5-Apr	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site5-May	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site5-Jun	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site5-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site5-Aug	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site5-Sep	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site6-Oct	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site6-Nov	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site6-Dec	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site6-Jan	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligosaprobic
site6-Feb	oligo-mesotrophic	mesotrophic	meso- eutrophic	mesotrophic	beta- mesosaprobic	oligo-mesotrophic	Hyper eutrophic	oligosaprobic
site6-Mar	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligosaprobic
site6-Apr	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	betamesosaprobic
site6-May	oligo-mesotrophic	mesotrophic	meso- eutrophic	mesotrophic	beta- mesosaprobic	no diatom	eutrophic	betamesosaprobic
site6-Jun	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site6-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	oligo-mesotrophic	eutrophic	oligo to metamesosaprobic
site6-Aug	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	no diatom	Hyper eutrophic	oligosaprobic
site6-Sep	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	no diatom	Hyper eutrophic	oligosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site7-Oct	oligo- mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site7-Nov	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site7-Dec	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site7-Jan	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	oligo to metamesosaprobic
site7-Feb	oligo- mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site7-Mar	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligosaprobic
site7-Apr	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	oligo to metamesosaprobic
site7-May	mesotrophic	mesotrophic	meso- eutrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	eutrophic	oligo to metamesosaprobic
site7-Jun	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	mesotrophic	Hyper eutrophic	oligo to metamesosaprobic
site7-Jul	oligotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	no diatom
site7-Aug	oligo- mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site7-Sep	oligo- mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site8-Oct	oligotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	no diatom
site8-Nov	oligo- mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site8-Dec	oligo- mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site8-Jan	oligo- mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site8-Feb	oligo- mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	no diatom
site8-Mar	mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site8-Apr	mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site8-May	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site8-Jun	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site8-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site8-Aug	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligosaprobic
site8-Sep	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	beta to alfamesosaprobic
site9-Oct	oligotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	no diatom
site9-Nov	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	no diatom
site9-Dec	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	beta to alfamesosaprobic
site9-Jan	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	beta to alfamesosaprobic
site9-Feb	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site9-Mar	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site9-Apr	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligosaprobic
site9-May	mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site9-Jun	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	oligosaprobic
site9-Jul	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligosaprobic
site9-Aug	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	oligosaprobic
site9-Sep	mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	no diatom

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site10-Oct	oligotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	no diatom
site10-Nov	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	oligo to metamesosaprobic
site10-Dec	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site10-Jan	oligotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site10-Feb	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site10-Mar	mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligosaprobic
site10-Apr	oligo-mesotrophic	mesotrophic	mesotrophic	mesotrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site10-May	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site10-Jun	oligotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site10-Jul	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site10-Aug	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	no diatom
site10-Sep	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	meso-eutrophic	no diatom
site11-Oct	oligotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site11-Nov	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site11-Dec	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site11-Jan	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site11-Feb	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	betamesosaprobic
site11-Mar	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	betamesosaprobic

Table 22 (continued)

Sampling	AARL	Wang Index	Thailand Index	Mekong Index	Ping_Nan Index	Mae Sa Index	Van Dam Index	Rott Index
site11-Apr	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site11-May	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta- mesosaprobic	no diatom	eutrophic	betamesosaprobic
site11-Jun	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site11-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site11-Aug	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site11-Sep	oligo-mesotrophic	meso- eutrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site12-Oct	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site12-Nov	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site12-Dec	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site12-Jan	oligotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site12-Feb	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site12-Mar	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	Hyper eutrophic	oligo to metamesosaprobic
site12-Apr	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligo to metamesosaprobic
site12-May	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site12-Jun	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site12-Jul	oligo-mesotrophic	mesotrophic	mesotrophic	meso- eutrophic	beta-alfa mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic
site12-Aug	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	oligosaprobic
site12-Sep	oligo-mesotrophic	mesotrophic	meso- eutrophic	meso- eutrophic	alfa- mesosaprobic	meso- eutrophic	eutrophic	betamesosaprobic