CHAPTER 4
RESULTS

4.1 Benthic diatoms

4.1.1 Diatom diversity

A total of two hundred and fifty two species of benthic diatoms were found from 14 sampling sites in the Mekong River and its tributaries in Thailand. It could be classified into 3 classes, 6 subclasses, 14 orders, 27 families and 53 genera. It was found that 88.5% of them were classified in Class Bacillariophyceae, 6.0% in Class Fragilariophyceae and 5.5% in Class Coscinodiscineae, respectively. Two hundred and two taxa could be identified to species level and 50 only to the level of genus. *Nitzschia* spp. was a genus with the highest numbers of species (30 species) followed by *Navicula* spp. (25 species), *Gomphonema* spp. (16 species), *Eunotia* spp. (14 species), *Luticola* spp. (12 species) and *Pinnularia* spp. (8 species), respectively.

A species list of benthic diatoms from 14 sampling sites in the Mekong River and its tributaries in Thailand were classified systematically into categories and shown in the Table 8. Light micrographs of living diatoms were shown in Figures 4-5, scanning electron micrographs were also shown in Figures 6-7. In addition, light micrographs of cleaned diatoms were shown in Figures 8-53.

In addition, fifty five species of benthic diatoms were considered to be newly recorded in Thailand. It could be classified into 3 classes, 11 orders, 22 families and 32 genera. Hand drawing micrographs of them were shown in figures 54-56. The species of diatoms were compared with the check list of freshwater algae in Thailand by Lewmanomont *et al.* (1995), Pekthong (1998 and 2002a), Waiyaka (1998), Kunpradid (2000 and 2005), Wanathong *et al.*, (2000), Suphan (2004), Inthasotti (2006a,b), Leelahakriengkrai (2007a,b) and Preuthiworanon (2008). The species list of new records of Thailand was shown in Table 9.

Table 8 Species list of benthic diatoms in Mekong River and its tributaries in Thailand

TAXA
Division Bacillariophyta
Class Coscinodiscineae
Subclass Thalassiosirophycidae
Order Thalassiosirales
Family Stephanodiscaceae
Cyclotella meneghiniana Kützing
Discostella stelligera (Cleve & Grunow) Houk & Klee
Discostella pseudostelligera (Hustedt) Houk & Klee
Stephanodiscus cf. *vestibulis* Hakansson, Theriot& Stoermer
Stephanodiscus sp.1
Stephanodiscus sp.2
Stephanodiscus sp.3
Subclass Coscinodiscophycidae
Order Melosirales
Family Melosiraceae
Melosira varians C. Agardh
Order Aulacoseirales
Family Aulacoseiraceae
Aulacoseira cf. *alpigena* (Grunow) Krammer
Aulacoseira ambigua (Grunow) Simonsen
Aulacoseira granulata (Ehrenberg) Simonsen
Aulacoseira muzzanensis (Meister) Krammer
Subclass Biddulphiophycidae
Order Triceratiales
Family Triceratiaceae
Pleurosira laevis (Ehrenberg) Compère
Order Biddulphiales
Family Biddulphiaceae
Hydrosera whampoensis (A.F.Schwarz)Deby
Class Fragilariophyceae
Subclass Fragilariophycidae
Order Fragilariales
Family Fragilariaceae
Diatoma mesodon(Ehrenberg)Kützing
Fragilaria acus (Kützing) Lange-Bertalot in Krammer and Lange-Bertalot
Fragilaria bidens Heiberg
Fragilaria capucina Desmazières
Fragilaria capucina var. *vaucheriae* (Kützing) Lange-Bertalot
Synedra cf. *amphicephala* var. *austriaca* (Grunow) Hustedt
Synedra lanceolata Kützing

Table 8 (continued)

TAXA
Family Fragilariaceae
Synedra ulna var. *aequalis* (Kützing) Hustedt
Synedra ulna var. *amphirhynchus* (Ehrenberg) Grunow
Synedra ulna var. *spathulifera* Grunow
Synedra ulna var. *subaequalis* Grunow
Tabularia fasciculata (C. Agardh) D.M. Williams & Round
Ulnaria biceps (Kützing) P. Compère
Ulnaria ulna (Nitzsch) P. Compère
Class Bacillariophyceae
Subclass Eunotiophycidae
Order Eunotiales
Family Eunotiaceae
Eunotia camelus var. *arcuata* J. Frenguelli
Eunotia cf.*curtiraphe* Metzeltin & Lange-Bertalot
Eunotia cf. *femoriformis* (Patrick) Hustedt
Eunotia indica Grunow
Eunotia cf. *mucophila* (Lange-Bertalot & Norpel) Lange-Bertalot
Eunotia repens A. Berg
Eunotia sp.1
Eunotia sp.2
Eunotia sp.3
Eunotia sp.4
Eunotia sp.5
Eunotia sp.6
Eunotia sp.7
Eunotia sp.8
Subclass Bacillariophycidae
Order Cymbellales
Family Cymbellaceae
Cymbella cistula (Hemprich & Ehrenberg) O. Kirchner
Cymbella naviculiformis (Auerswald) Cleve
Cymbella sumatrensis Hustedt
Cymbella tumida (Brébisson) Van Heurck
Cymbella turgidula Grunow
Cymbella sp.1
Cymbella sp.2
Cymbopleura cf. *laterostrata* var. *rostrata* Krammer
Encyonema minutum (Hilse in Rabenhorst) D.G.Mann in Round, Crawford & Mann
Encyonema prostratum (Berkeley) Kützing
Family Cymbellaceae
Encyonema silesiacum (Bleisch) D.G. Mann
Encyonema sp.1
Encyonema sp.2

Table 8 (continued)

TAXA
Family Cymbellaceae
Encyonopsis leei var. *leei* Krammer
Encyonopsis microcephala (Grunow) Krammer
Placoneis abundans Metzeltin, Lange-Bertalot & García-Rodríguez
Placoneis gracilis Metzeltin, Lange-Bertalot & Garcia-Rodriguez
Placoneis symmetrica (Hustedt) Lange-Bertalot
Placoneis undulata (Østrup) Lange-Bertalot
Placoneis sp.1
Family Gomphonemataceae
Gomphonema gracile Ehrenberg
Gomphonema inaequilongum (Kobayasi) Kobayasi & Mayama
Gomphonema lagenula Kützing
Gomphonema parvulum (Kützing) Kützing var. *parvulum*
Gomphonema parvulum var. *exilissimum* Grunow
Gomphonema affine Kützing
Gomphonema pseudoaugur Lange-Bertalot
Gomphonema subtile Ehrenberg
Gomphonema minutiforme Lange-Bertalot & Reichardt
Gomphonema contraturris Lange-Bertalot & Reichardt
Gomphonema transilvanicum J. Pantocsek
Gomphonema turris var. *brasiliensis* (F. Fricke) J. Frenguelli
Gomphonema sp.1
Gomphonema sp.2
Gomphoneis rhombica (Fricke) V. Merino *et al.*
Gomphoneis cf. *heterominuta* Mayama et Kawashima
Order Achnanthales
Family Achnanthaceae
Achnanthes crenulata Grunow
Achnanthes exigua var. *constricta* (Grunow) Hustedt
Achnanthes exigua var. *elliptica* Hustedt
Achnanthes inflata (Kützing) Grunow
Planothidium delicatulum (Kützing) Round & L. Bukhtiyarova
Family Achnanthaceae
Planothidium frequentissimum (Lange-Bertalot) Round & L. Bukhtiyarova
Planothidium rostratum (Østrup) Lange-Bertalot
Planothidium sp.1

Table 8 (continued)

TAXA
Family Cocconeidaceae
Cocconeis pediculus Kützing
Cocconeis placentula Ehrenberg
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow
Cocconeis placentula var. *lineata* (Ehrenberg) van Heurck
Cocconeis placentula var. *pseudolineata* Geitler
Family Achnanthidiaceae
Achnanthidium catenatum (Bily & Marvan) Lange-Bertalot
Achnanthidium convergens (H. Kobayasi) H. Kobayasi
Achnanthidium cf. *japonicum* (H. Kobayasi) H. Kobayasi
Achnanthidium minutissimum (Kützing) Czarnecki
Achnanthidium minutissimum var. *robusta* Hustedt
Achnanthidium sp.1
Order Naviculales
Family Diadesmidaceae
Diadesmis confervacea Kützing
Diadesmis contenta (Grunow) D.G. Mann
Diadesmis sp.1
Family Diadesmidaceae
Luticola cf.*falknerorum* Metzeltin & Lange-Bertalot
Luticola goeppertiana (Bleisch) D.G.Mann in Round,Crawford&Mann
Luticola monita (Hustedt) D.G. Mann
Luticola nivalis (Ehrenberg) D.G. Mann in Round, Crawford & Mann
Luticola peguana (Grunow) D.G. Mann
Luticola cf. *permuticoides* Metzeltin & Lange-Bertalot
Luticola saxophila (Bock ex Hustedt) D.G. Mann
Luticola sp.1
Luticola sp.2
Luticola sp.3
Luticola sp.4
Luticola sp.5
Family Amphipleuraceae
Frustulia undosa D. Metzeltin & H. Lange-Bertalot
Frustulia saxonica Rabenhorst
Frustulia rhomboides (Ehrenberg) De Toni
Frustulia pararhomboides var. *pararhomboides* H. Lange-Bertalot
Frustulia sp.1
Family Brachysiraceae
Brachysira neoexilis Lange-Bertalot
Brachysira sp.1

Table 8 (continued)

TAXA
Family Neidiaceae
Neidium affine (Ehrenberg) Pfizer
Neidium binodis (Ehrenberg) Hustedt
Neidium dubium (Ehrenberg) Cleve
Neidium floridanum Reimer
Neidium cf. *kozlowii* Mereschkovsky
Family Sellaphoraceae
Sellaphora bacillum (Ehrenberg) D.G. Mann
Sellaphora pupula (Kützing) Mereschkovsky
Sellaphora sp.1
Sellaphora sp.2
Fallacia insociabilis(Krasske) D.G. Mann
Fallacia meridionalis Metzeltin, Lange-Bertalot and Garcia-Rodriguez
Fallacia cf. *pygmaea* (Kützing) A.J. Stickle & D.G. Mann
Family Pinnulariaceae
Pinnularia acrosphaeria (Brébisson) W. Smith
Pinnularia brauniana (Grunow) Studnicka
Pinnularia graciloides Hustedt
Pinnularia microstauron (Ehrenberg) Cleve
Pinnularia similis Hustedt
Pinnularia subcapitata W. Gregory
Pinnularia sp.1
Pinnularia sp.2
Family Diploneidaceae
Diploneis elliptica (Kützing) Cleve
Diploneis pseudovalis Hustedt
Diploneis puella (Schumann) Cleve
Diploneis subovalis Cleve
Family Naviculaceae
Caloneis bacillum (Grunow) Cleve
Caloneis sp.1
Eolimna minima (Grunow) Lange-Bertalot
Eolimna subminuscula (Manguin) Gerd Moser
Eolimna tantula (Hustedt) Lange-Bertalot
Eolimna sp.1
Eolimna sp.2
Eolimna sp.3
Family Naviculaceae
Geissleria decussis (Østrup) Lange-Bertalot&Metzeltin
Geissleria punctifer (Hustedt) Metzeltin,Lange-Bertalot&Garcia-Rodriguez
Hippodonta capitata (Ehrenberg)Lange-Bertalot,Metzeltin & Witkowski

Table 8 (continued)

TAXA
Family **Naviculaceae**
Hippodonta hungarica (Grunow) Lange-Bert, Metzeltin &Witkowski
Mayamaea atomus (Kützing) H. Lange-Bertalot
Naviculadicta nanogomphonema Lange-Bertalot & U.Rumrich
Naviculadicta tridentula(Krasske) Lange-Bertalot & Metzeltin
Navicula capitatoradiata Germain
Navicula cryptotenella Lange-Bertalot
Navicula radiosa Kützing
Navicula rostellata Kützing
Navicula symmetrica R.M. Patrick
Navicula viridula var. *viridula* (Kützing) Ehrenberg
Navicula cf. *menisculus* Schumann
Navicula cryptotenelloides Lange-Bertalot
Navicula cinctaeformis Hustedt
Navicula lanceolata (C. Agardh) Kützing
Navicula phyllepta Kützing
Navicula microcari Lange-Bertalot
Navicula schroeteri F. Meister
Navicula radiosafallax Lange-Bertalot
Navicula kuseliana Lange-Bertalot & U.Rumrich
Navicula cari Ehrenberg
Navicula germainii J. H. Wallace
Navicula novaesiberica Lange-Bertalot
Navicula rhynchocephala Kützing
Navicula sp.1
Navicula sp.2
Navicula sp.3
Navicula sp.4
Navicula sp.5
Navicula sp.6
Nupula sp.1
Family **Pleurosigmataceae**
Pleurosigma salinarum (Grunow) Grunow
Pleurosigma cf. *salinarum* var. *boyeri* (Keeley) Reimer
Pleurosigma sp.1
Gyrosigma acuminatum (Kützing) Rabenhorst
Gyrosigma cf. *eximium* (Thwaites) Van Heurck
Gyrosigma cf. *exilis* (Grunow) C.W.Reimer
Gyrosigma nodiferum (Grunow) Reimer
Gyrosigma obscurum (W. Smith) J.W. Griffith & Henfrey
Gyrosigma scalproides (Rabenhorst) Cleve

Table 8 (continued)

TAXA
Family Pleurosigmataceae
Gyrosigma spencerii (J.W. Bailey ex Quekett) Griffith & Henfrey
Family Stauroneidaceae
Craticula ambigua (Ehrenberg) D.G. Mann
Craticula cf. *subhalophila* (Hustedt) Lange-Bertalot
Stauroneis anceps Ehrenberg
Stauroneis smithii Grunow
Order Thalassiophysales
Family Catenulaceae
Amphora montana Krasske
Amphora sp.1
Order Bacillariales
Family Bacillariaceae
Bacillaria paxillifer (O.F.Müller) Hendey
Hantzschia amphioxys (Ehrenberg) Grunow
Nitzschia acicularis (Kützing) W.Smith
Nitzschia acidoclinata Lange-Bertalot
Nitzschia amphibia Grunow
Nitzschia capitellata Hustedt
Nitzschia clausii Hantzsch
Nitzschia dissipata (Kützing) Grunow
Nitzschia filiformis (W. Smith) Hustedt
Nitzschia fonticola (Grunow) Grunow
Nitzschia gracilis Hantzsch
Nitzschia geitlerii Hustedt
Nitzschia inconspicua Grunow
Nitzschia intermedia Hantzsch
Nitzschia linearis var. *linearis* (Agardh ex.W. Smith) W.Smith
Nitzschia liebetruthii Rabenhorst
Nitzschia lorenziana var. *incerta* Grunow
Nitzschia microcephala Grunow
Family Bacillariaceae
Nitzschia nana Grunow
Nitzschia obtusa W. Smith
Nitzschia palea (Kützing) W. Smith
Nitzschia palea var. *debilis* (Kützing) Grunow
Nitzschia paleacea Grunow
Nitzschia cf. *perminuta* (Grunow) M. Peragallo
Nitzschia pumila Hustedt
Nitzschia pseudofonticola Hustedt
Nitzschia subacicularis Hustedt
Nitzschia subcohaerens (Grunow.) Van Heurck

Table 8 (continued)

TAXA
Nitzschia supralitorea Lange-Bertalot
Nitzschia tabellaria (Grunow) Grunow
Nitzschia terrestris (J.B. Petersen) Hustedt
Nitzschia sp.1
Tryblionella acuminata W. Smith
Tryblionella balatonis (Grunow in Cleve & Grunow) D.G. Mann
Tryblionella calida (Grunow) D.G.Mann
Tryblionella coarctata (Grunow) D.G. Mann
Tryblionella levidensis W. Smith
Tryblionella salinarum (Grunow) Pantocsek
Order Rhopalodiales
Family Rhopalodiaceae
Epithemia sorex Kützing
Rhopalodia brebissonii Krammer
Rhopalodia gibba var. *gibba* (Ehrenberg) O. Müller
Rhopalodia gibberula (Ehrenberg) O.F. Müller
Rhopalodia operculata (Agardh) Håk
Rhopalodia sp.1
Order Surirellales
Family Surirellaceae
Surirella angusta Kützing
Surirella capronii Brébisson ex F. Kitton
Surirella nervosa (A. Schmidt) A. Mayer
Surirella roba Leclercq
Surirella splendida Kützing
Surirella sp.1
Surirella sp.2
Surirella sp.3

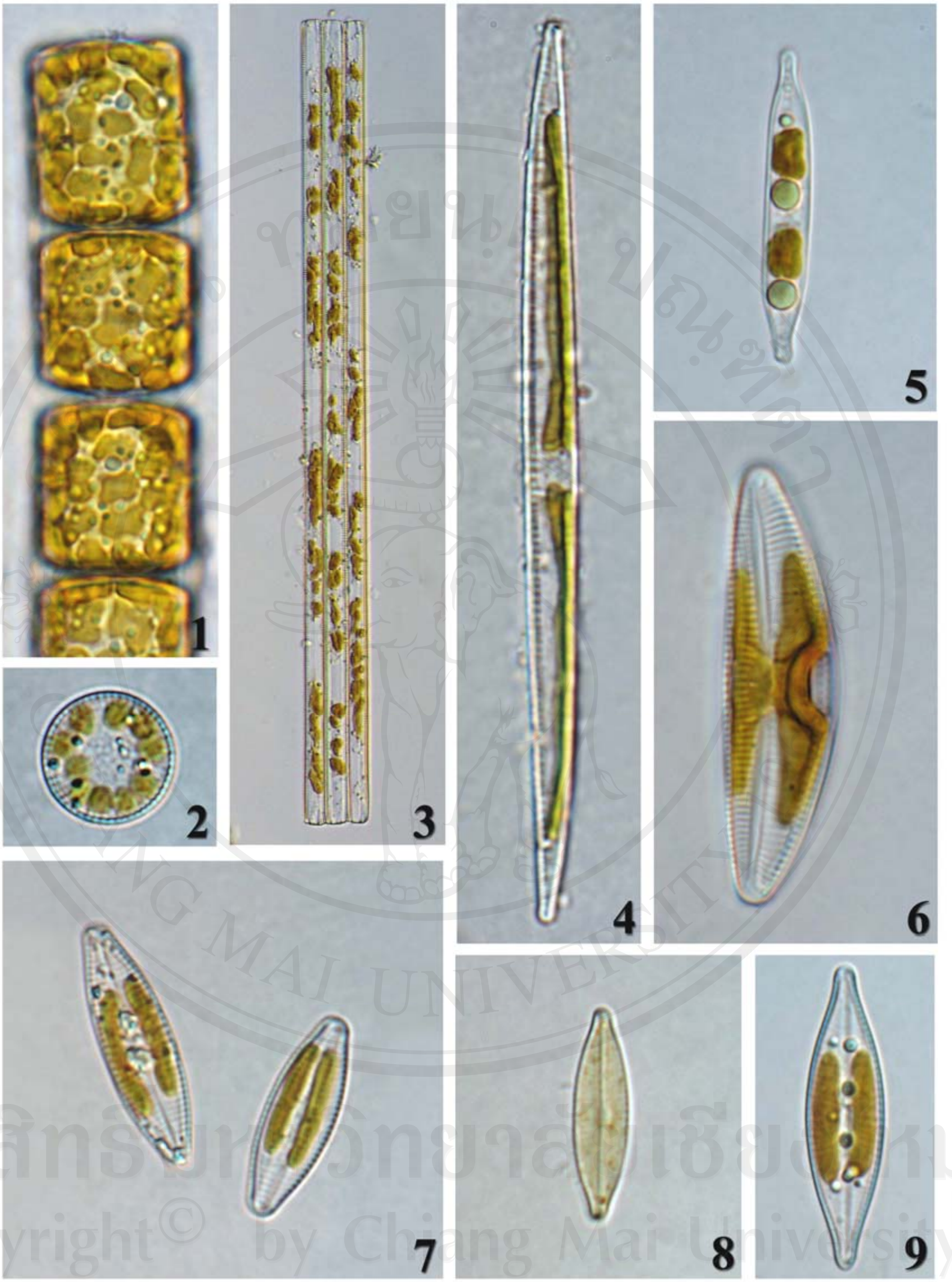


Figure 4 Light micrographs of some living diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Melosira varians* C. Agardh, (2) *Cyclotella meneghiniana* Kützing, (3) *Synedra ulna* var. *aequalis* (Kützing) Hustedt, (4) *Nitzschia filiformis* (W. Smith) Hustedt, (5) *Nitzschia dissipata* (Kützing) Grunow, (6 *Cymbella turgiguliformis* Krammer, (7) *Navicula cryptotenelloides* Lange-Bertalot, (8) *Navicula germainii* J. H. Wallace, (9) *Navicula rhynchocephala* Kützing

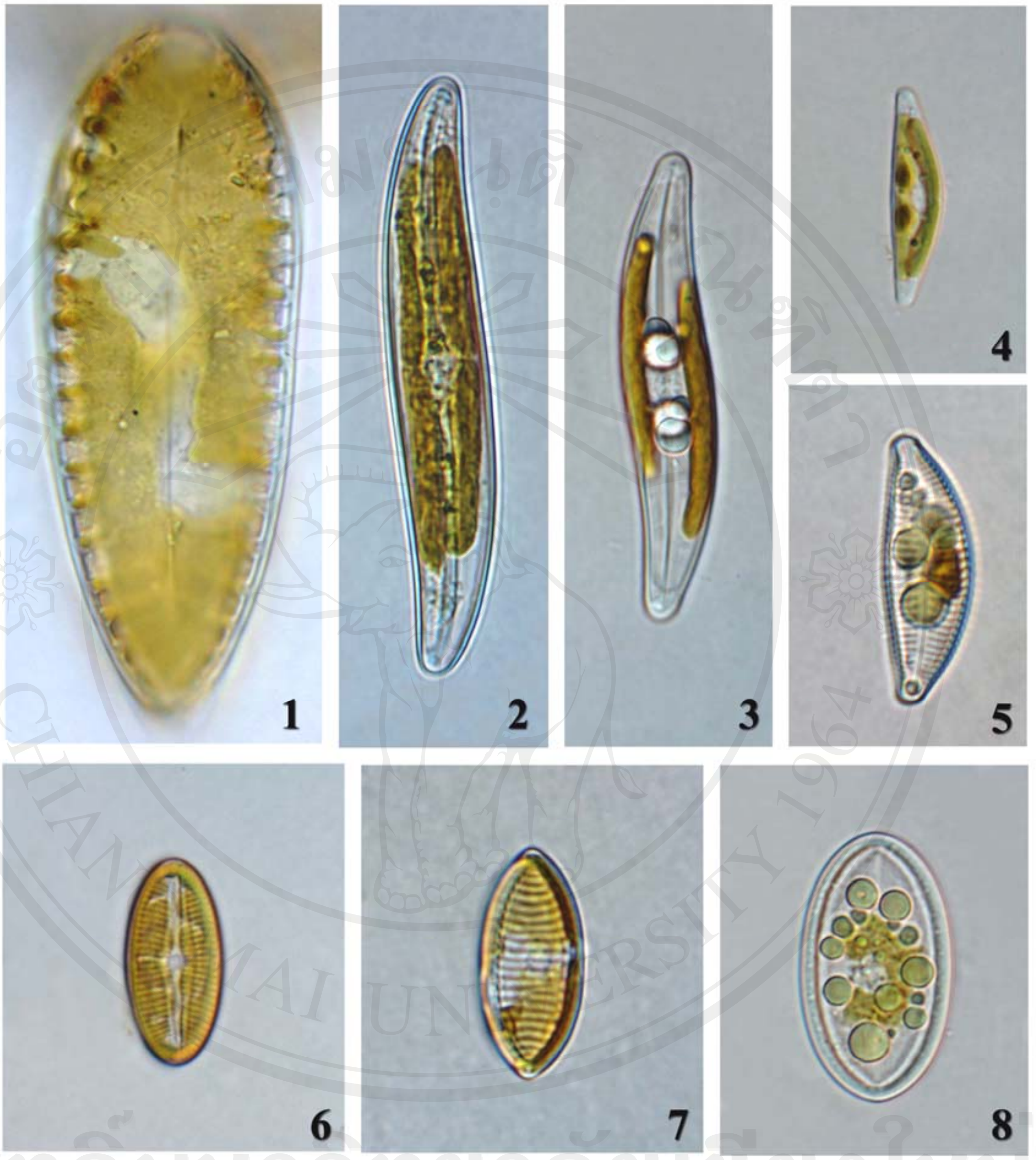


Figure 5 Light micrographs of some living diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Surrirella* sp., (2) *Gyrosigma* cf. *exilis* (Grunow) C.W.Reimer, (3) *Gyrosigma scalproides* (Rabenhorst) Cleve, (4) *Encyonema* sp.1, (5) *Cymbella turgidula* Grunow, (6) *Diploneis elliptica* (Kützing) Cleve, (7) *Tryblionella levidensis* W. Smith, (8) *Cocconeis placentula* Ehrenberg

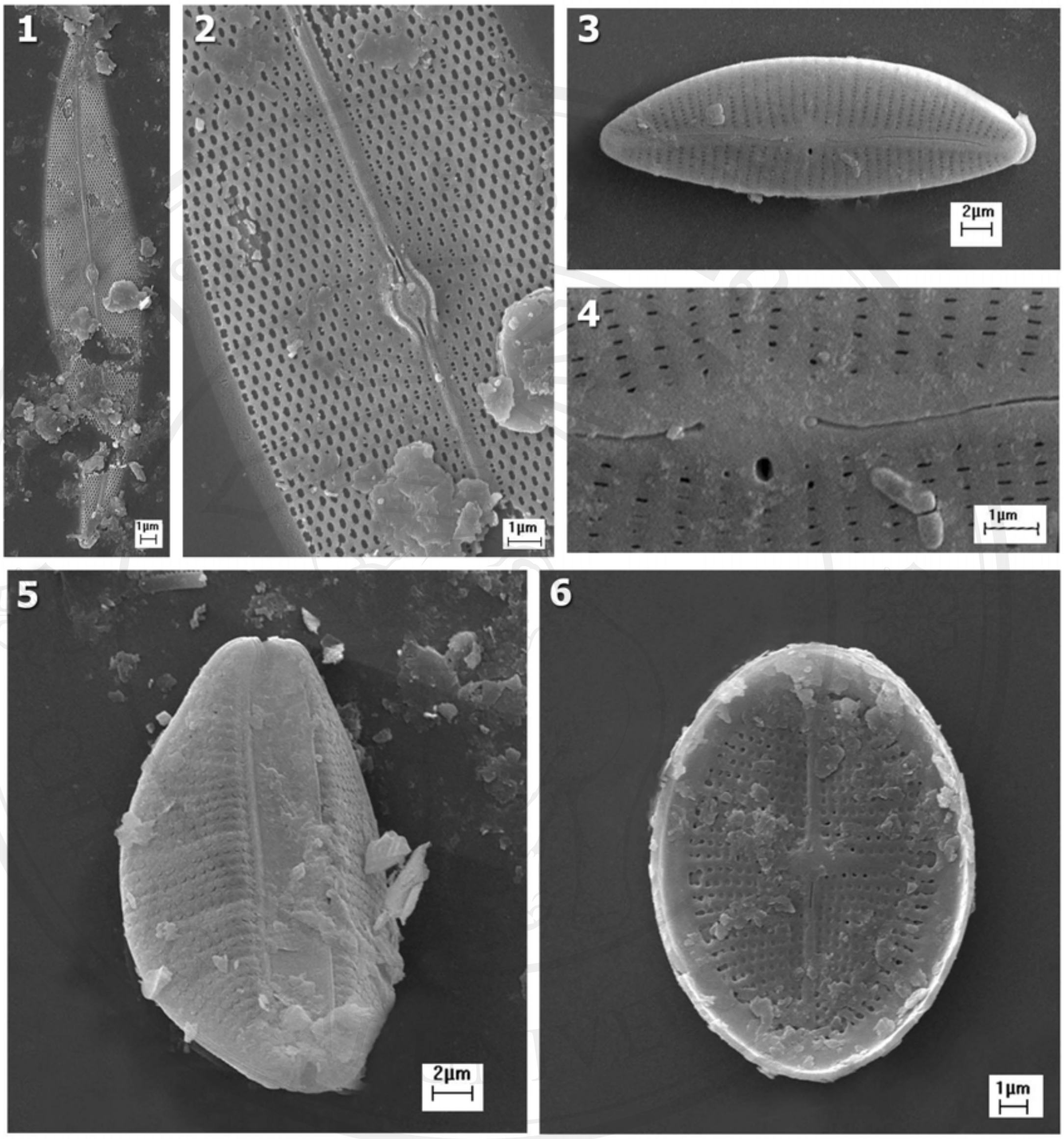


Figure 6 Scanning electron micrographs of some benthic diatoms in Mekong River and its tributaries in the part of Thailand

(1-2) *Pleurosigma salinarum* Grunow, internal view showing central area; (3-4) *Cymbella* sp.1, external view showing one stigmata; (5) *Rhopalodia operculata* (Agardh) Håk; (6) *Cocconeis pediculus* Ehrenberg, internal view showing raphe in the central of valve

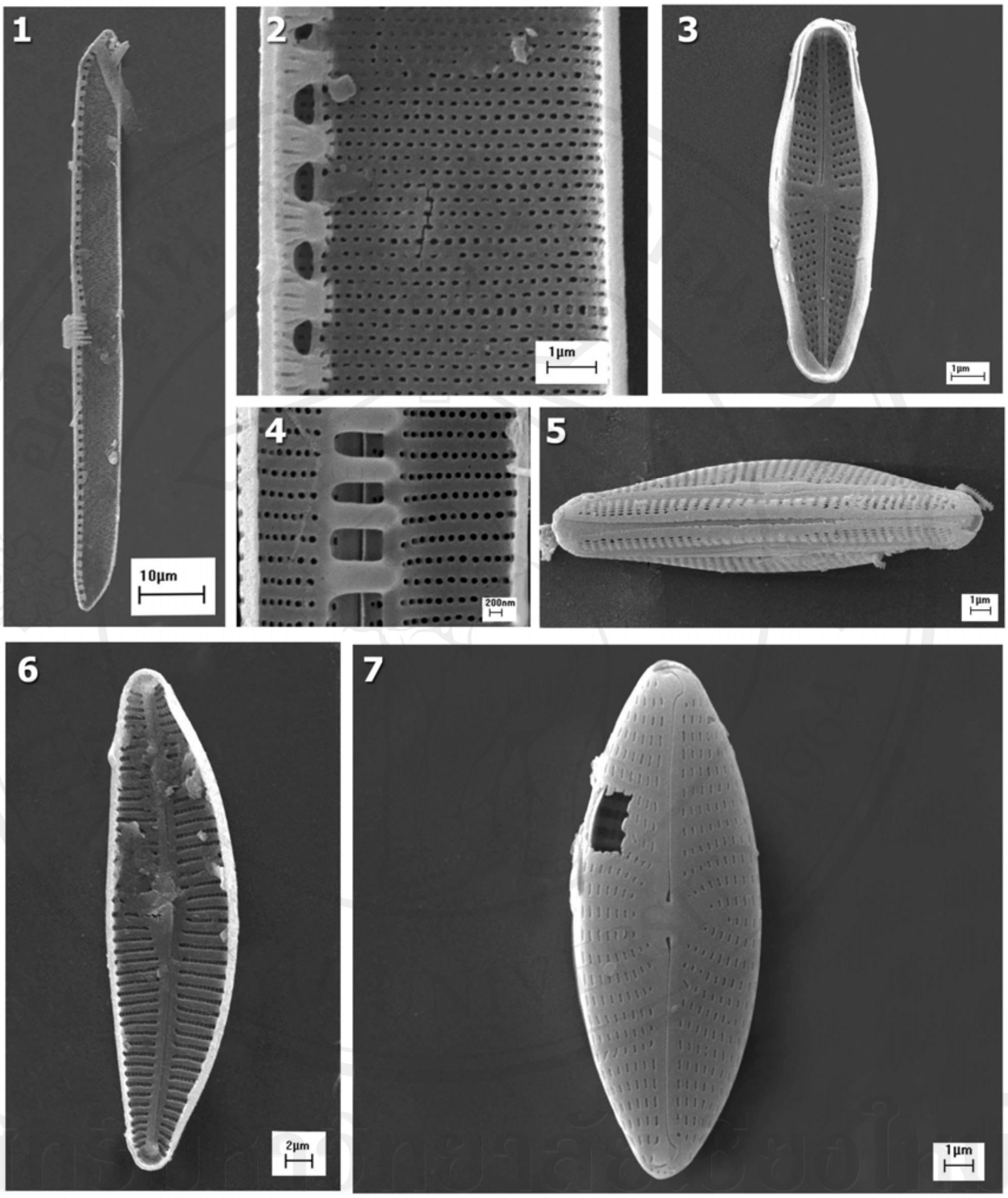


Figure 7 Scanning electron micrographs of some benthic diatoms in Mekong River and its tributaries in the part of Thailand

(1-2) *Nitzschia obtusa* W. Smith; internal view showing the small fibula in bar shape; (3) *Achnanthidium minutissimum* (Kützing) Czarnecki, interior surface of a raphe valve; (4) *Bacillaria paxillifer* (O.F.Mülleur) Hendey, showing raphe system central and striae uniseriate; (5) *Encyonema silesiacum* (Bleisch) D.G. Mann; (6) *Cymbella sumatrensis* Hustedt, external view; (7) *Navicula* cf. *menisculus* Schumann, external view of valve face

Figure 8 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-5) *Cyclotella meneghiniana* Kützing, (6-10) *Discostella stelligera* (Cleve & Grunow) Houk & Klee, (11) *Stephanodiscus* cf. *vestibulis* Hakansson, Theriot& Stoermer, (12) *Stephanodiscus* sp.1, (13-14) *Stephanodiscus* sp.2, (15) *Stephanodiscus* sp.3, (17-18) *Melosira varians* C. Agardh, (16, 19-20) *Aulacoseira ambigua* (Grunow) Simonsen, (22-23) *Aulacoseira* cf. *alpigena* (Grunow) Krammer, (21, 24-26) *Aulacoseira granulata* (Ehrenberg) Simonsen

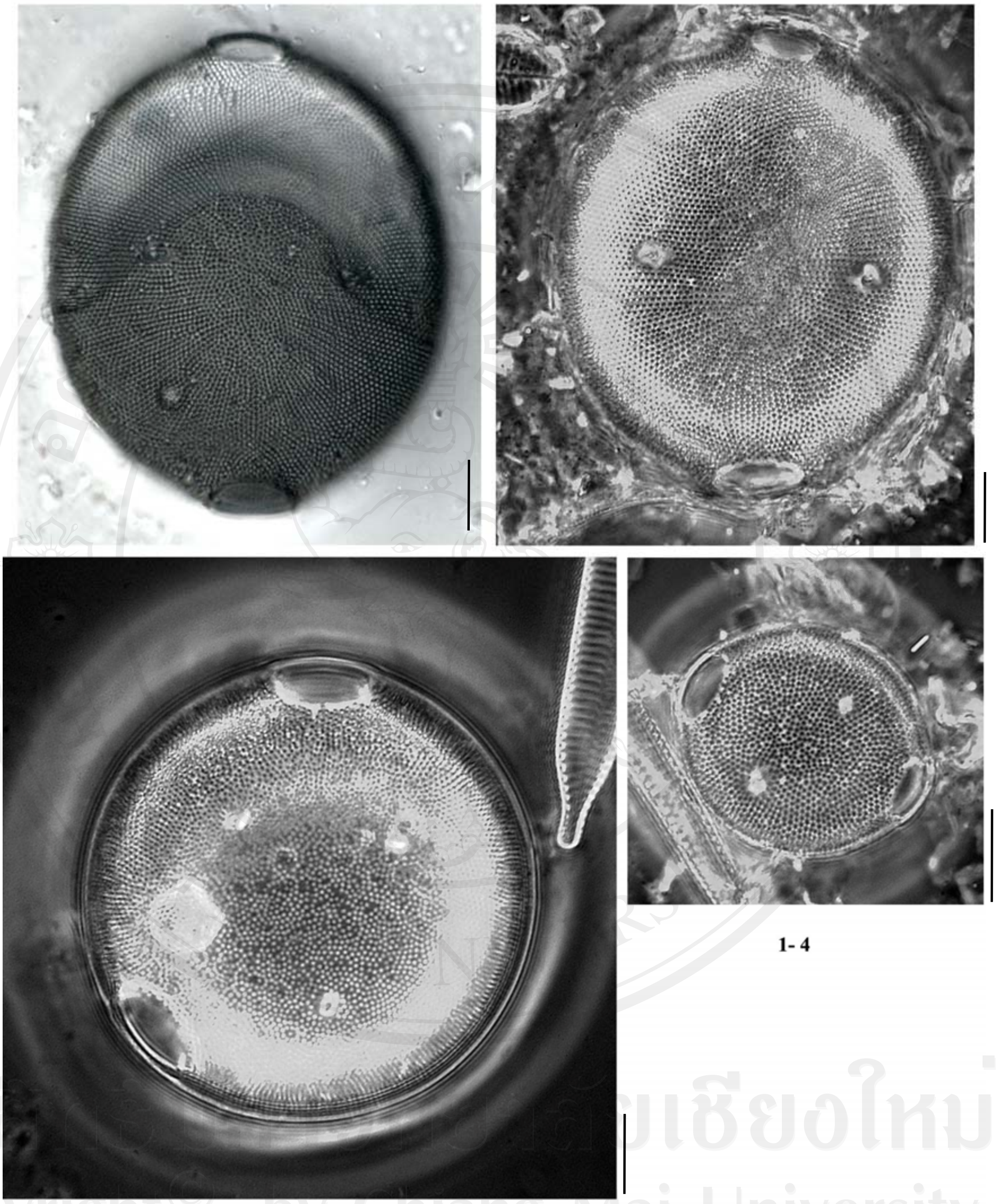
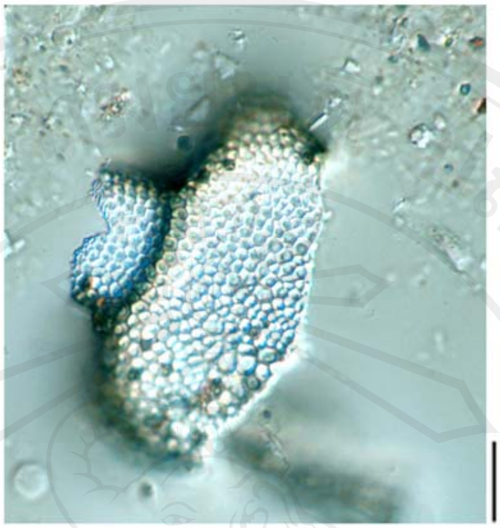


Figure 9 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Pleurosira laevis* (Ehrenberg) Compère



1

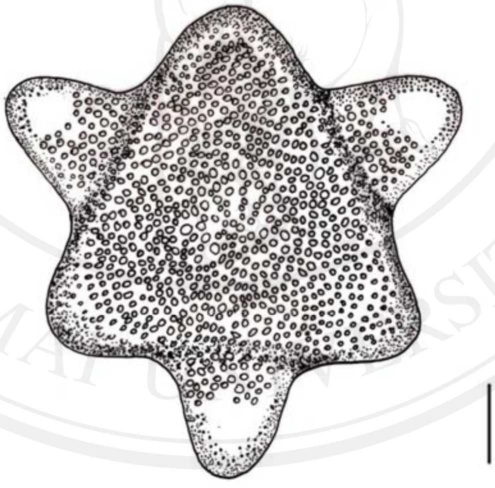


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Figure 10 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Hydrosera whampoensis* (A.F. Schwarz) Deby

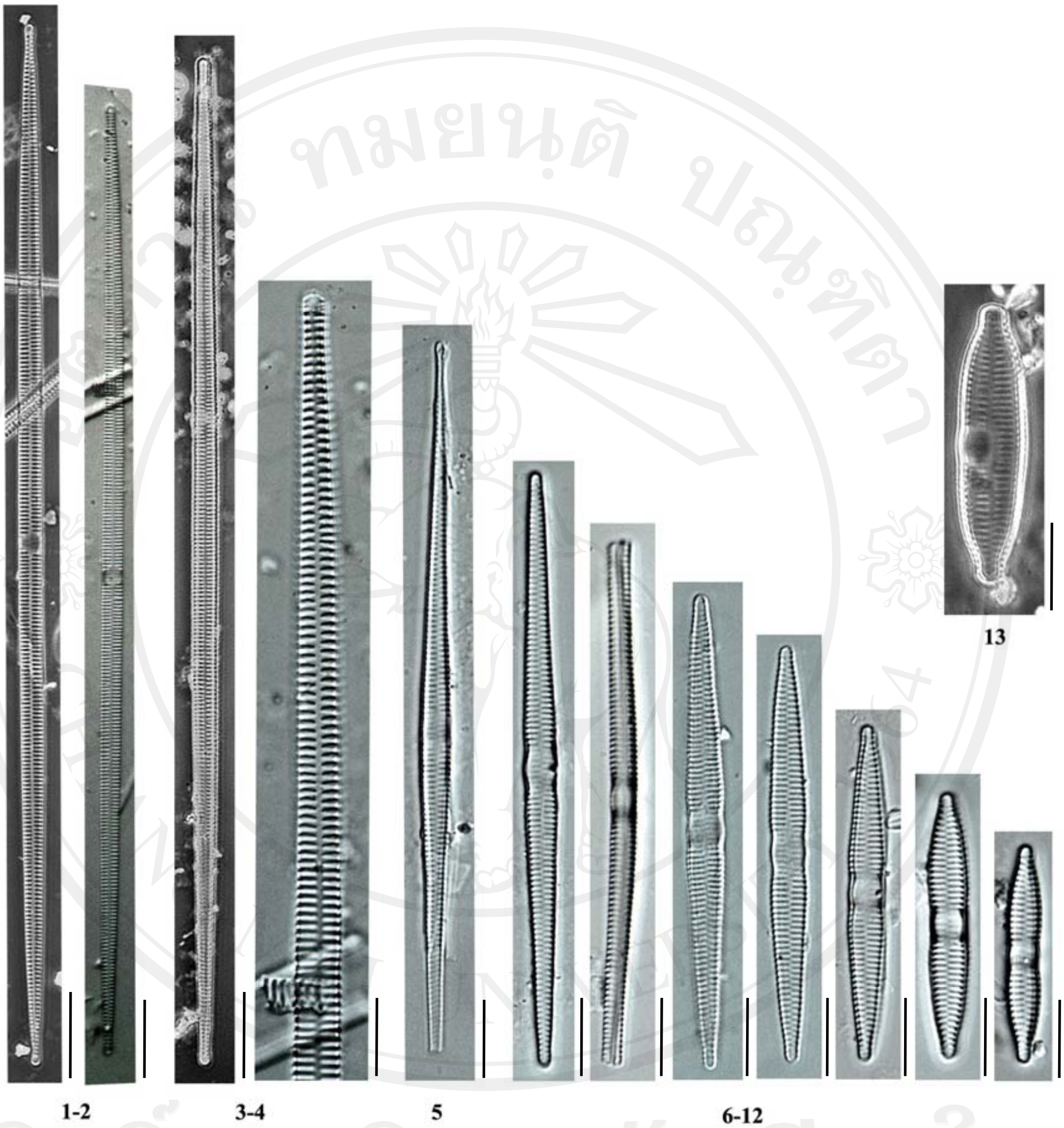


Figure 11 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Synedra ulna* var. *amphirhynchus* (Ehrenberg) Grunow, (3-4) *Fragilaria tenera* (W. Smith) Lange-Bertalot, (5) *Synedra* cf. *amphicephala* var. *austriaca* (Grunow) Hustedt, (6-12) *Fragilaria bidens* Heiberg , (13) *Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot

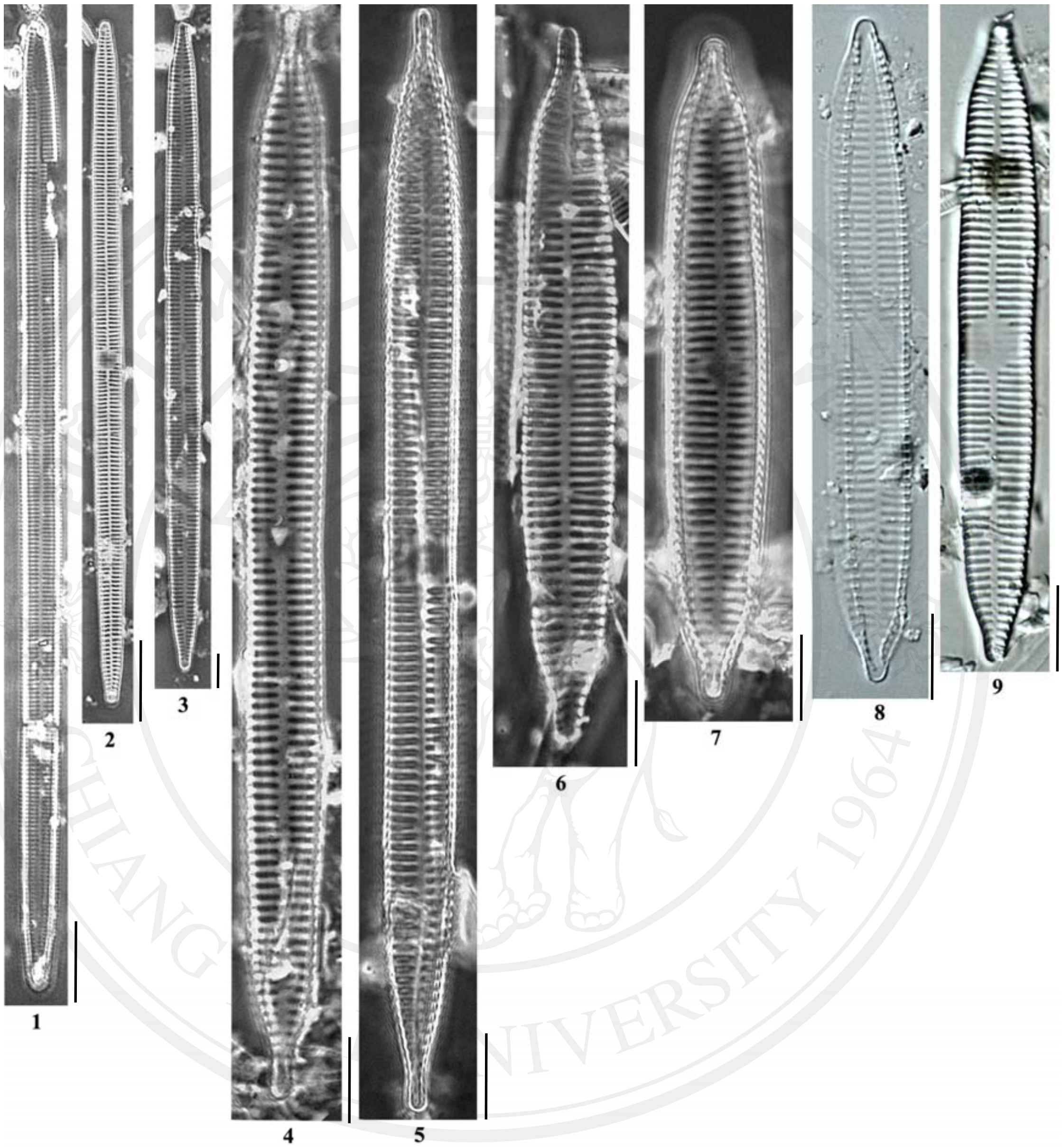


Figure 12 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Synedra ulna* var. *subaequalis* Grunow, (2) *Synedra ulna* var. *spathulifera* Grunow, (3-5) *Ulnaria ulna* (Nitzsch) P. Compère, (6-9) *Synedra lanceolata* Kützing

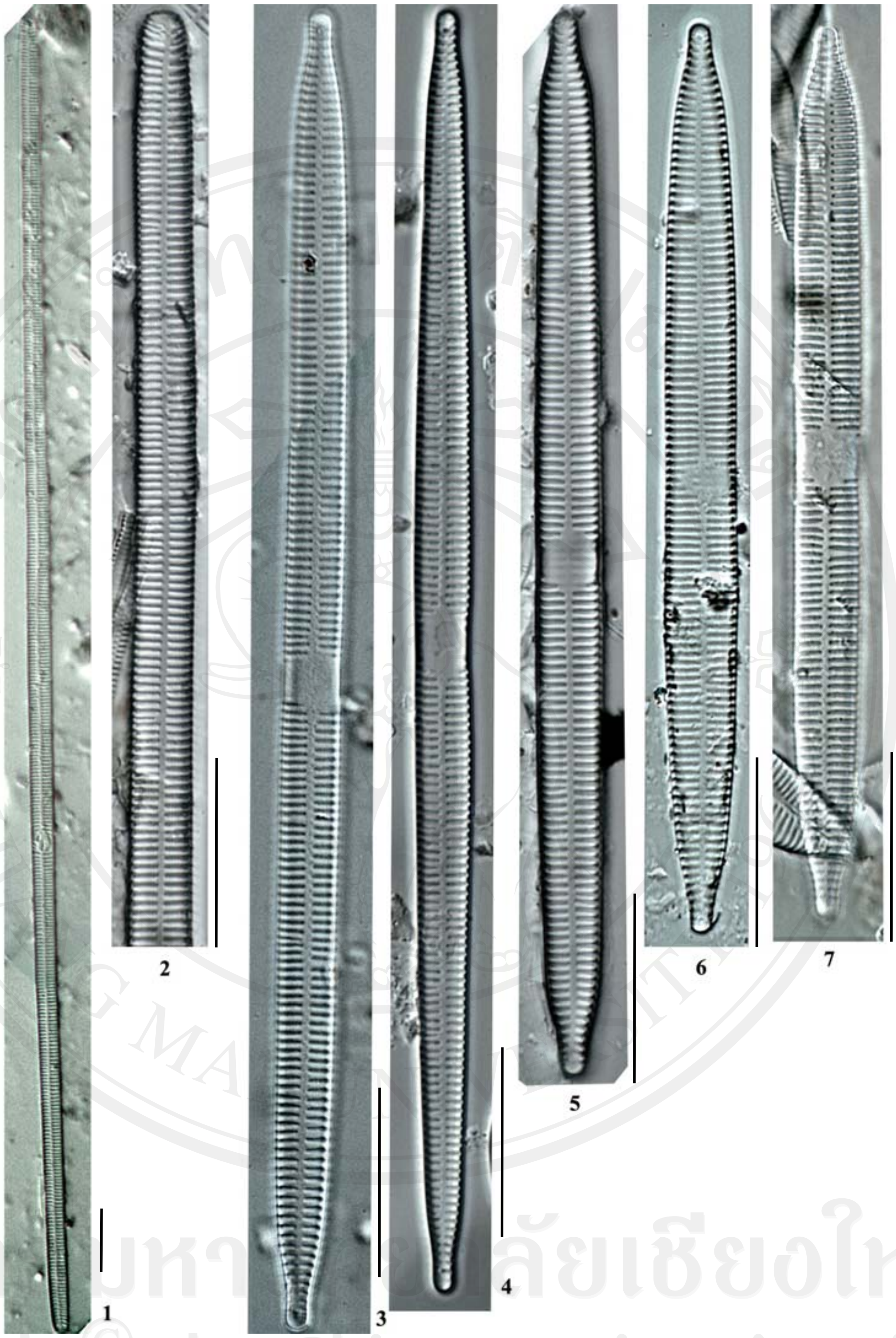


Figure 13 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Synedra ulna* var. *aequalis* (Kützing) Hustedt, (3-7) *Ulnaria ulna* (Nitzsch) P. Compère

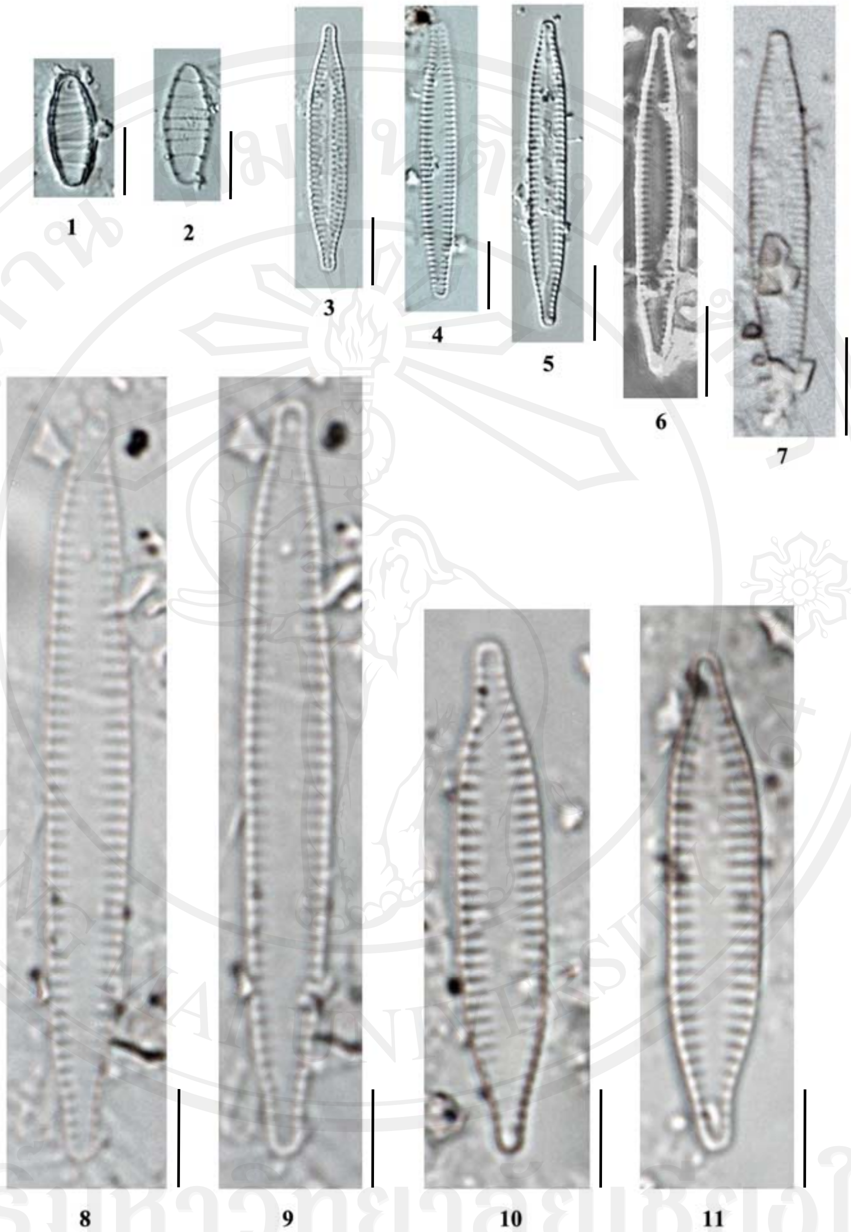


Figure 14 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Diatoma mesodon* (Ehrenberg)Kuetzing, (3-11) *Tabularia fasciculata* (C. Agardh) D.M. Williams & Round

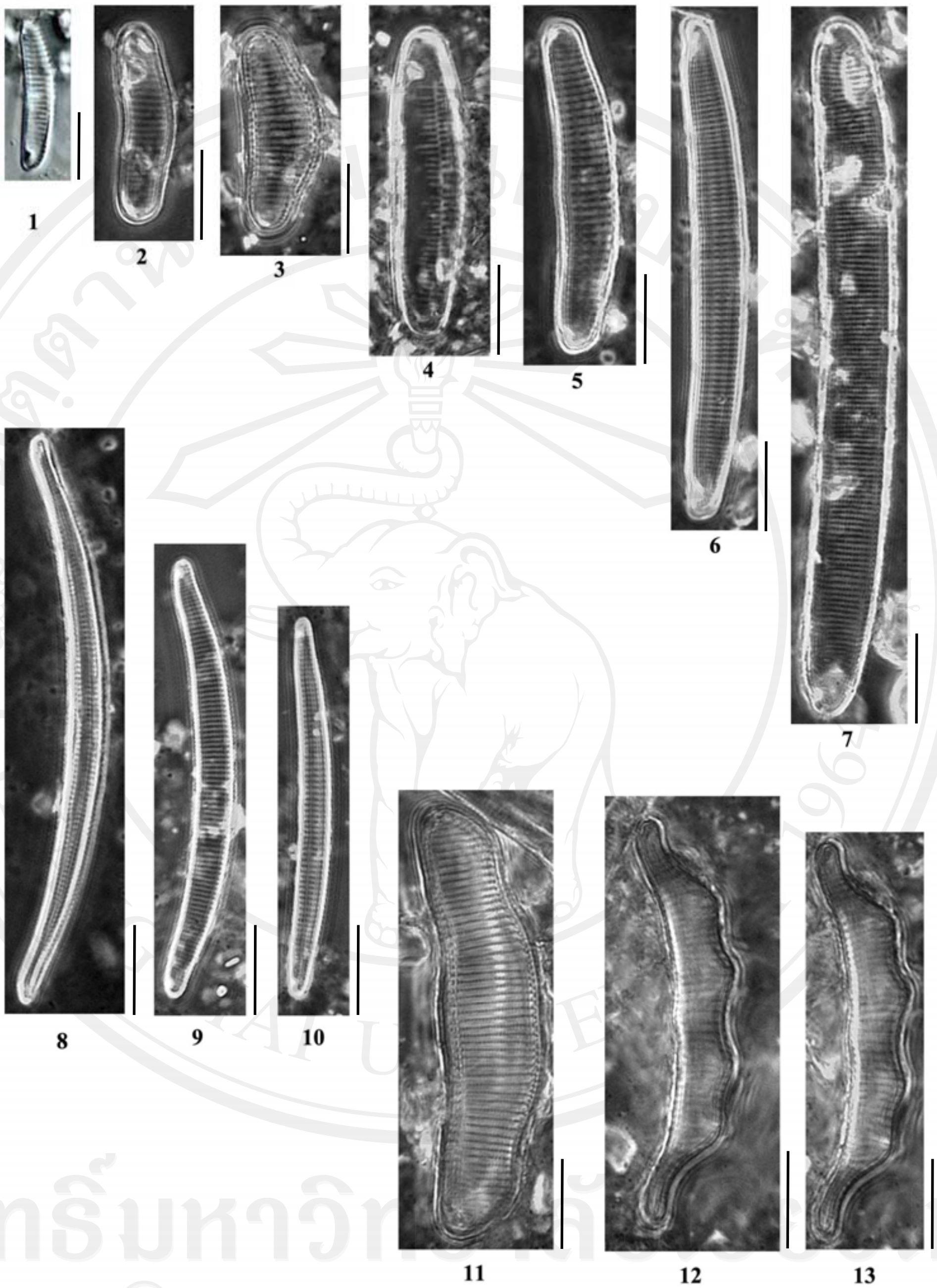


Figure 15 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-6) *Eunotia* sp.1-6, (7) *Eunotia* cf. *curtiraphe* Metzeltin & Lange-Bertalot,
(8-10) *Eunotia* cf. *mucophila* (Lange-Bertalot & Norpel) Lange-Bertalot,
(11) *Eunotia indica* Gronow , (12-13) *Eunotia camelus* var. *arcuata* J. Frenguelli

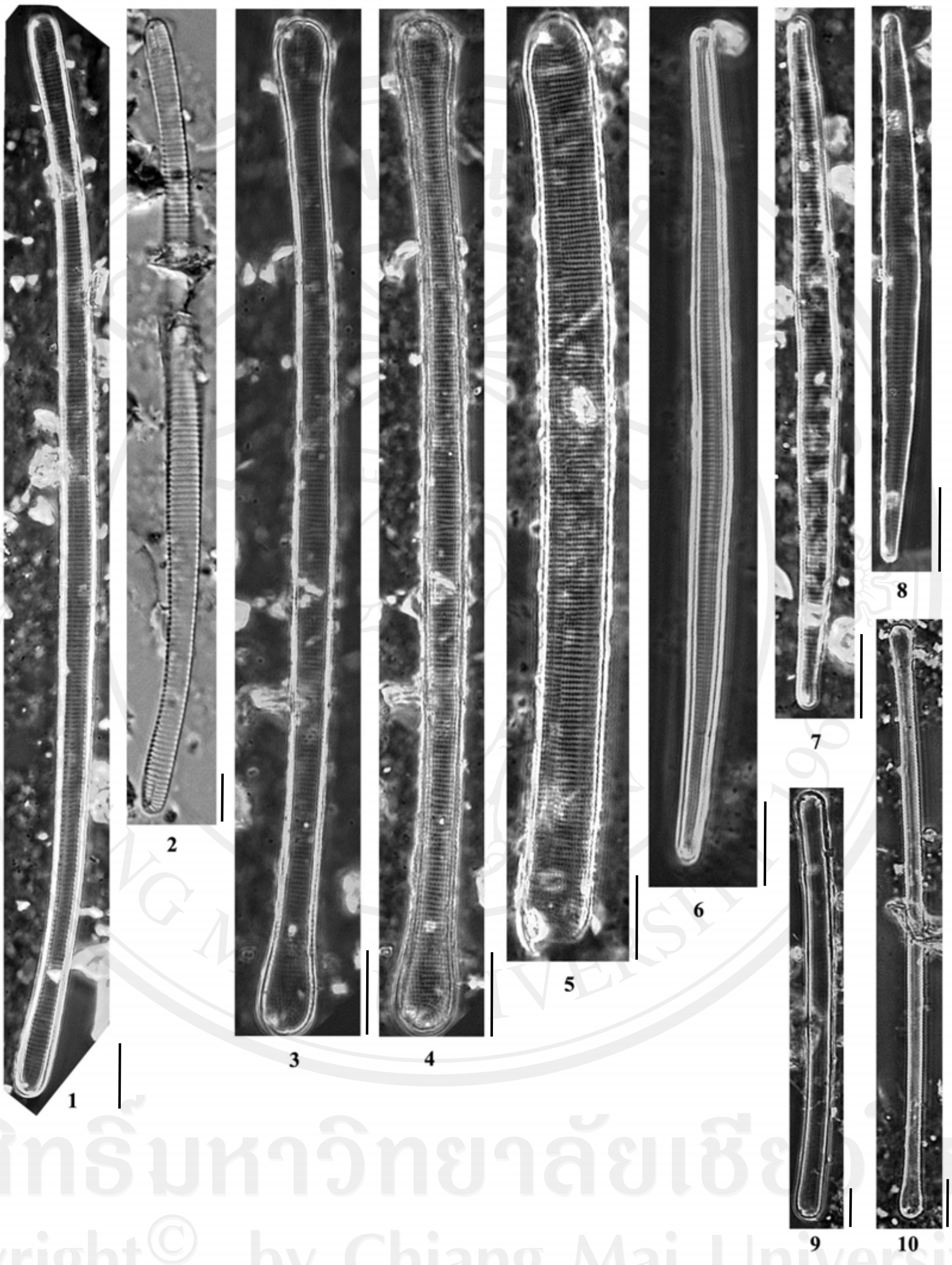


Figure 16 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Eunotia repens* A. Berg, (3-4, 10) *Ulnaria ulna* (Nitzsch) P. Compère, (5,9) *Eunotia* sp.7, (6-8) *Eunotia* sp.8

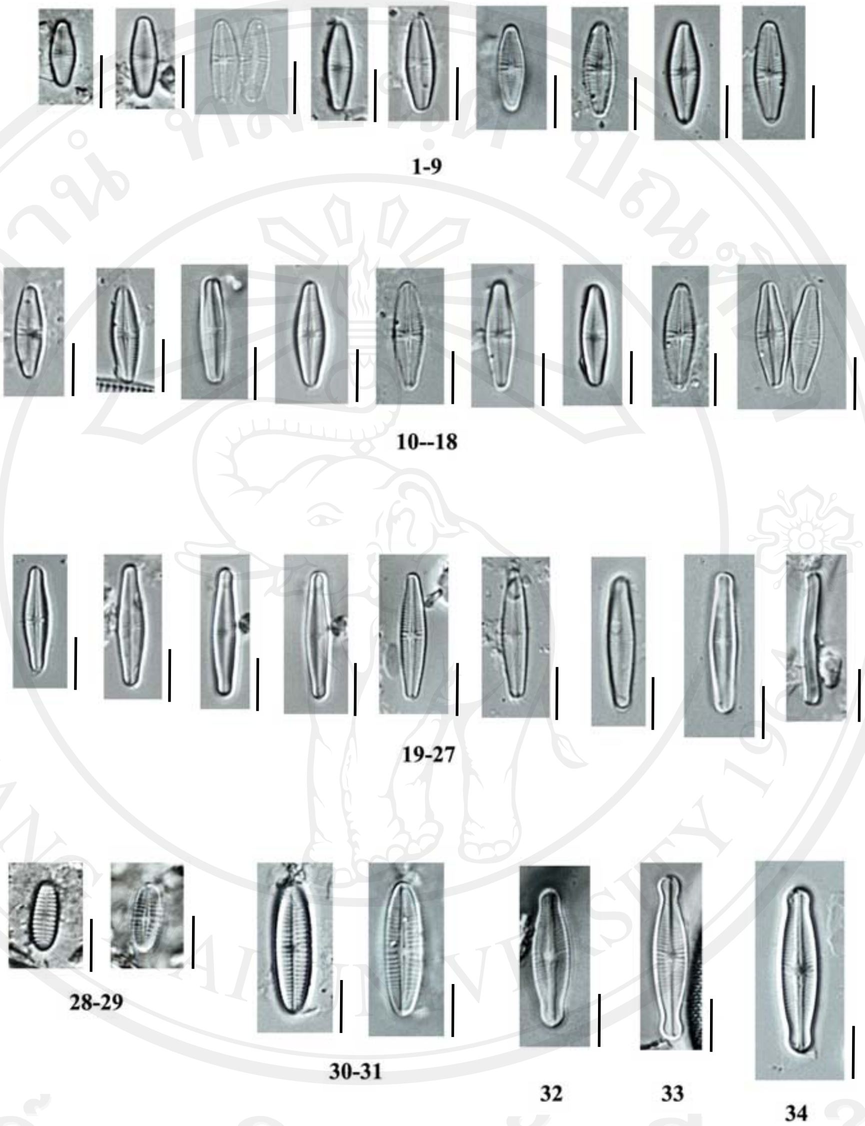


Figure 17 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-18) *Achnanthidium minutissimum* (Kützing) Czarnecki, (19-27) *Achnanthidium catenatum* (Bily & Marvan) Lange-Bertalot, (28-29) *Achnanthidium* sp.1, (30-31) *Achnanthidium* cf. *japonicum* (H. Kobayasi) H. Kobayasi, (32-34) *Achnanthidium convergens* (H. Kobayasi) H. Kobayasi

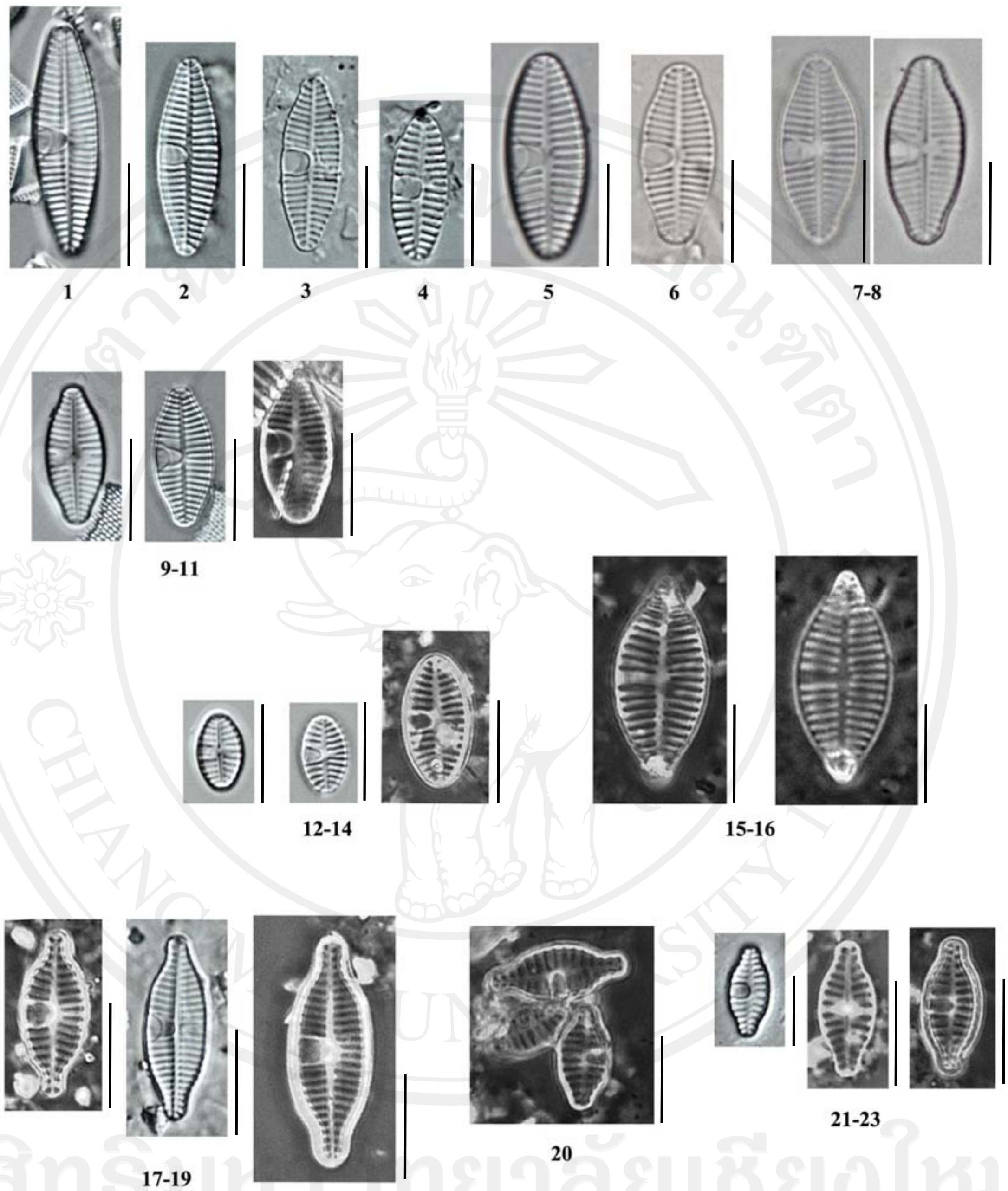


Figure 18 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-11) *Planothidium frequentissimum* (Lange-Bertalot) Round & L. Bukhtiyarova, (12-14) *Planothidium* sp.1, (15-16) *Planothidium delicatulum* (Kützing) Round & L. Bukhtiyarova, (17-23) *Planothidium rostratum* (Østrup) Lange-Bertalot

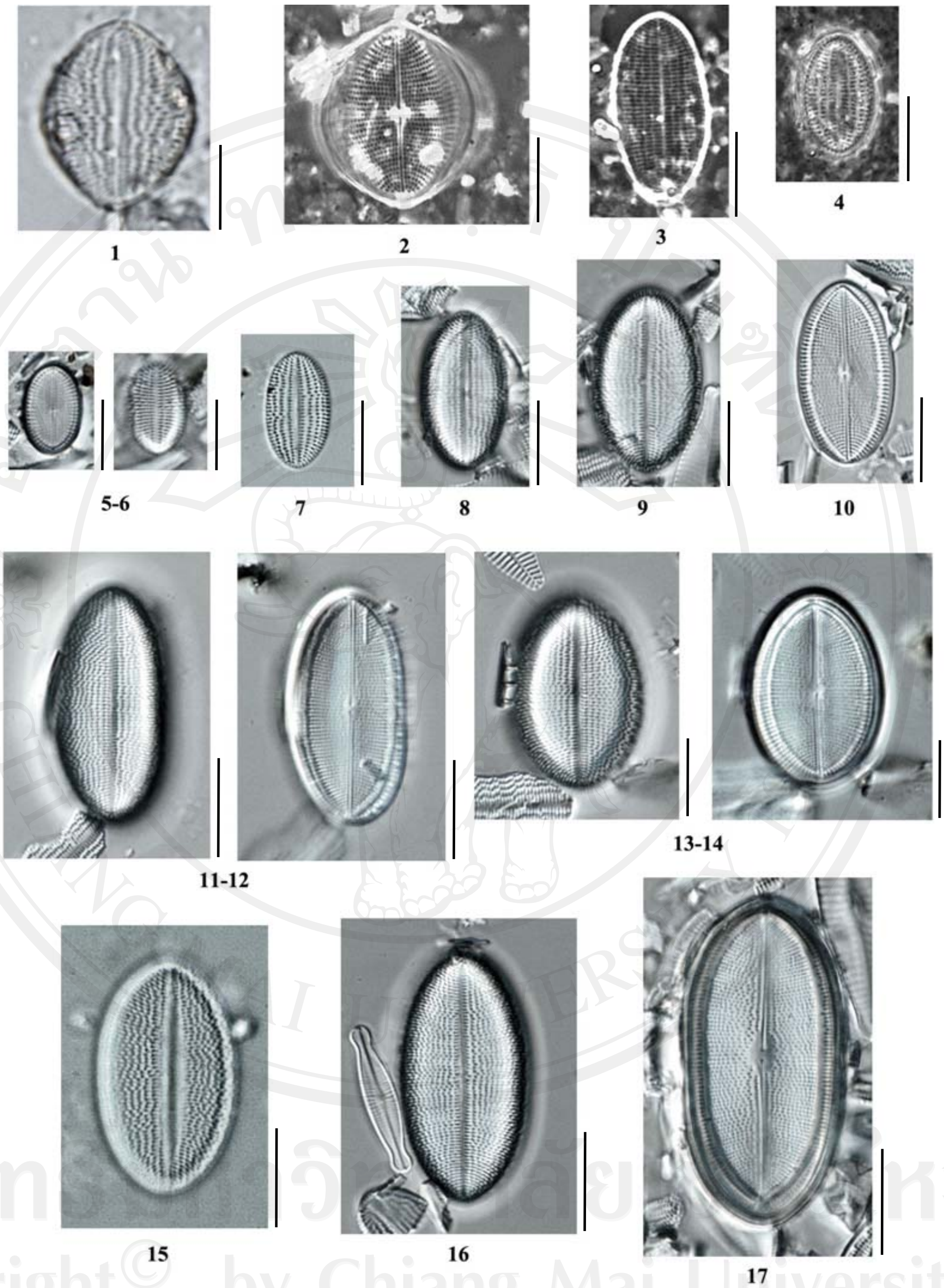


Figure 19 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Cocconeis pediculus* Kützing, (3-6) *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow, (7-14,16-17) *Cocconeis placentula* var. *lineata* (Ehrenberg) van Heurck, (15) *Cocconeis placentula* var. *pseudolineata* Geitler

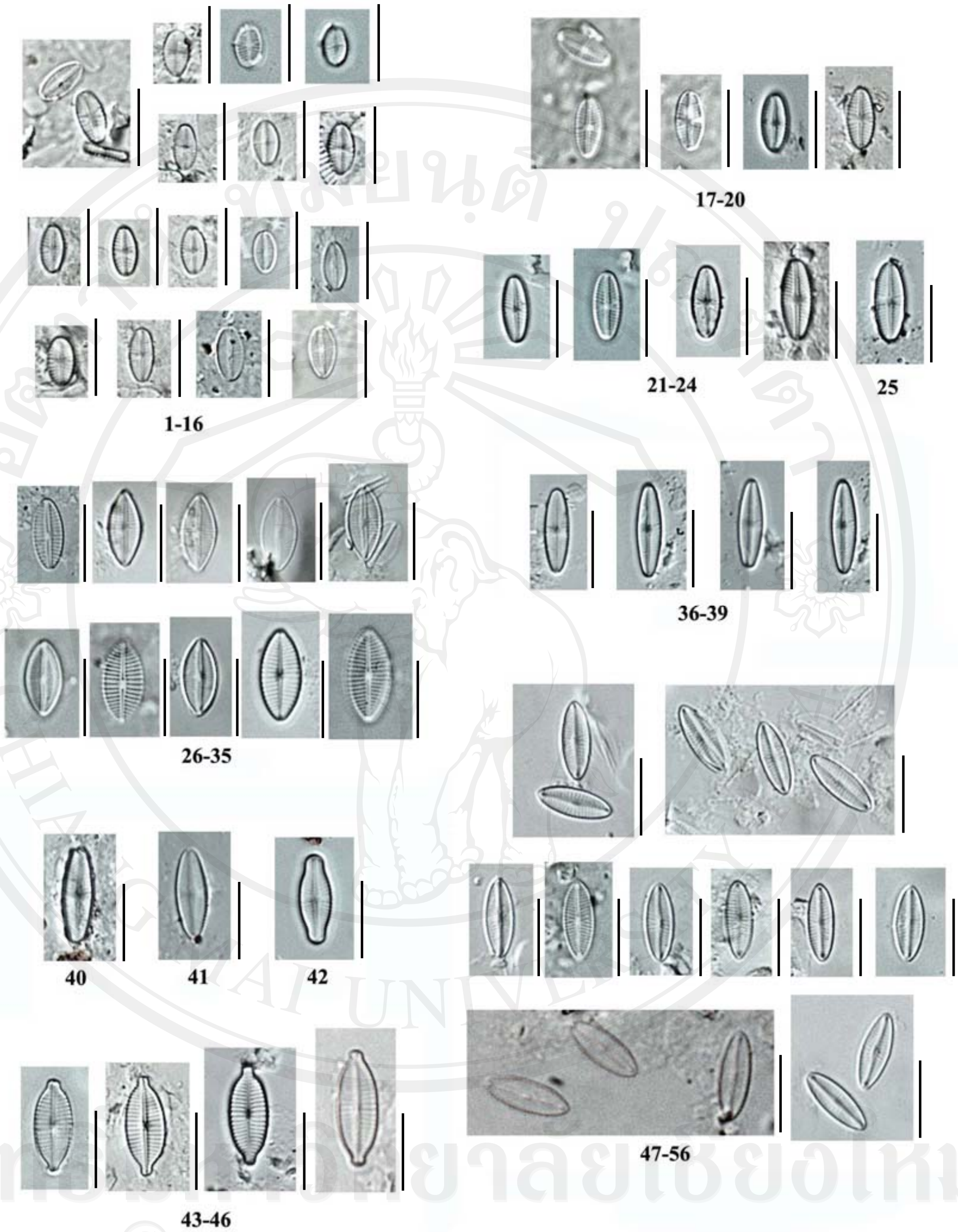


Figure 20 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-16) *Eolimna minima* (Grunow) Lange-Bertalot, (17-25) *Eolimna tantula* (Hustedt) Lange-Bertalot, (26-35) *Eolimna subminuscula* (Manguin) Gerd Moser, (36-40) *Eolimna* sp.1, (41) *Eolimna* sp.2, (42) *Eolimna* sp.3, (43-46) *Naviculadicta nanogomphonema* Lange-Bertalot & U.Rumrich, (47-56) *Mayamaea atomus* (Kützing) H. Lange-Bertalot

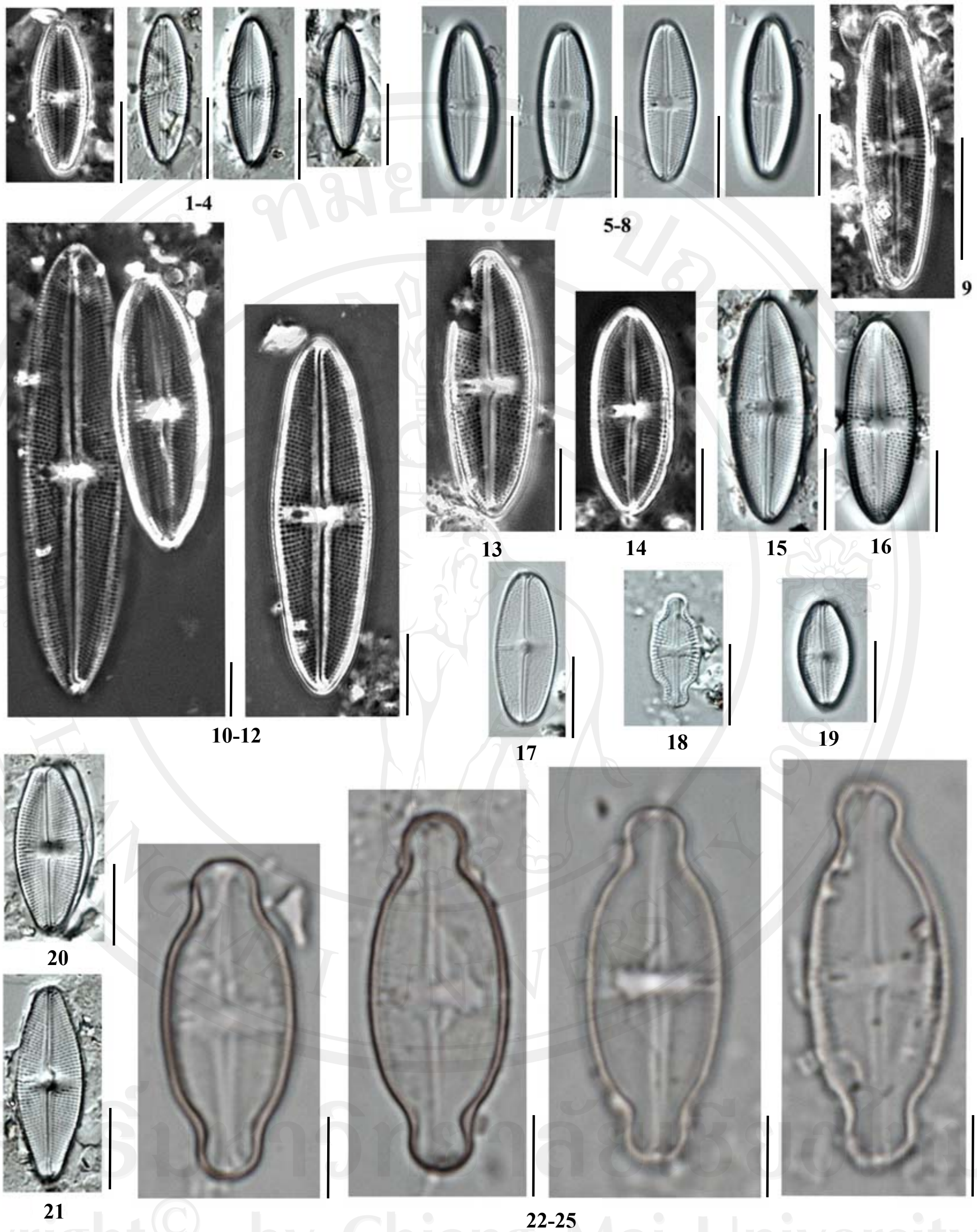


Figure 21 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Luticola goeppertiana* (Bleisch) D.G. Mann in Round, Crawford & Mann, (5-9) *Luticola* cf. *falknerorum* Metzeltin & Lange-Bertalot, (10,12) *Luticola peguana* (Grunow) D.G. Mann, (11,13-14) *Luticola* cf. *permuticoides* Metzeltin & Lange-Bertalot, (15-16) *Luticola saxophila* (Bock ex Hustedt) D.G. Mann,(17) *Luticola* sp.2, (18) *Luticola nivalis* (Ehrenberg) D.G. Mann in Round, Crawford & Mann, (19) *Luticola* sp.1, (20) *Luticola* sp.3, (21) *Luticola* sp.4, (22-25) *Luticola* sp.5

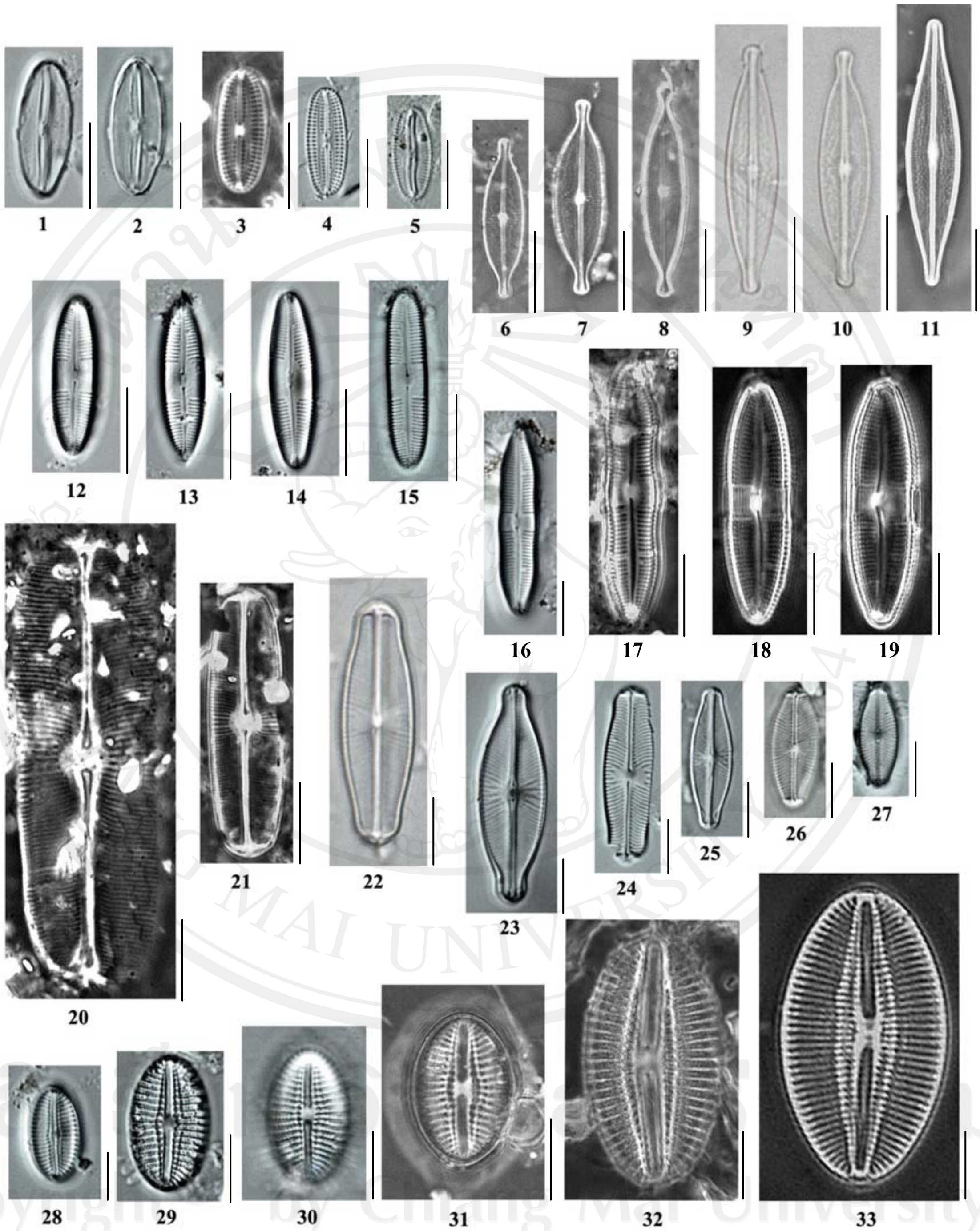


Figure 22 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Fallacia* cf. *pygmaea* (Kützing) A.J. Stickle & D.G. Mann, (3-4) *Fallacia meridionalis* Metzeltin, Lange-Bertalot and Garcia-Rodriguez, (5) *Fallacia insociabilis* (Krasske) D.G. Mann, (6-10) *Brachysira neoexilis* Lange-Bertalot, (11) *Brachysira* sp.1, (12-14,18-19) *Caloneis bacillum* (Grunow) Cleve, (15) *Caloneis* sp.1, (16-17) *Caloneis silicula* (Ehrenberg) Cleve, (20) *Sellaphora* sp.2, (21) *Sellaphora bacillum* (Ehrenberg) D.G. Mann, (22,24,26-27) *Sellaphora pupula* (Kützing) Mereschkovsky, (23-25) *Sellaphora* sp.1, (28,30) *Diploneis pseudovalis* Hustedt, (29,31-32) *Diploneis subovalis* Cleve, (33) *Diploneis elliptica* (Kützing) Cleve

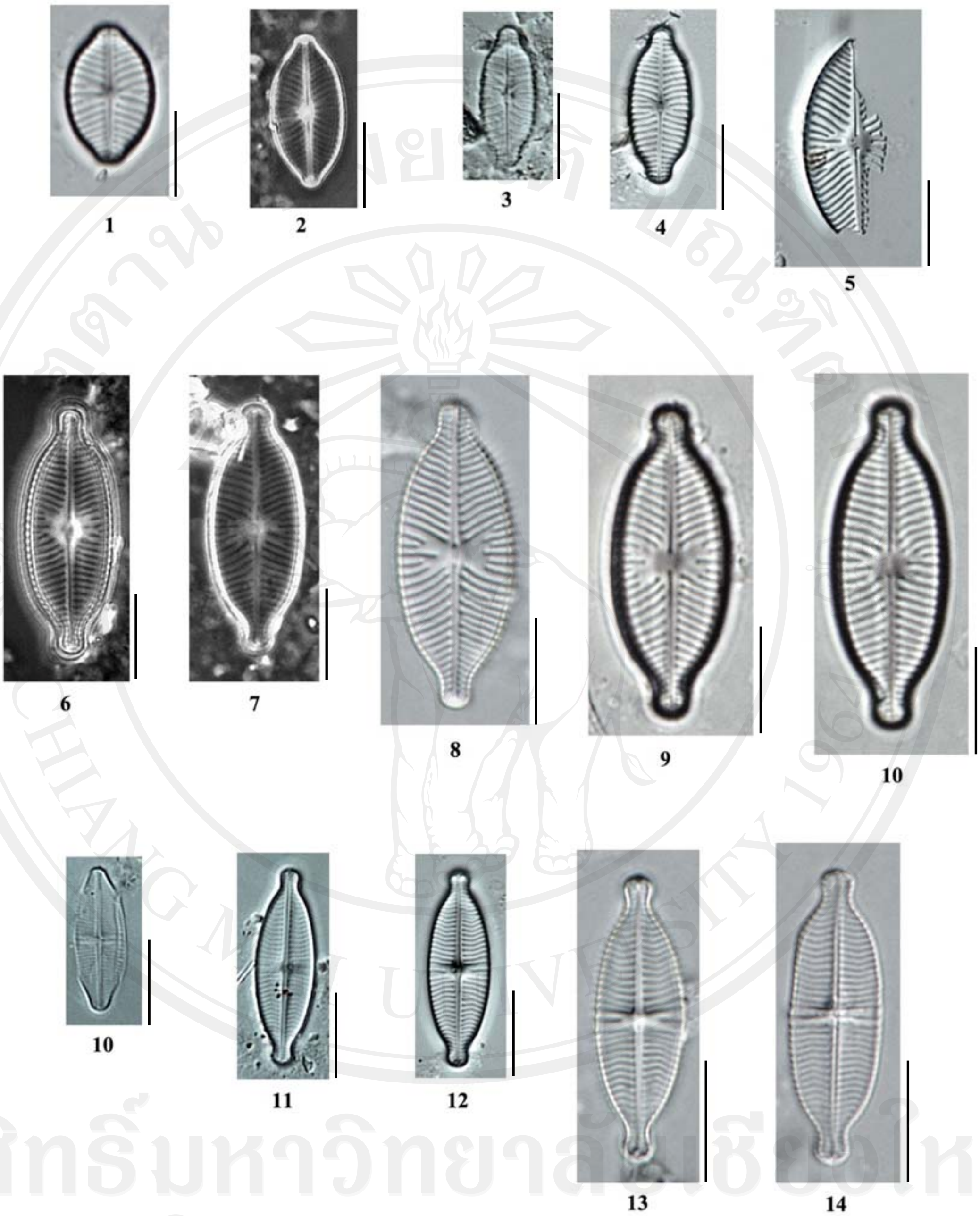


Figure 23 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Placoneis gracilis* Metzeltin, Lange-Bertalot & Garcia-Rodriguez, (3) *Placoneis* sp.1, (4) *Placoneis undulata* (Østrup) Lange-Bertalot, (5) *Placoneis abundans* Metzeltin, Lange-Bertalot & García-Rodríguez, (6-9) *Placoneis symmetrica* (Hustedt) Lange-Bertalot, (10) *Geissleria punctifer* (Hustedt) Metzeltin, Lange-Bertalot & Garcia-Rodriguez, (11-14) *Geissleria decussis* (Østrup) Lange-Bertalot&Metzeltin

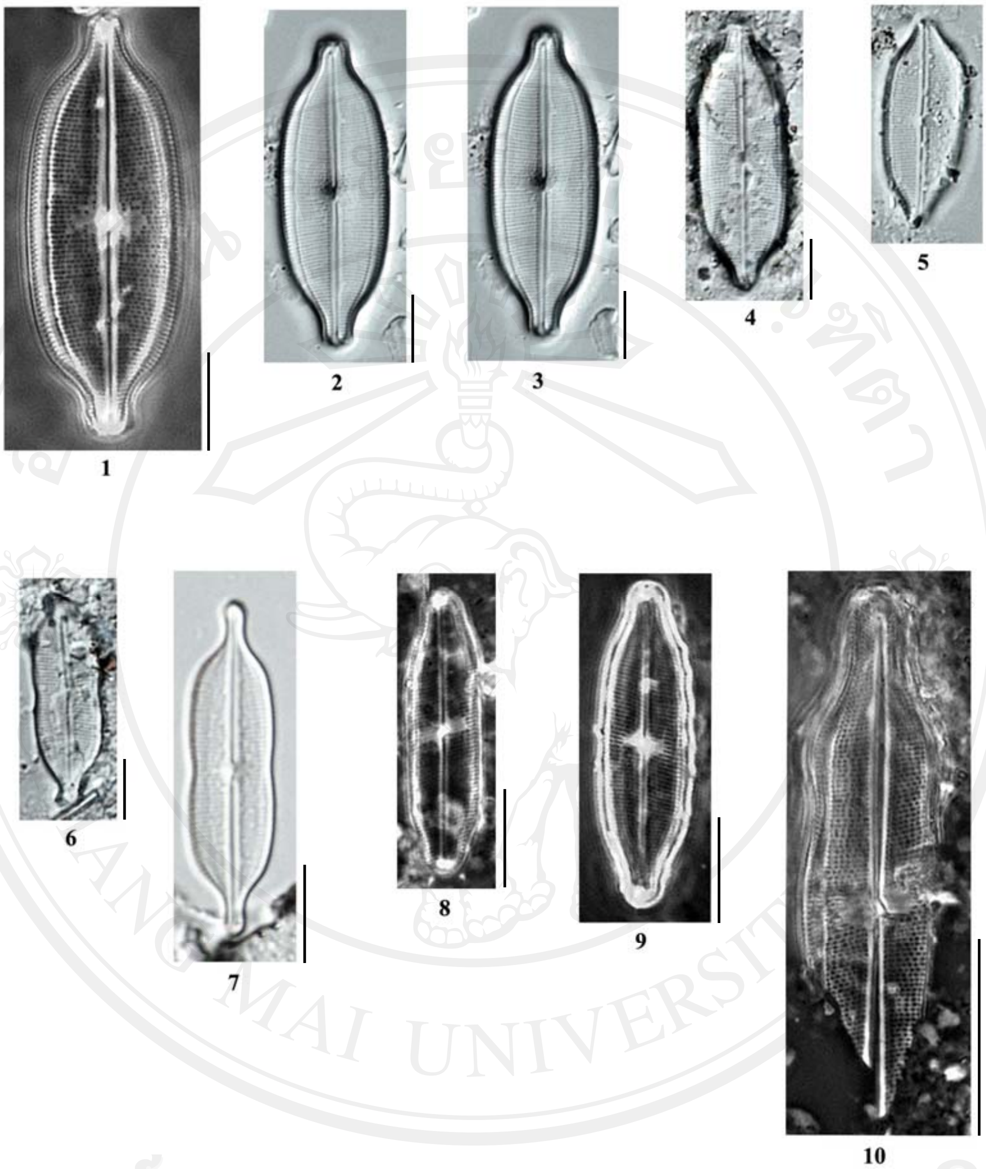


Figure 24 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-5) *Neidium dubium* (Ehrenberg) Cleve, (6-7) *Neidium binodis* (Ehrenberg) Hustedt, (8) *Neidium* cf. *kozlowii* Mereschkovsky, (9) *Neidium affine* (Ehrenberg) Pfizer, (10) *Neidium floridanum* Reimer

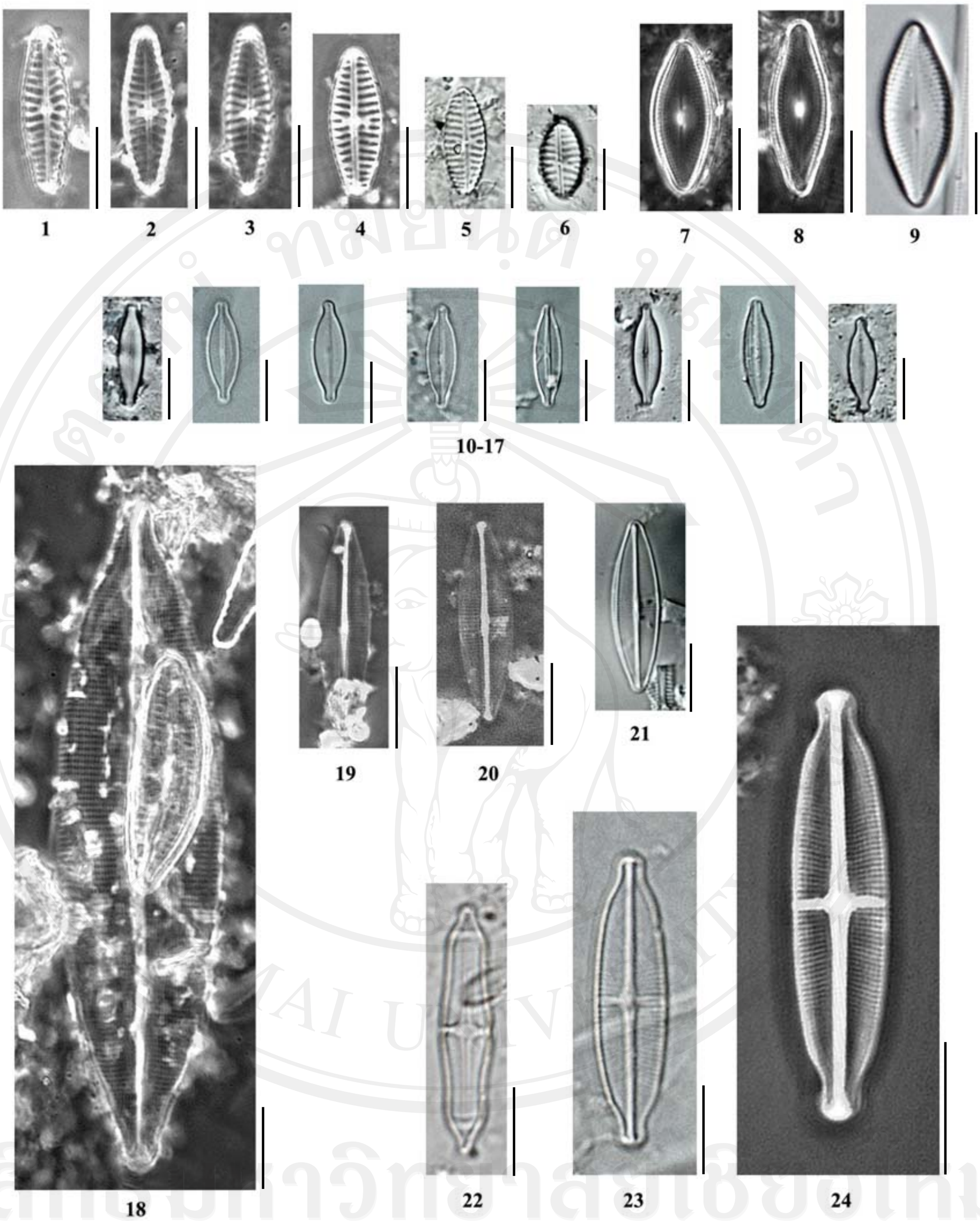


Figure 25 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-3) *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski, (4-6) *Hippodonta hungarica* (Grunow) Lange-Bert, Metzeltin &Witkowski, (7-9) *Diadesmis confervacea* Kützing, (10-17) *Nupula* sp.1, (18) *Craticula ambigua* (Ehrenberg) D.G. Mann, (19-21) *Craticula* cf. *subhalophila* (Hustedt) Lange-Bertalot, (22) *Stauroneis smithii* Grunow , (23-24) *Stauroneis anceps* Ehrenberg

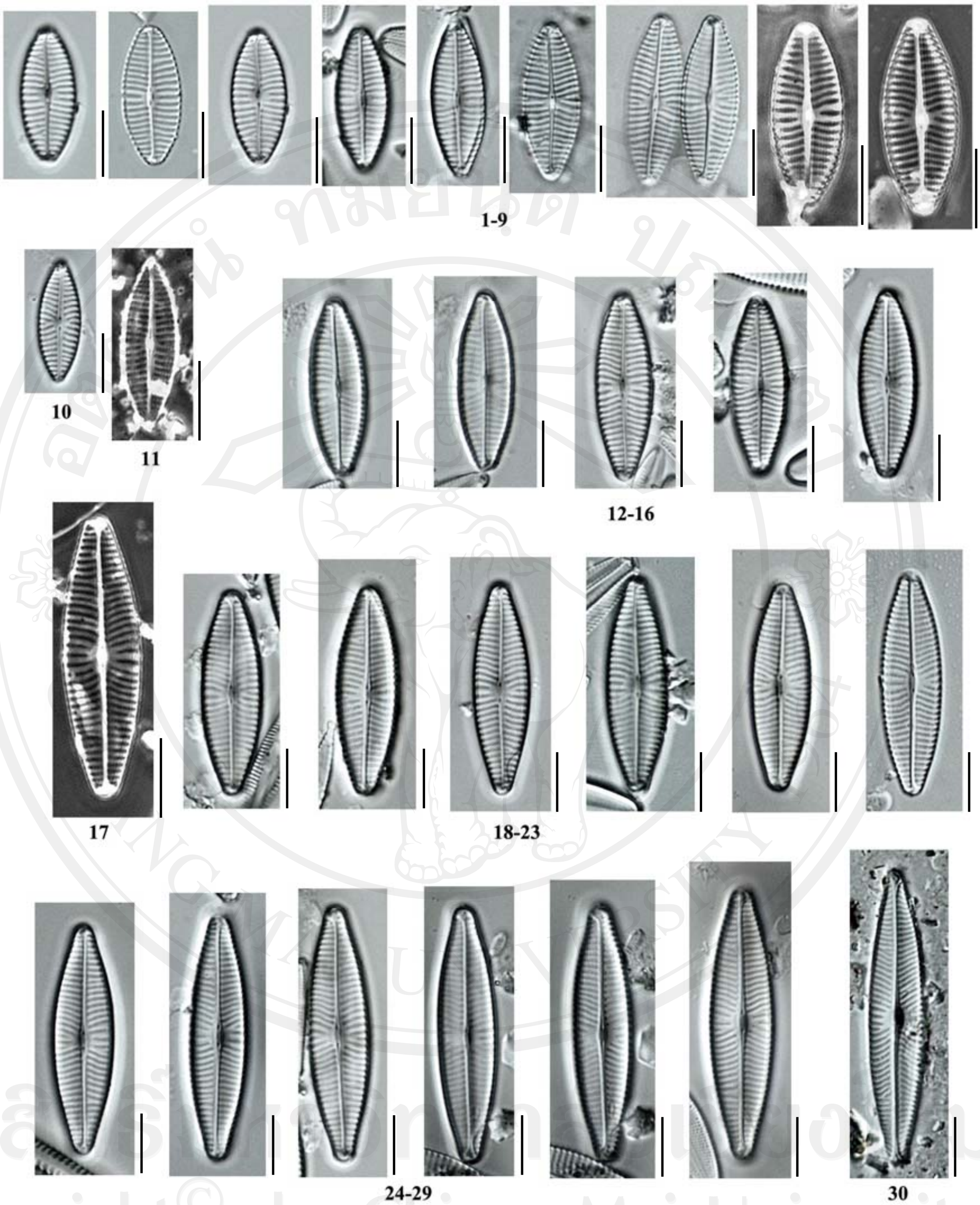


Figure 26 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-9) *Navicula* cf. *menisculus* Schumann, (10-11) *Navicula cryptotenelloides* Lange-Bertalot, (12-23) *Navicula cinctaeformis* Hustedt, (24-30) *Navicula lanceolata* (C. Agardh) Kützing

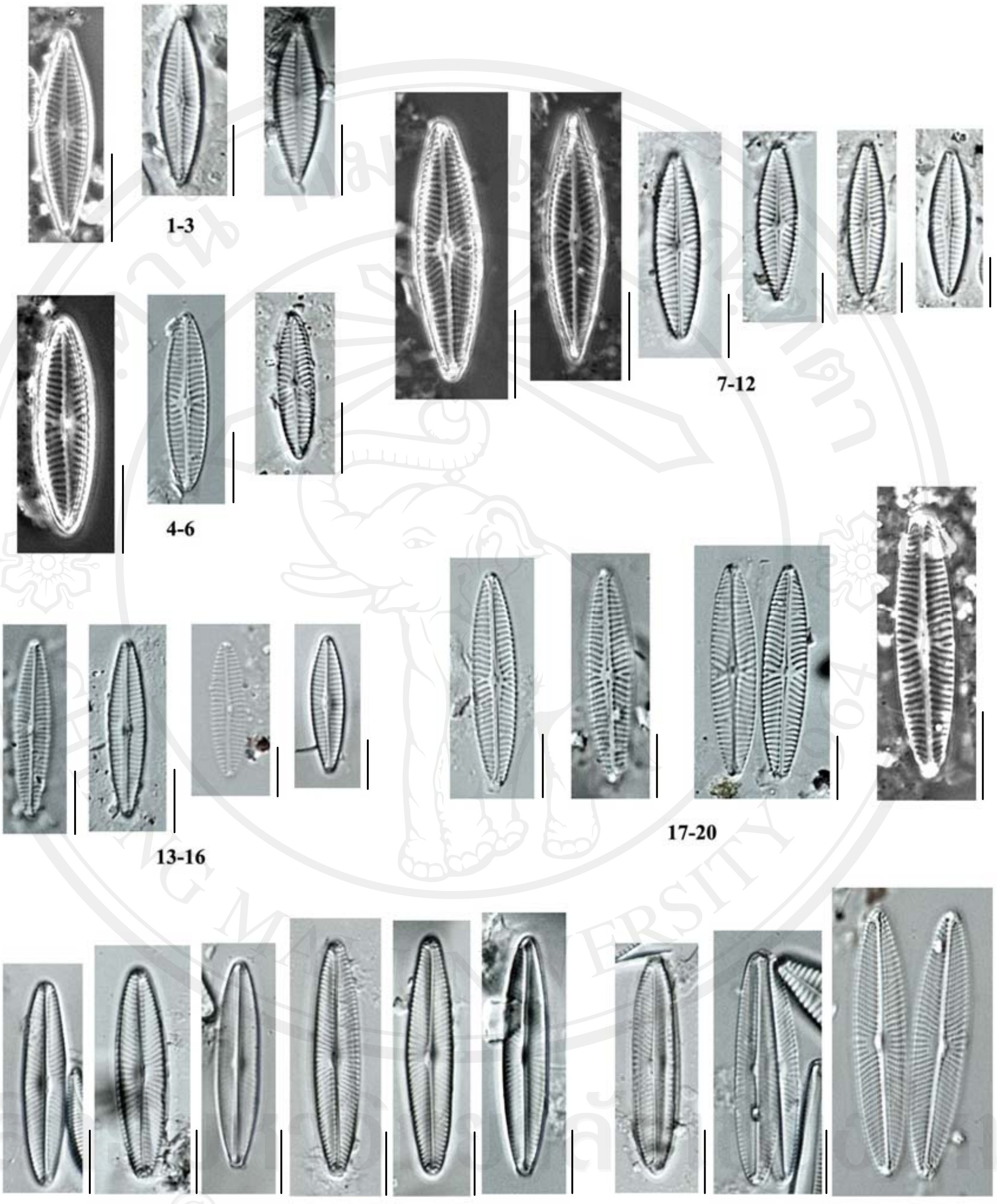


Figure 27 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-3) *Navicula phyllepta* Kützing, (4-6) *Navicula* sp.1, (7-12) *Navicula cryptotenella* Lange-Bertalot, (13-16) *Navicula* sp.1, (17-20) *Navicula microcari* Lange-Bertalot, (21-26) *Navicula symmetrica* R.M. Patrick, (27-29) *Navicula schroeteri* F. Meister

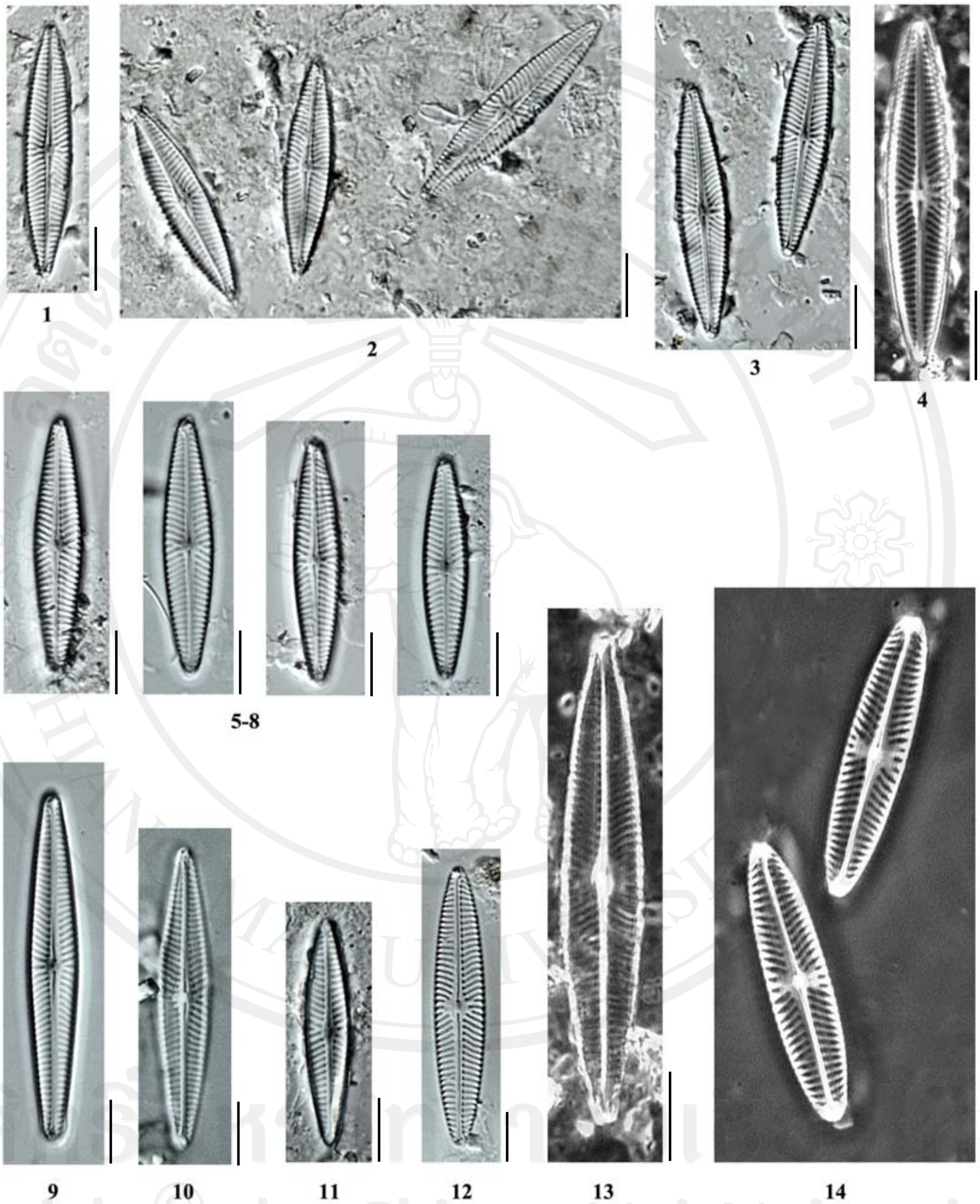


Figure 28 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Navicula* spp., (5-8) *Navicula radiosafallax* Lange-Bertalot, (9-10) *Navicula* sp.3, (11) *Navicula* sp.4, (12-13) *Navicula kuseliana* Lange-Bertalot & U.Rumrich, (14) *Navicula cari* Ehrenberg

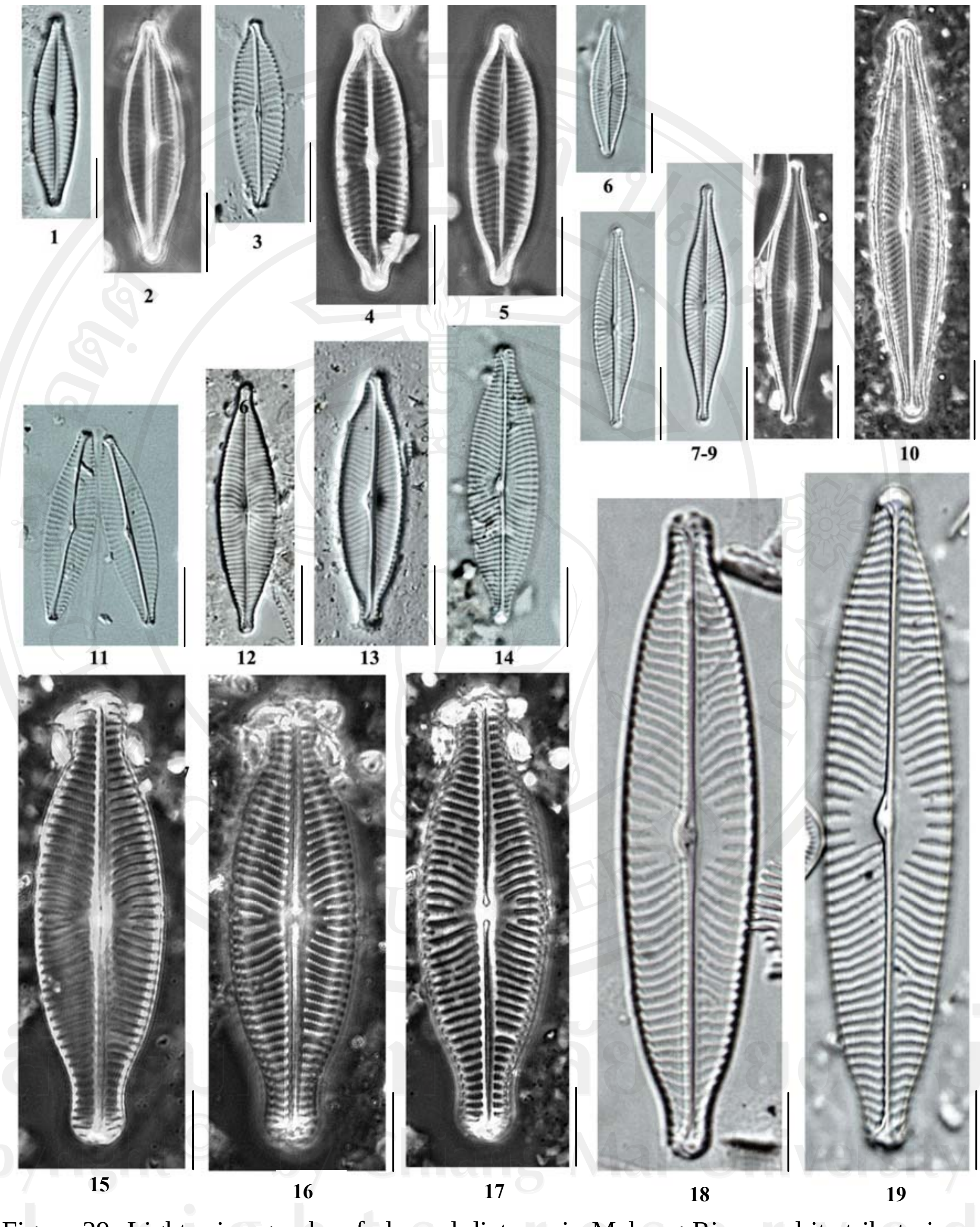


Figure 29 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2,11) *Navicula germainii* J. H. Wallace, (3-5) *Navicula novaesiberica* Lange-Bertalot, (6) *Navicula* sp.5, (7-10) *Navicula rhynchocephala* Kützing, (12) *Navicula capitatoradiata* Germain, (13-14) *Navicula rostellata* Kützing, (15-17) *Navicula* sp.6, (18-19) *Navicula viridula* (Kützing) Ehrenberg var. *viridula*

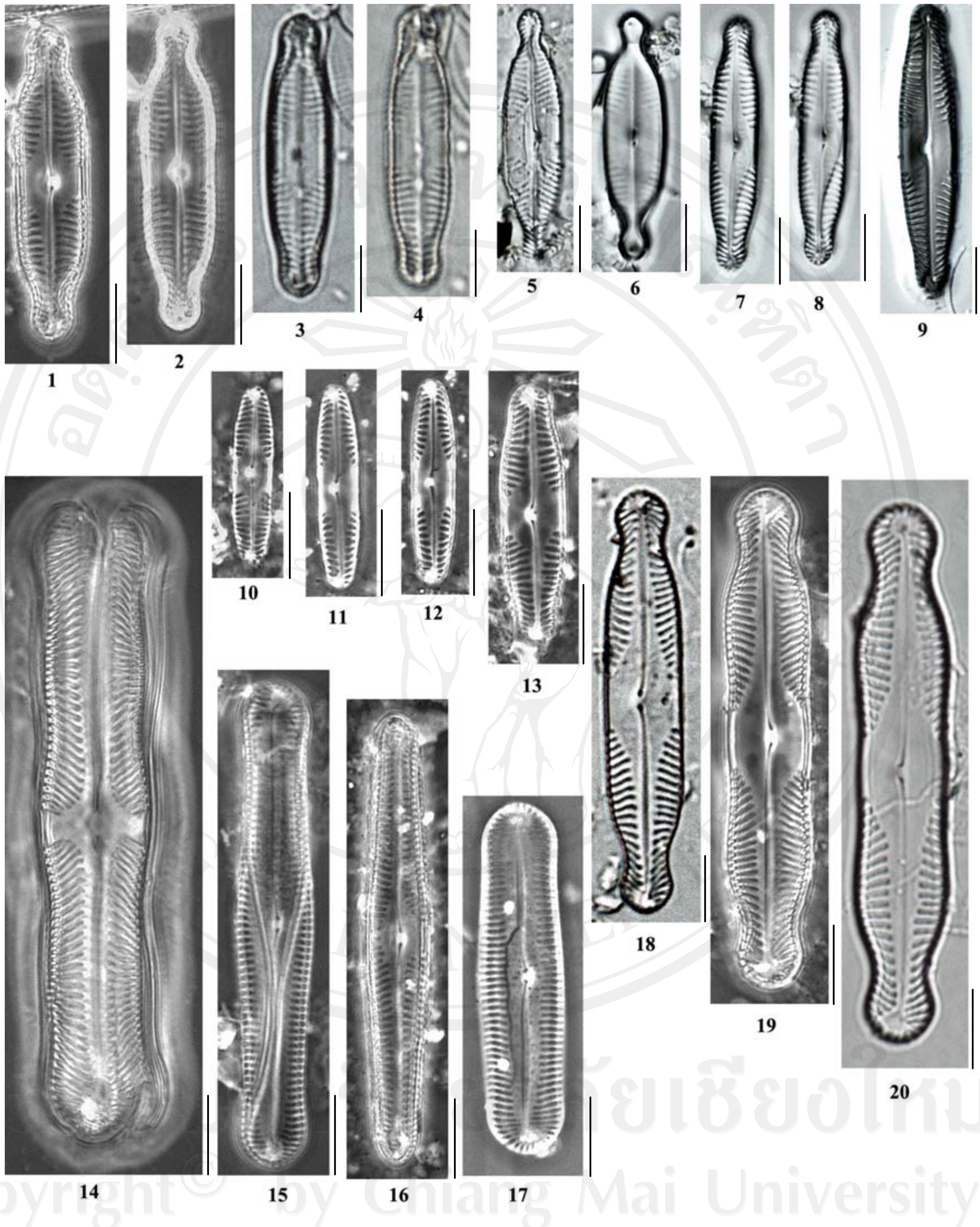


Figure 30 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Pinnularia subcapitata* W. Gregory, (5-6) *Pinnularia brauniana* (Grunow) Studnicka, (7-9) *Pinnularia microstauron* (Ehrenberg) Cleve, (10-12) *Pinnularia* sp.1, (13) *Pinnularia* sp.2, ((14) *Pinnularia graciloides* Hustedt, (15,17) *Pinnularia acrosphaeria* (Brébisson)W. Smith, (16) *Pinnularia similis* Hustedt, (18-20) *Pinnularia mesolepta* (Ehrenberg) W. Smith

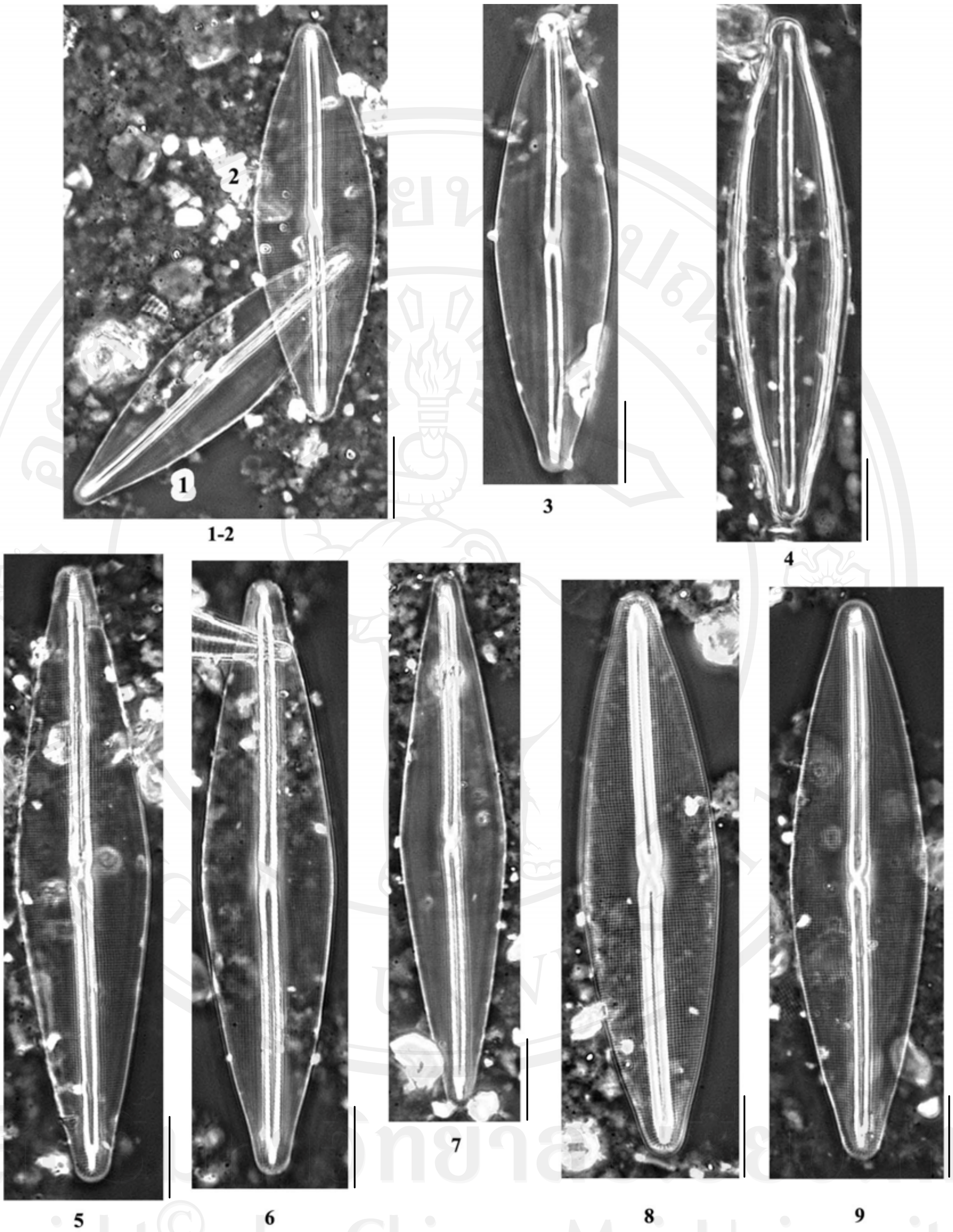


Figure 31 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1,3) *Frustulia undosa* D. Metzeltin & H. Lange-Bertalot, (2) *Frustulia saxonica* Rabenhorst, (4-6) *Frustulia rhomboides* (Ehrenberg) De Toni, (7-9) *Frustulia* sp.1

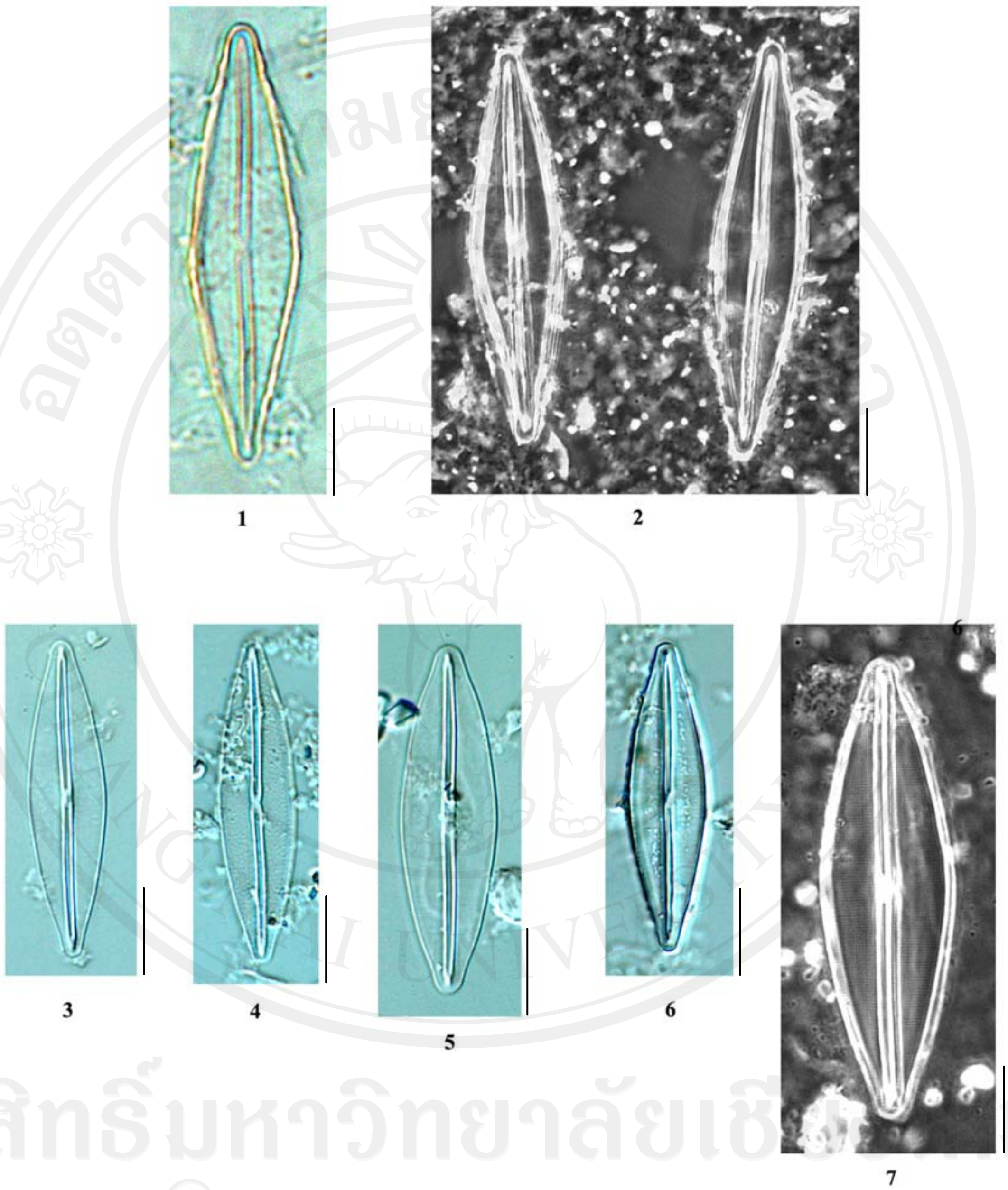


Figure 32 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Frustulia pararhomboides* var. *pararhomboides* H. Lange-Bertalot, (2,6-7) *Frustulia undosa* D. Metzeltin & H. Lange-Bertalot, (3-5) *Frustulia saxonica* Rabenhorst

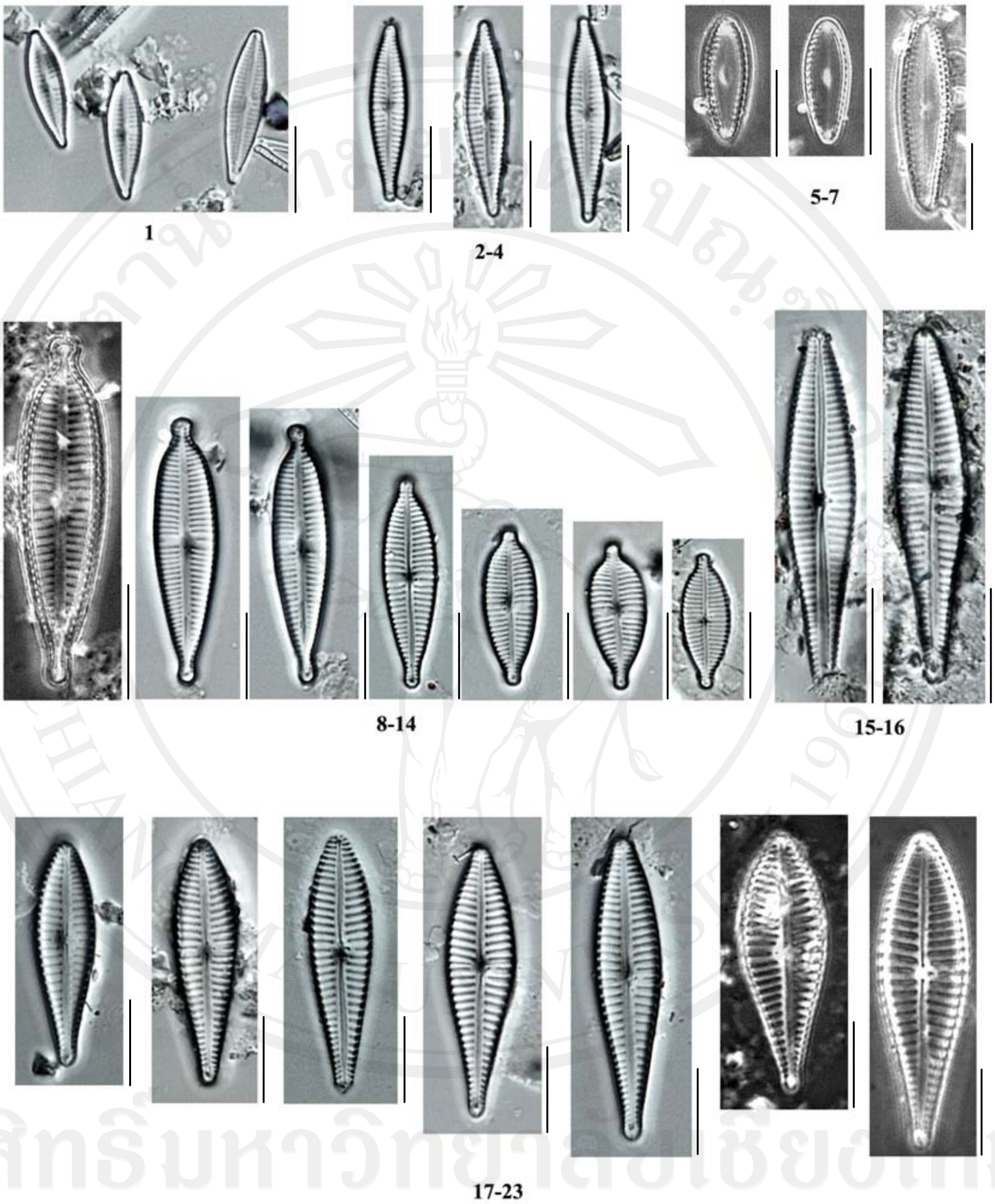


Figure 33 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Gomphonema parvulum* (Kützing) Kützing ver. *parvulum*, (2-4) *Gomphonema parvulum* var. *exilissimum* Grunow, (5-7) *Gomphonema* sp.1, (8-14) *Gomphonema lagenula* Kützing, (15-16) *Gomphonema affine* Kützing, (17-23) *Gomphonema pseudoaugur* Lange-Bertalot

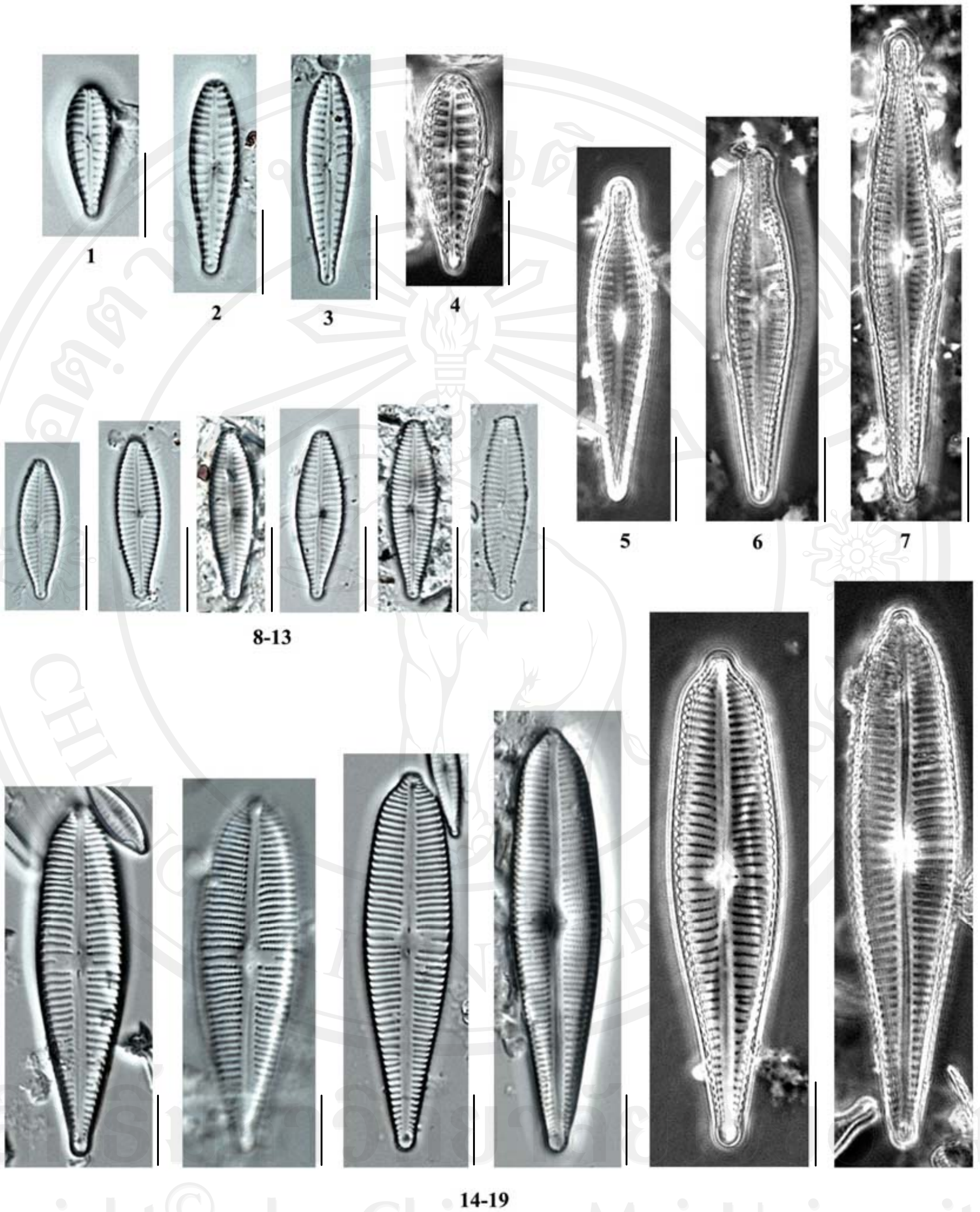


Figure 34 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Gomphonema* cf. *innocens* E. Reichardt, (5-7) *Gomphonema* cf. *subtile* Ehrenberg, (8-13) *Gomphonema minutiforme* Lange-Bertalot & Reichardt, (14-19) *Gomphonema contraturris* Lange-Bertalot & Reichardt

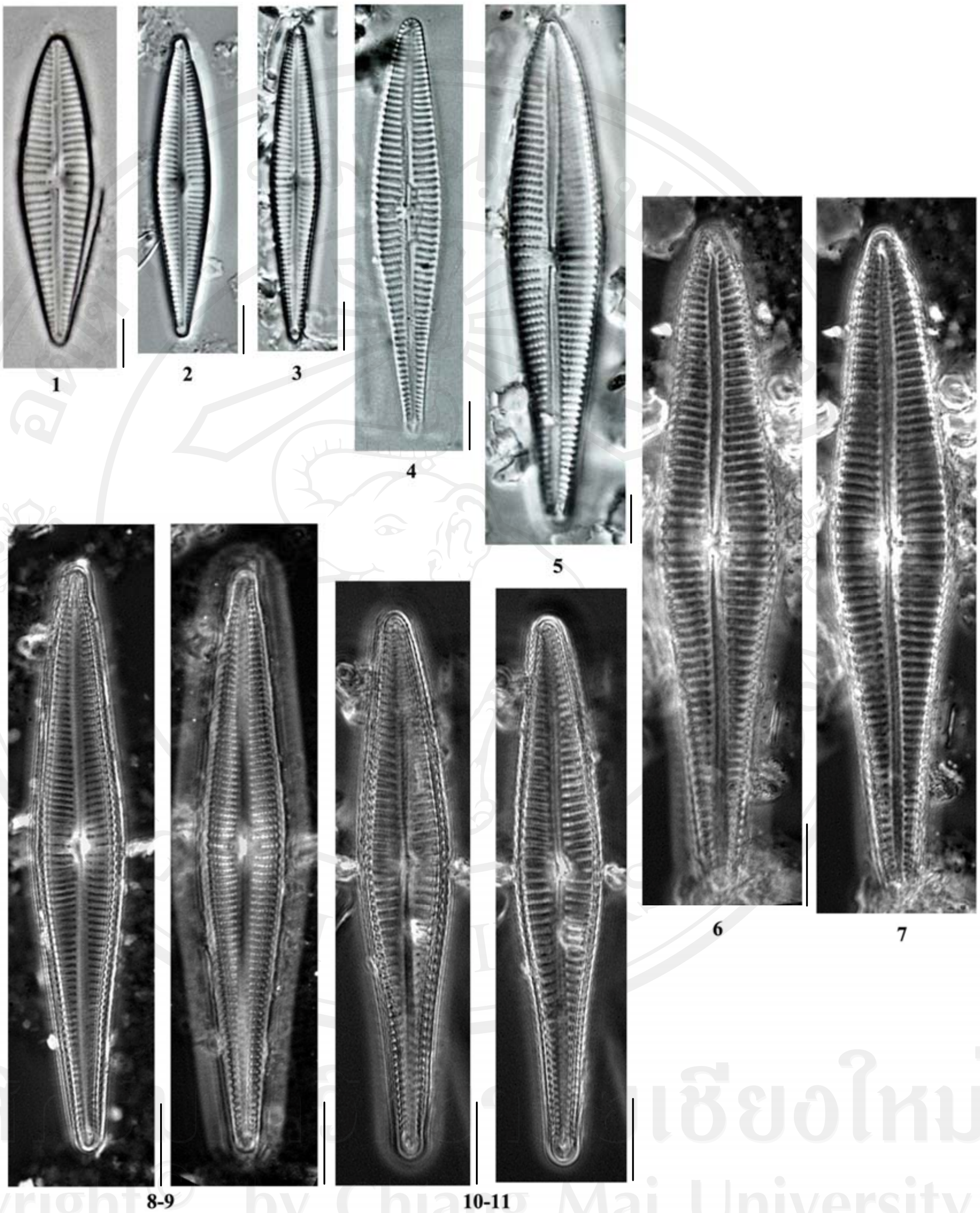
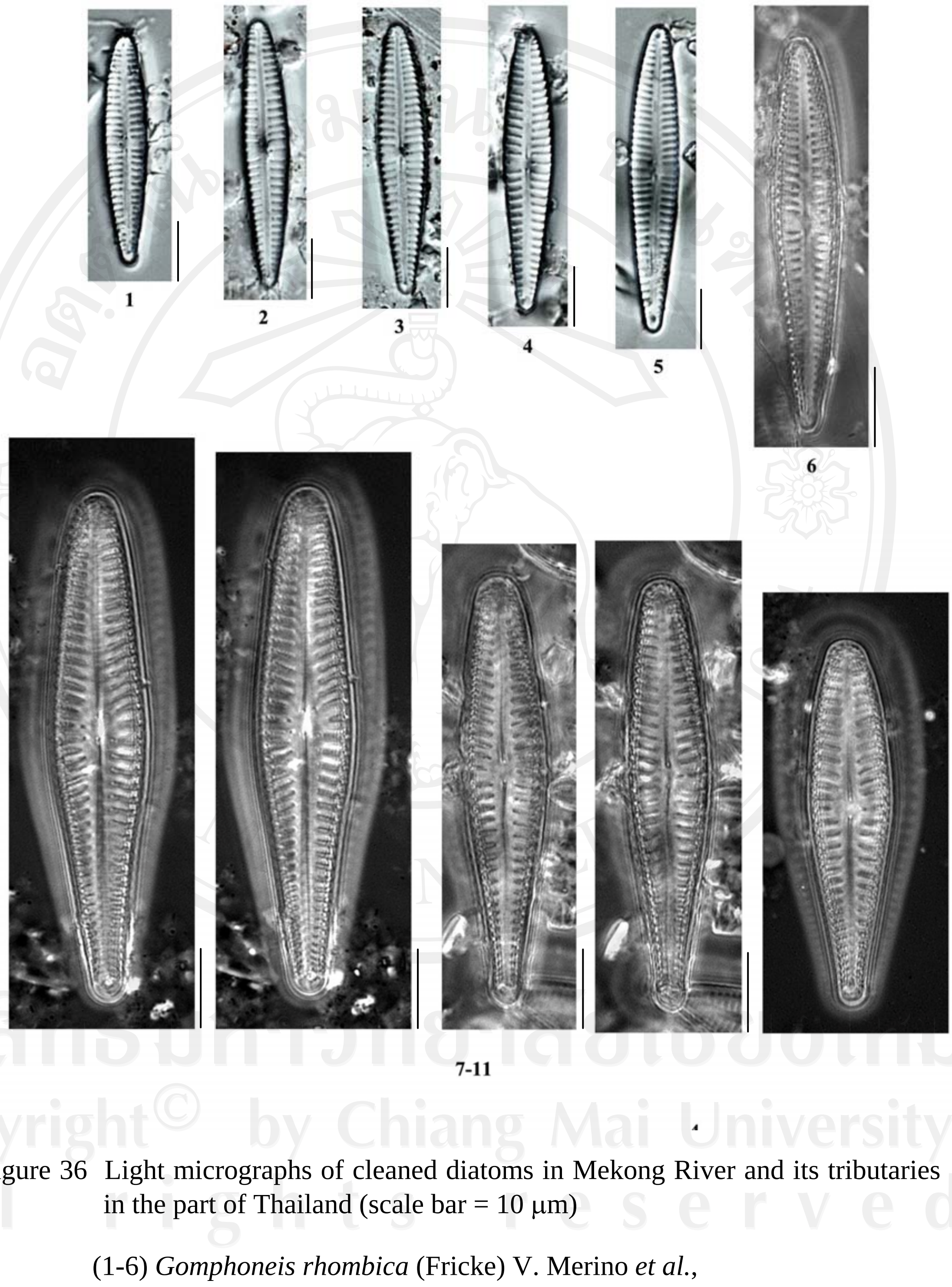


Figure 35 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4, 6-11) *Gomphonema gracile* Ehrenberg, (5) *Gomphonema contraturris* Lange-Bertalot & Reichardt



7-11

Figure 36 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-6) *Gomphoneis rhombica* (Fricke) V. Merino *et al.*,
(7-11) *Gomphoneis* cf. *heterominuta* Mayama *et* Kawashima

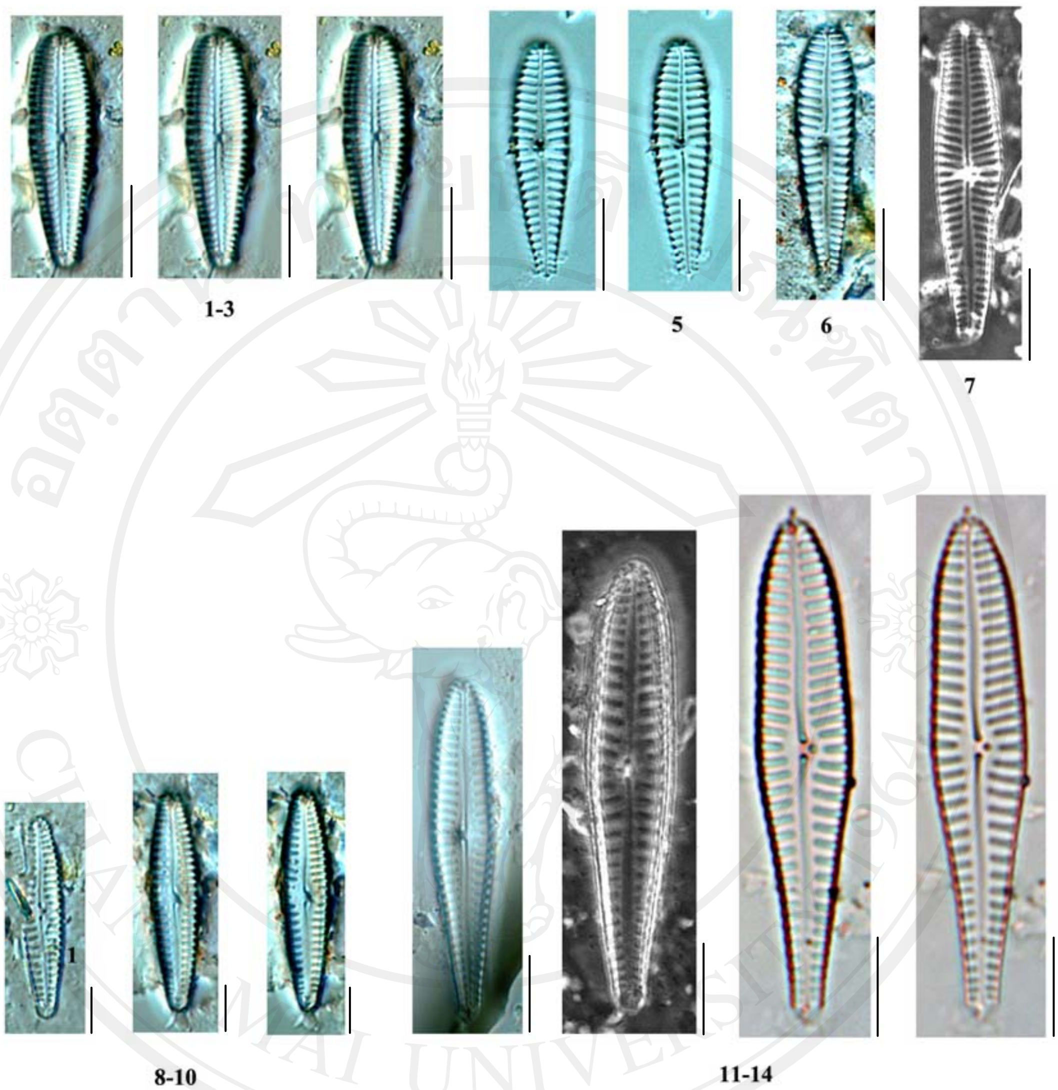


Figure 37 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-7) *Gomphoneis* sp.1, (8-10) *Gomphoneis rhombica* (Fricke) V. Merino *et al*., (11-14) *Gomphoneis* sp.2

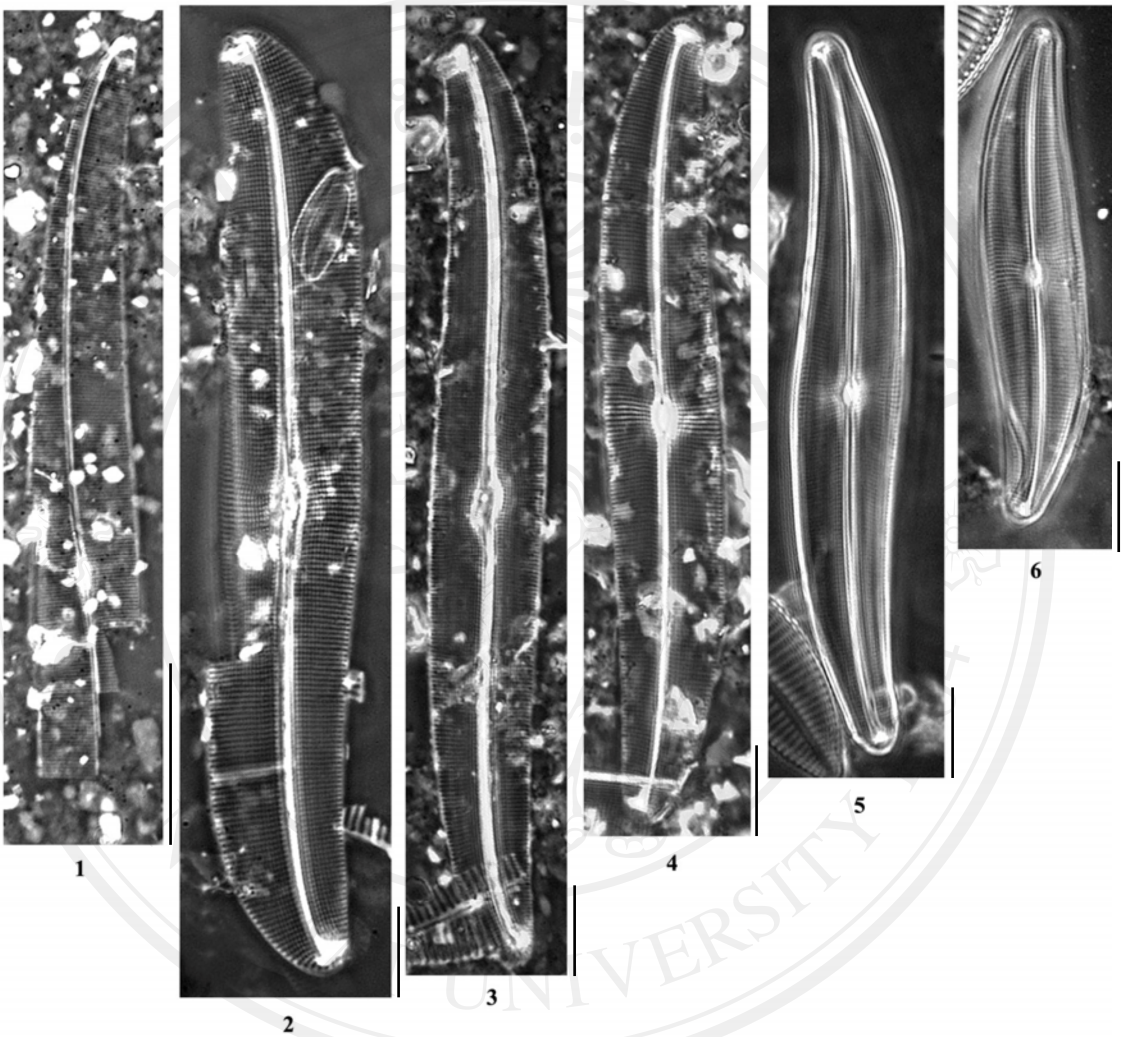


Figure 38 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Gyrosigma obscurum* (W. Smith) J.W. Griffith & Henfrey, (2) *Gyrosigma* cf. *eximium* (Thwaites) Van Heurck, (3) *Gyrosigma nodiferum* (Grunow) Reimer, (4) *Gyrosigma* cf. *exilis* (Grunow) C.W.Reimer , (5) *Gyrosigma spencerii* (J.W. Bailey ex Quekett) Griffith & Henfrey , (6) *Gyrosigma scalproides* (Rabenhorst) Cleve

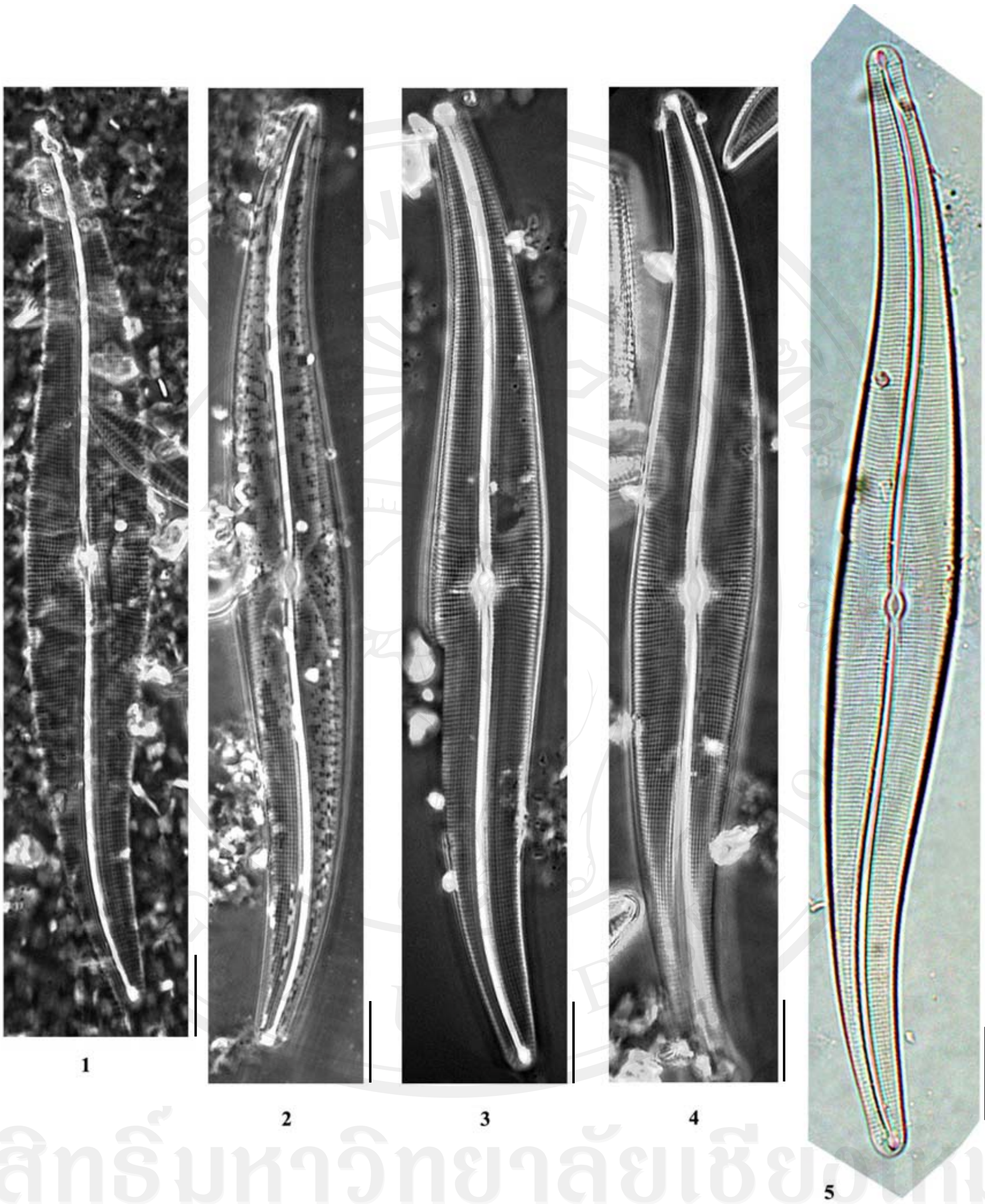


Figure 39 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Gyrosigma acuminatum* (Kützing) Rabenhorst, (2-5) *Gyrosigma spencerii* (J.W. Bailey ex Quekett) Griffith & Henfrey

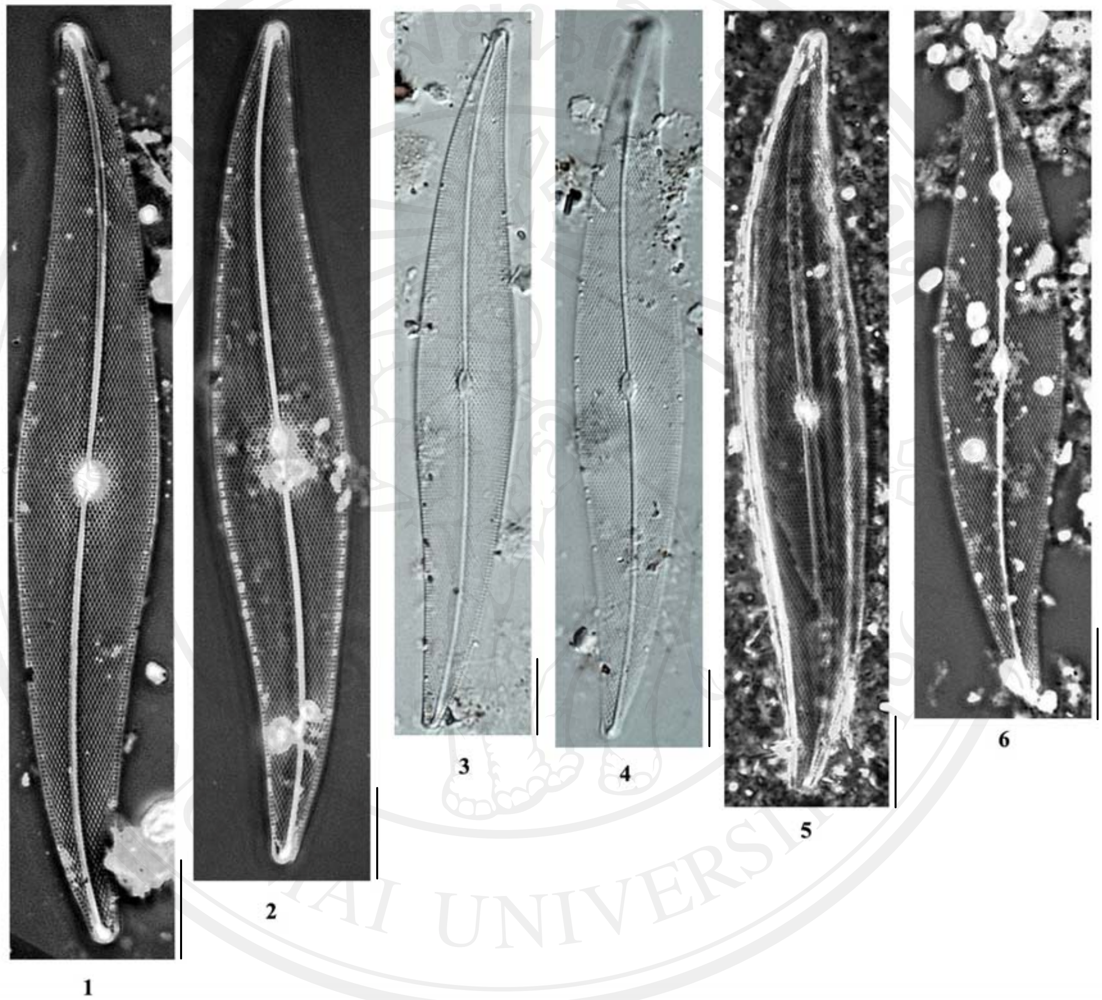


Figure 40 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-5) *Pleurosigma salinarum* (Grunow) Grunow, (6) *Pleurosigma* cf. *salinarum* var. *boyeri* (Keeley) Reimer

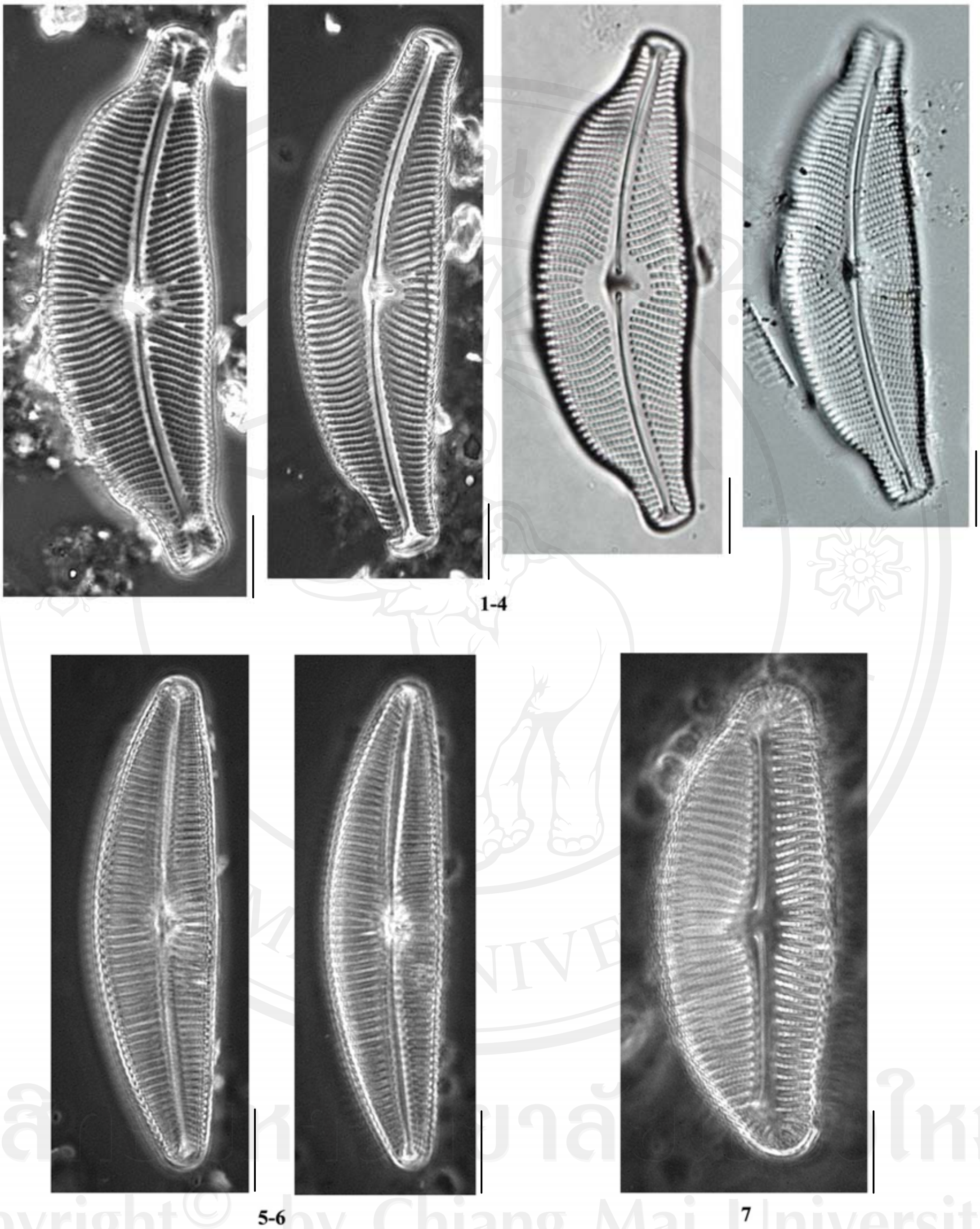


Figure 41 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Cymbella tumida* (Brébisson) Van Heurck, (5-6) *Cymbella turgiguliformis* Krammer, (7) *Encyonema prostratum* (Berkeley) Kützing

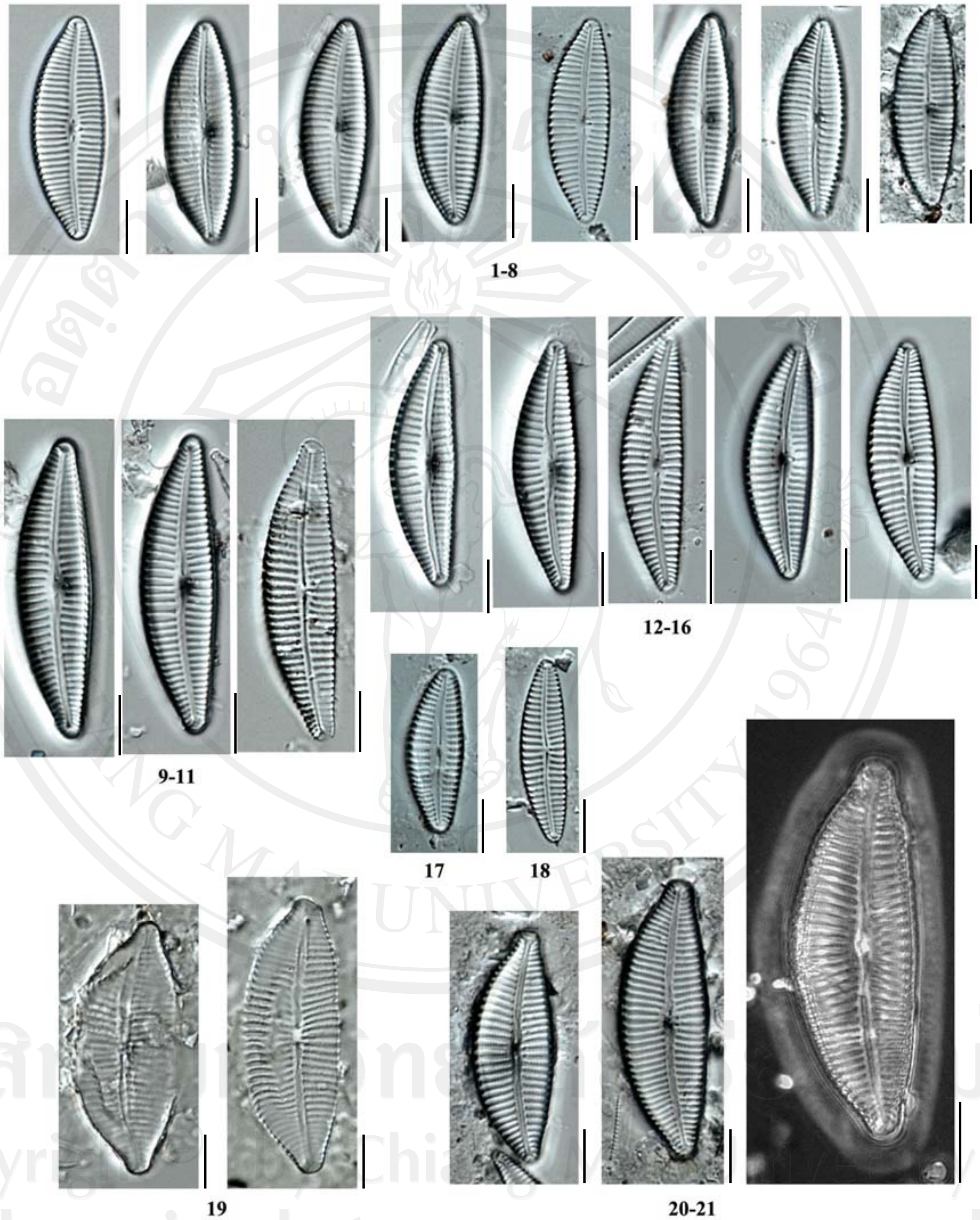


Figure 42 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-11) *Cymbella sumatrensis* Hustedt, (12-16,18) *Cymbella cistula* (Hemprich & Ehrenberg) O. Kirchner, (17) *Cymbella* sp.2, (19-21) *Cymbella turgidula* Grunow

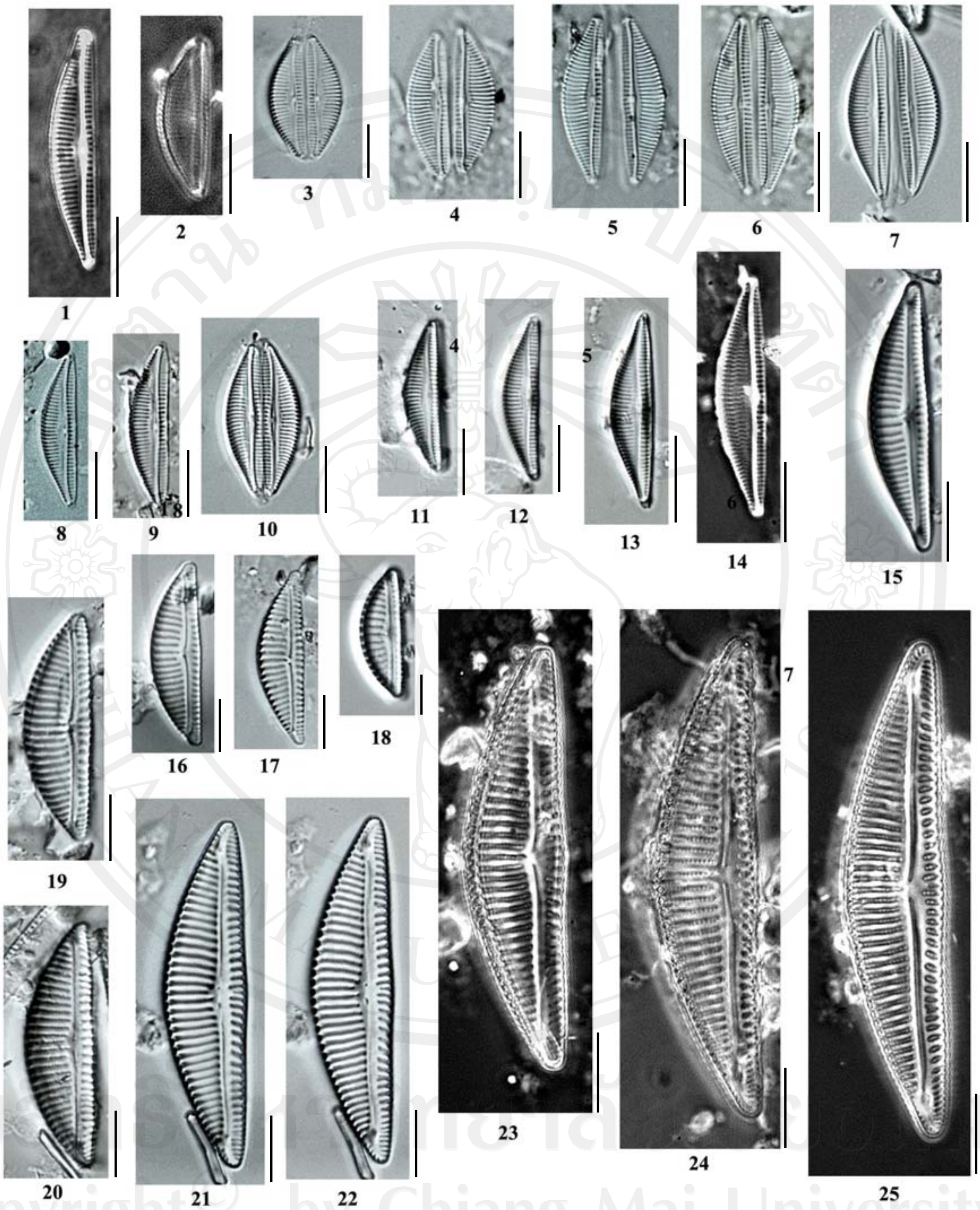


Figure 43 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Encyonema* sp.1, (2-14) *Encyonema* sp.2, (15) *Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann in Round, Crawford & Mann, (16-20) *Encyonema silesiacum* (Bleisch) D.G. Mann, (21-25) *Encyonema vulgare* Krammer

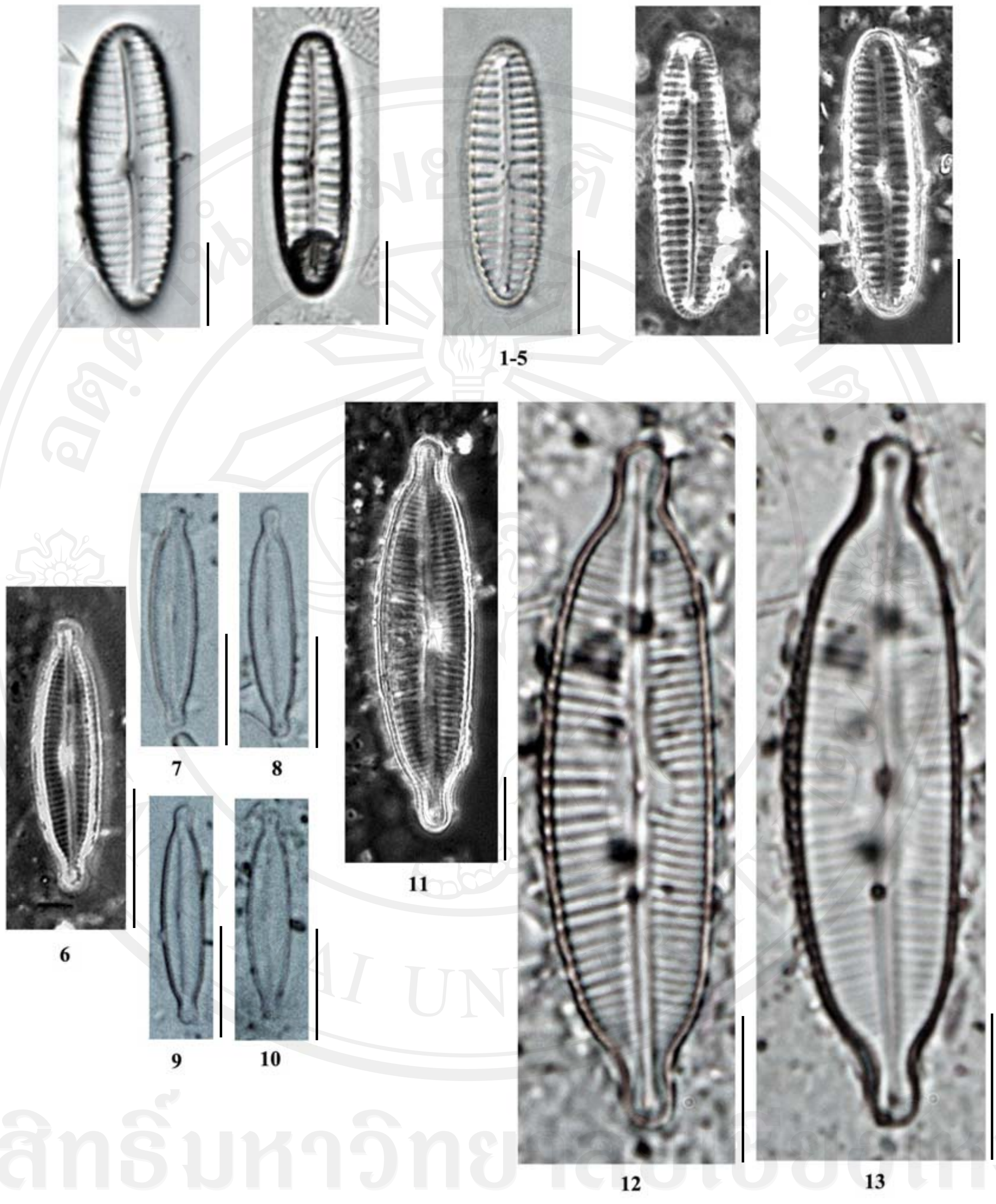


Figure 44 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-5) *Encyonopsis leei* Krammer var. *leei*, (6-10) *Encyonopsis microcephala* (Grunow) Krammer, (11-13) *Cymbella naviculiformis* (Auerswald) Cleve

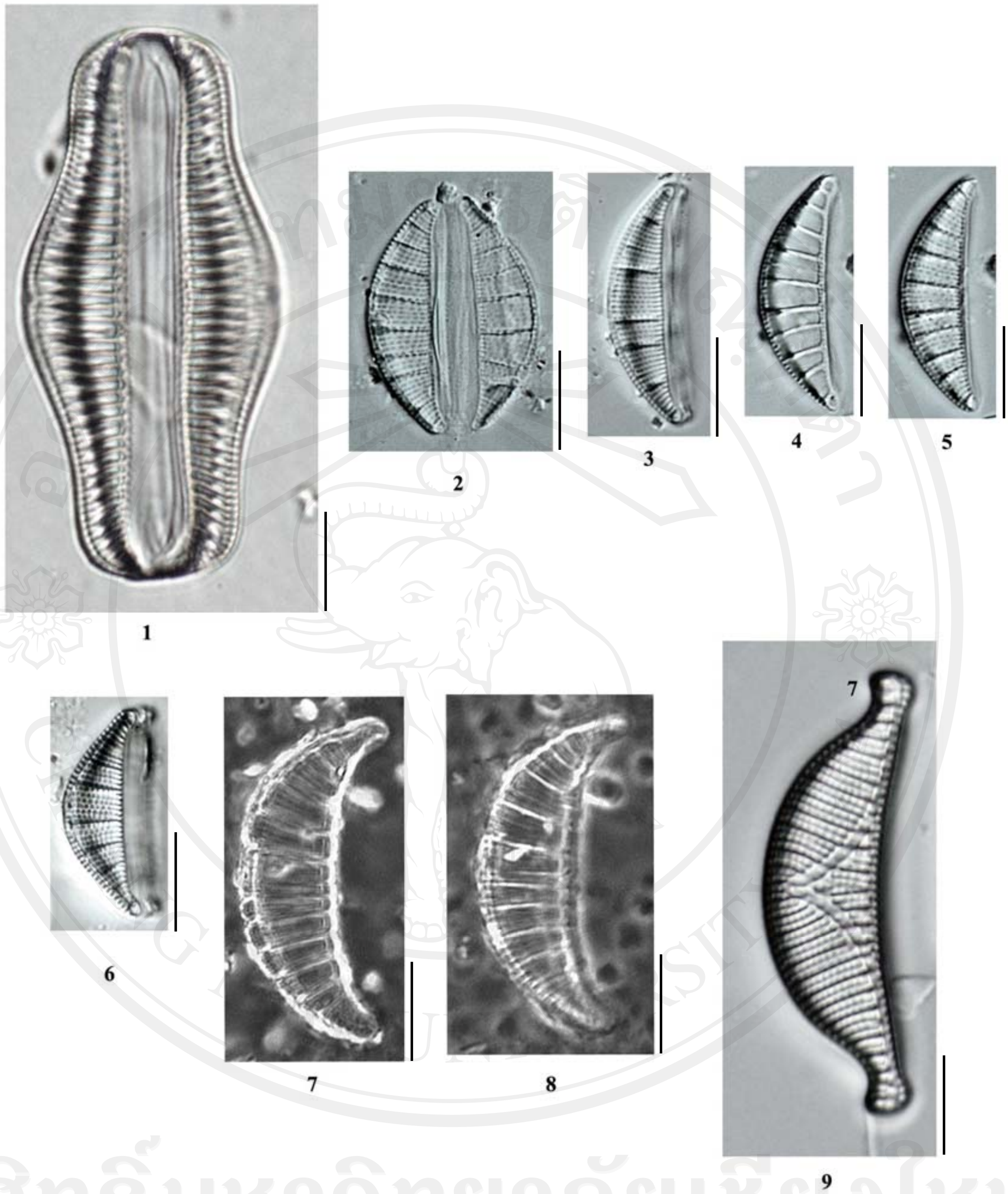


Figure 45 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Rhopalodia gibba* var. *gibba* (Ehrenberg) O. Müller, (2-5) *Rhopalodia operculata* (Agardh) Håk, (6) *Rhopalodia brebissonii* Krammer, (7-8) *Rhopalodia* sp.1, (9) *Epithemia sorex* Kützing

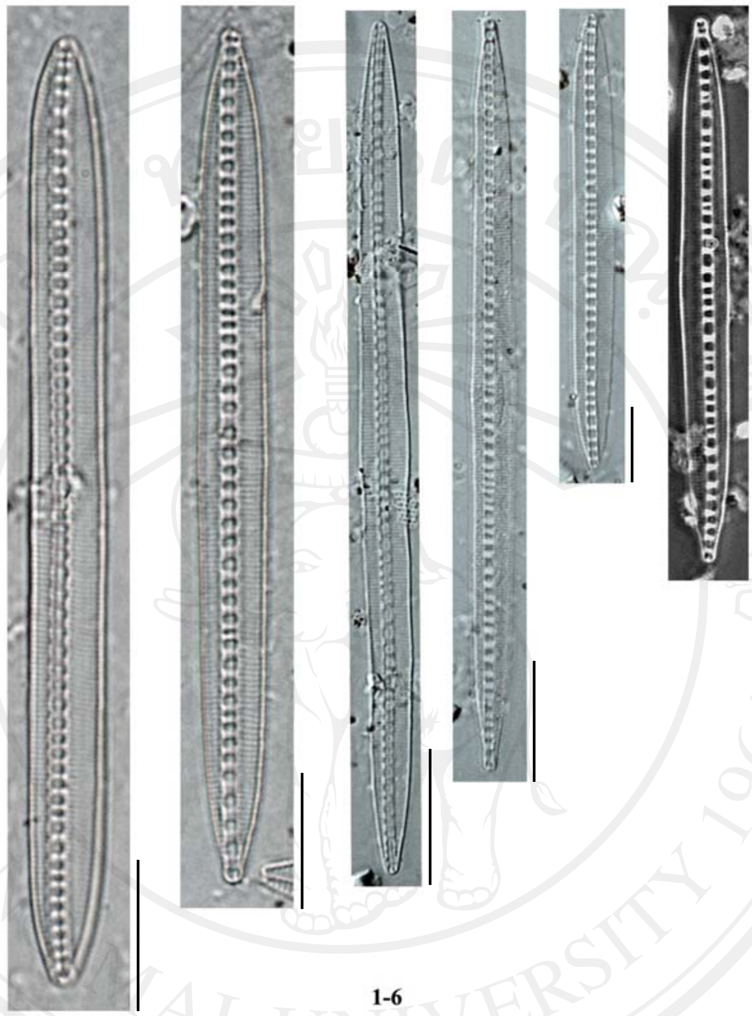


Figure 46 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-6) *Bacillaria paxillifer* (O.F.Müller) Hendey

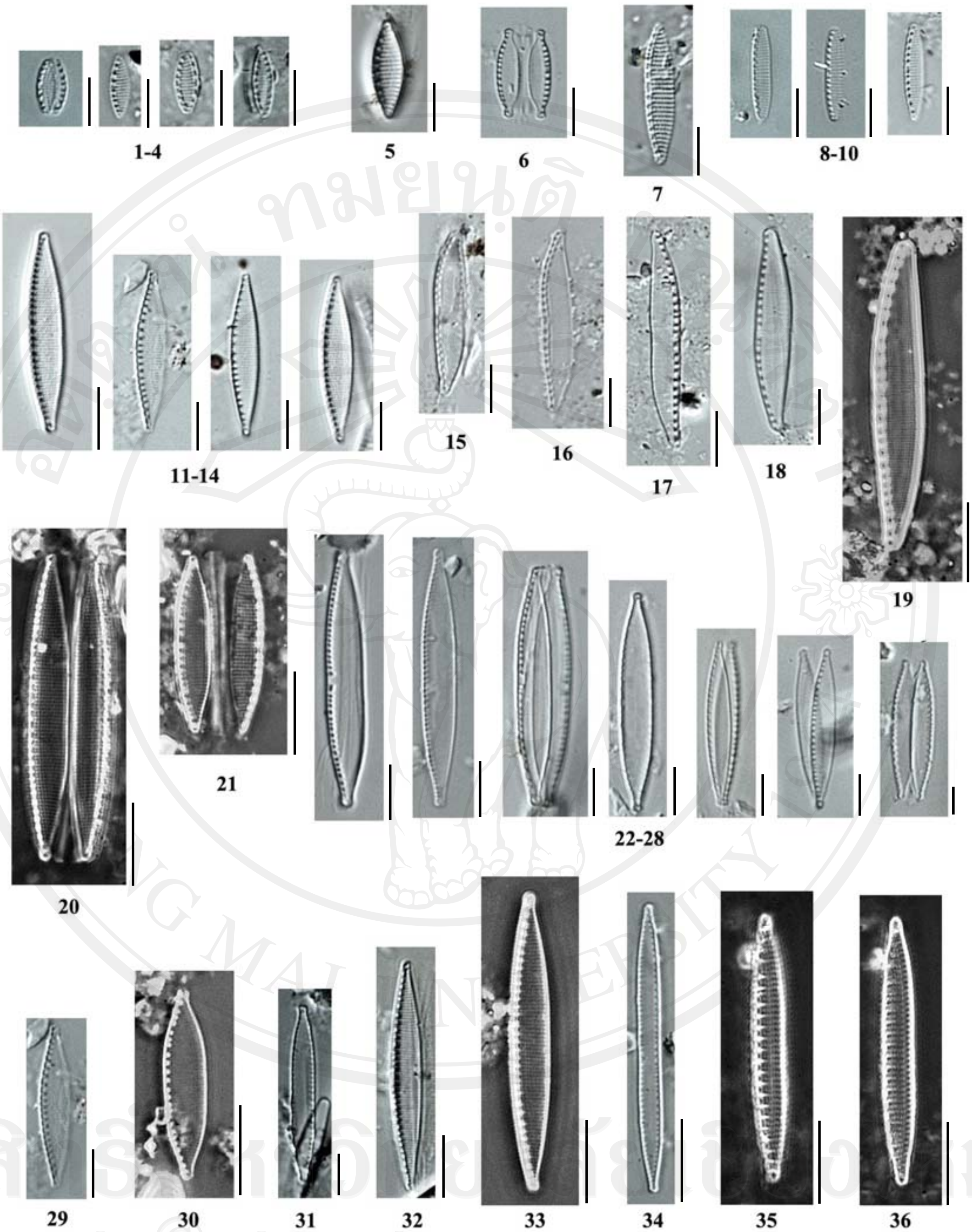


Figure 47 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4,8-10) *Nitzschia inconspicua* Grunow, (5) *Nitzschia fonticola* (Grunow) Grunow, (6) *Nitzschia microcephala* Grunow, (7) *Nitzschia liebetruthii* Rabenhorst, (11-14,29,32-33) *Nitzschia pseudofonticola* Hustedt, (15-17) *Nitzschia clausii* Hantzsch, (18-19) *Nitzschia subcohaerens* (Grunow) Van Heurck, (20,22-28,31) *Nitzschia supralitorea* Lange-Bertalot, (21) *Nitzschia amphibia* Grunow, (30) *Nitzschia capitellata* Hustedt, (34) *Nitzschia paleacea* Grunow, , (35-36) *Nitzschia* cf. *perminuta* (Grunow) M. Peragallo

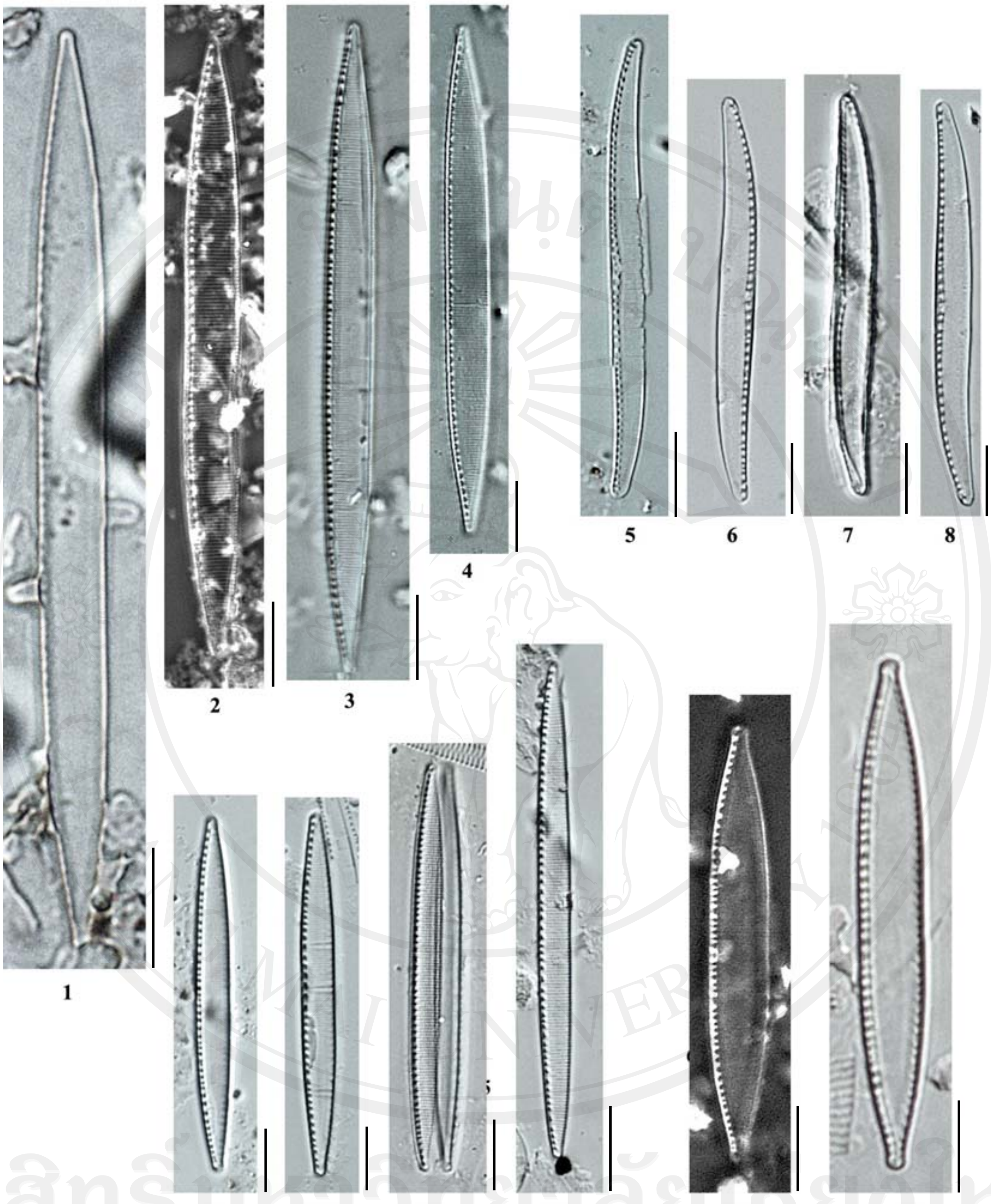


Figure 48 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4) *Nitzschia linearis* (Agardh ex.W. Smith)W.Smit var. *linearis*, (5-8) *Nitzschia nana* Grunow, (9-12) *Nitzschia* sp. , (13-14) *Nitzschia palea* (Kützing) W. Smith

1-9

Figure 49 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-4,6-9) *Nitzschia filiformis* (W. Smith) Hustedt, (5) *Nitzschia nana* Grunow

Figure 50 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Nitzschia geitlerii* Hustedt, (2-3) *Nitzschia sigma* (Kützing) W. Smith, (4,6) *Nitzschia gracilis* Hantzsch, (5,7) *Nitzschia subacicularis* Hustedt, (8) *Nitzschia reversa* W. Smith, (9-10) *Nitzschia pumila* Hustedt

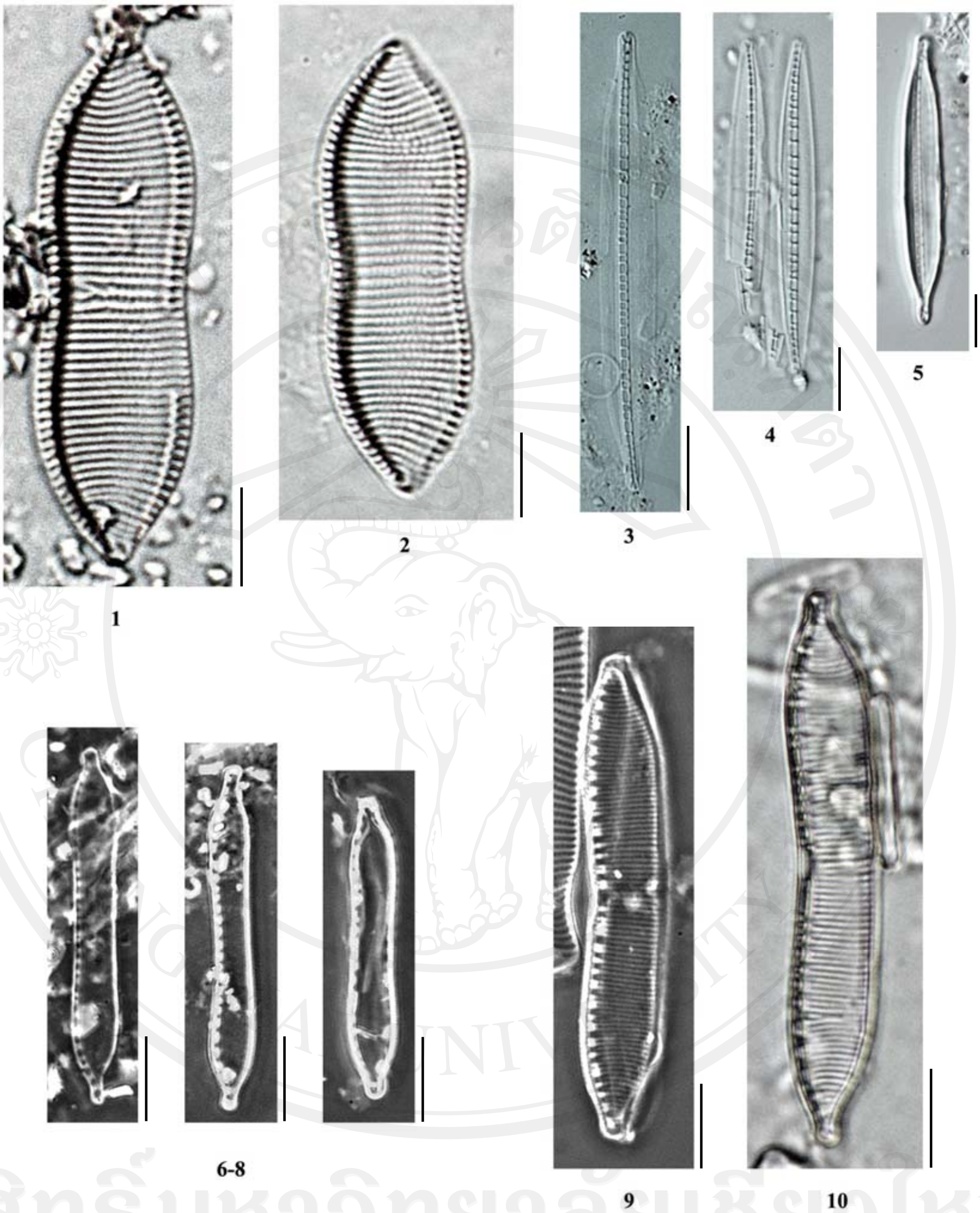


Figure 51 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-2) *Tryblionella coarctata* (Grunow) D.G. Mann, (3-5) *Nitzschia dissipata* (Kützing) Grunow, (6-8) *Nitzschia terrestris* (J.B. Petersen) Hustedt, (9-10) *Hantzschia amphioxys* (Ehrenberg) Grunow

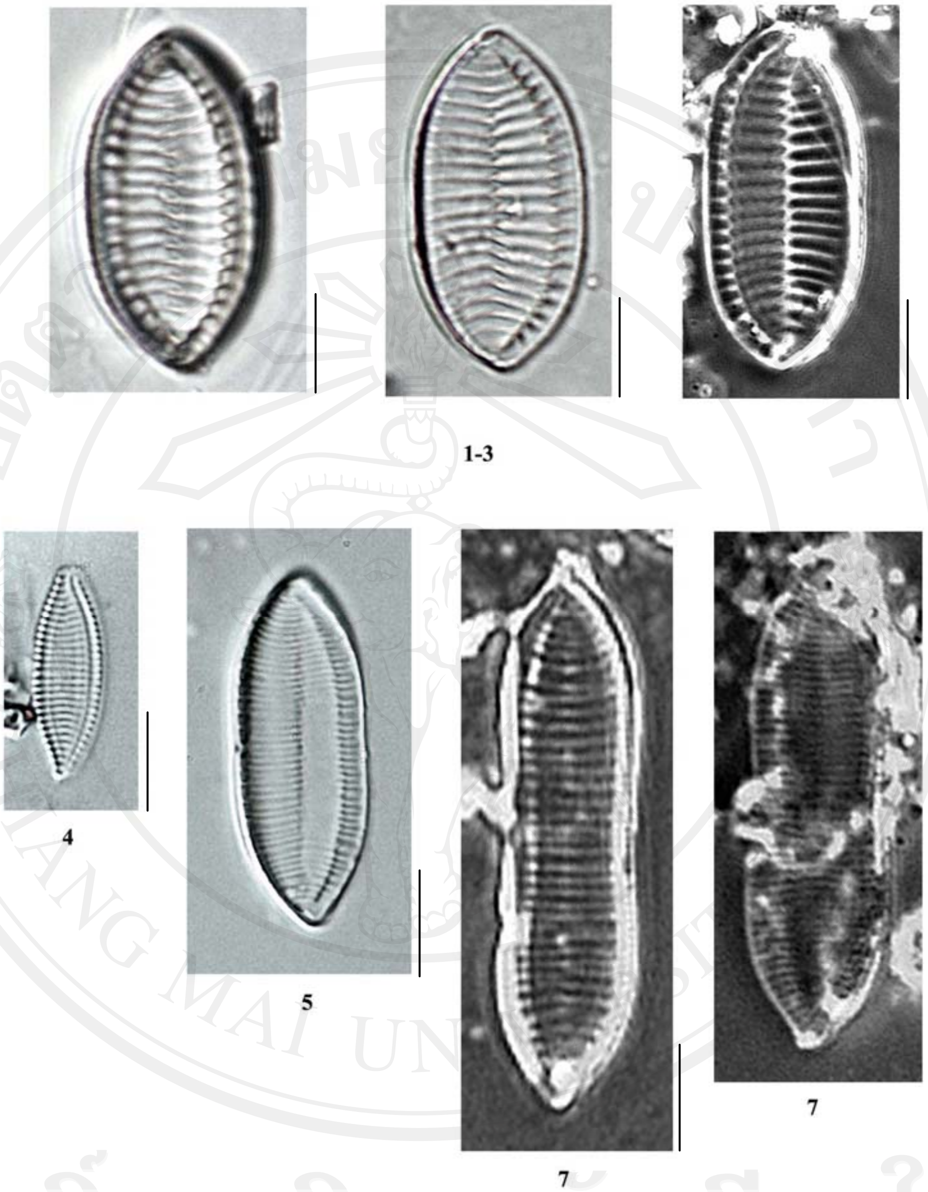


Figure 52 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1-3) *Tryblionella levidensis* W. Smith, (4) *Tryblionella balatonis* (Grunow in Cleve & Grunow) D.G. Mann, (5) *Tryblionella acuminata* W. Smith, (6-7) *Tryblionella calida* (Grunow) D.G.Mann

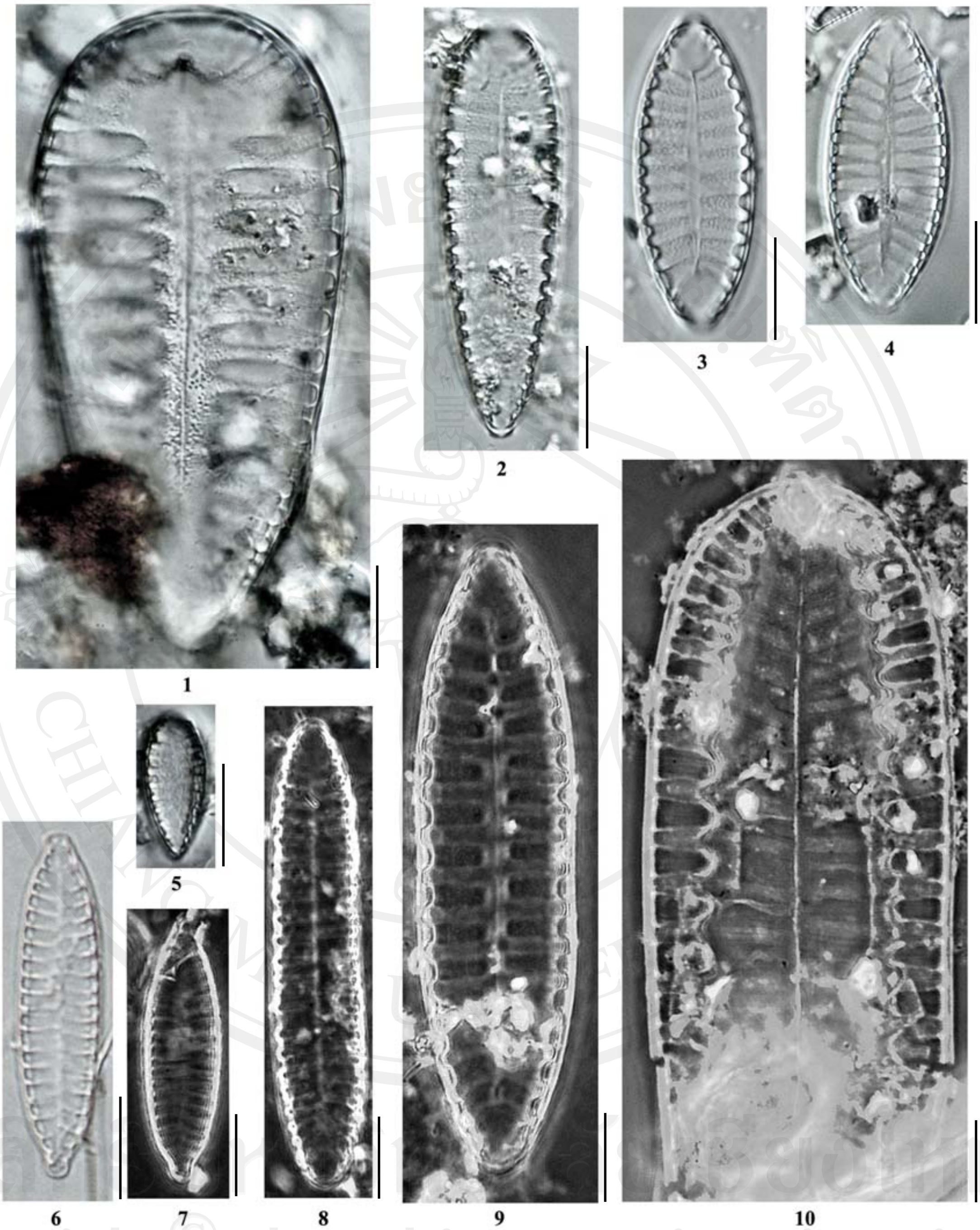


Figure 53 Light micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Surirella capronii* Brébisson ex F. Kitton, (2) *Surirella splendida* Krammer, (3-4) *Surirella* cf. *nervosa* (A. Schmidt) A. Mayer, (5) *Surirella* sp.1, (6-7) *Surirella angusta* Kützing, (8) *Surirella* cf. *roba* Leclercq, (9) *Surirella* sp.2,(10) *Surirella* sp.3

Table 9 Fifty five new records species of benthic diatoms in Thailand

TAXA
Division Bacillariophyta
Class Coscinodiscineae
Subclass Thalassiosirophycidae
Order Thalassiosirales
Family Stephanodiscaceae
Discostella stelligera (Cleve & Grunow) Houk & Klee
Discostella pseudostelligera (Hustedt) Houk & Klee
Subclass Coscinodiscophycidae
Order Aulacoseirales
Family Aulacoseiraceae
Aulacoseira ambigua (Grunow) Simonsen
Subclass Biddulphiophycidae
Order Biddulphiales
Family Biddulphiaceae
Hydrosera whampoensis (A.F.Schwarz)Deby
Class Fragilariophyceae
Subclass Fragilariophycidae
Order Fragilariales
Family Fragilariaceae
Diatoma mesodon(Ehrenberg)Kützing
Synedra ulna var. *amphirhynchus* (Ehrenberg) Grunow
Synedra ulna var. *spathulifera* Grunow
Synedra ulna var. *subaequalis* Grunow
Tabularia fasciculata (C. Agardh) D.M. Williams & Round
Ulnaria ulna (Nitzsch) P. Compère
Class Bacillariophyceae
Subclass Eunotiophycidae
Order Eunotiales
Family Eunotiaceae
Eunotia camelus var. *arcuata* J. Frenguelli
Eunotia repens A. Berg
Subclass Bacillariophycidae
Order Cymbellales
Family Cymbellaceae
Encyonema prostratum (Berkeley) Kützing
Encyonopsis microcephala (Grunow) Krammer
Placoneis gracilis Metzeltin, Lange-Bertalot & Garcia-Rodriguez
Placoneis symmetrica (Hustedt) Lange-Bertalot
Family Gomphonemataceae
Gomphonema pseudoaugur Lange-Bertalot
Gomphonema contraturris Lange-Bertalot & Reichardt
Gomphoneis rhombica (Fricke) V. Merino et al.
Order Achnanthales
Family Achnanthaceae
Planothidium delicatulum (Kützing) Round & L. Bukhtiyarova
Achnanthidium catenatum (Bily & Marvan) Lange-Bertalot

Table 9 (continued)

TAXA
Family Achnanthaceae
Achnanthidium convergens (H. Kobayasi) H. Kobayasi
Achnanthidium minutissimum (Kützing) Czarnecki
Order Naviculales
Family Diadesmidaceae
Diadesmis confervacea Kützing
Luticola nivalis (Ehrenberg) D.G. Mann in Round, Crawford & Mann
Luticola peguana (Grunow) D.G. Mann
Family Amphipleuraceae
Frustulia pararhomboides var. *pararhomboides* H. Lange-Bertalot
Family Neidiaceae
Neidium floridanum Reimer
Family Sellaphoraceae
Fallacia insociabilis (Krasske) D.G. Mann
Fallacia meridionalis Metzeltin, Lange-Bertalot and Garcia-Rodriguez
Family Diploneidaceae
Diploneis pseudovalis Hustedt
Family Naviculaceae
Eolimna minima (Grunow) Lange-Bertalot
Eolimna subminuscula (Manguin) Gerd Moser
Eolimna tantula (Hustedt) Lange-Bertalot
Geissleria punctifer (Hustedt) Metzeltin, Lange-Bertalot & Garcia-Rodriguez
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski
Navicula cryptotenelloides Lange-Bertalot
Navicula cinctaeformis Hustedt
Navicula phyllepta Kützing
Navicula radiosafallax Lange-Bertalot
Navicula kuseliana Lange-Bertalot & U.Rumrich
Family Pleurosigmataceae
Gyrosigma obscurum (W. Smith) J.W. Griffith & Henfrey
Order Bacillariales
Family Bacillariaceae
Nitzschia acidoclinata Lange-Bertalot
Nitzschia linearis (Agardh ex.W. Smith)W.Smit var. *linearis*
Nitzschia liebetruthii Rabenhorst
Nitzschia pseudofonticola Hustedt
Nitzschia supralitorea Lange-Bertalot
Nitzschia tabellaria (Grunow) Grunow
Nitzschia terrestris (J.B. Petersen) Hustedt
Tryblionella acuminata W. Smith
Tryblionella balatonis (Grunow in Cleve & Grunow) D.G. Mann
Tryblionella calida (Grunow) D.G.Mann
Tryblionella coarctata (Grunow) D.G. Mann
Tryblionella levidensis W. Smith
Order Rhopalodiales
Family Rhopalodiaceae
Rhopalodia operculata (Agardh) Håk

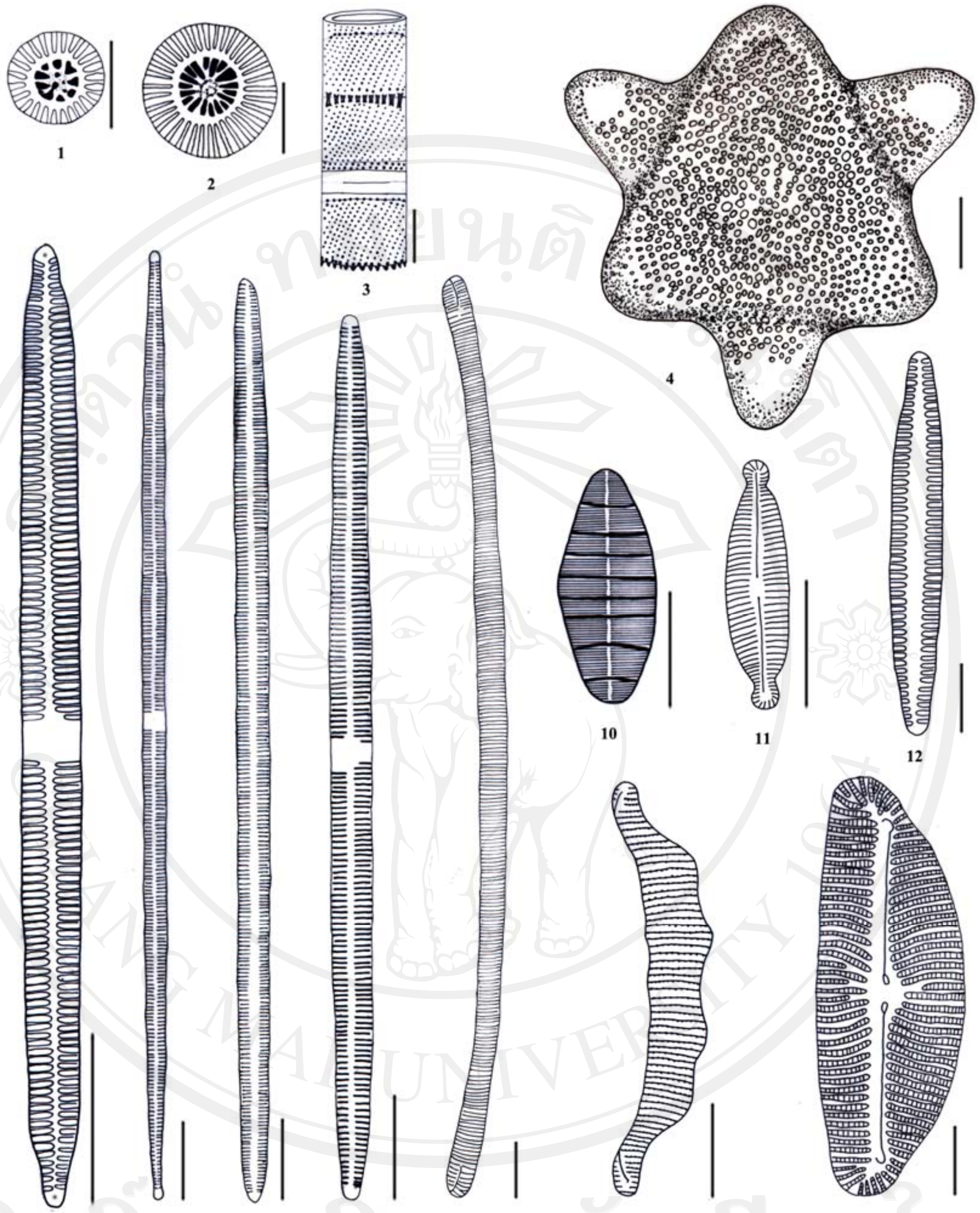


Figure 54 Hand drawing micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Discostella pseudostelligera* (Hustedt) Houk & Klee, (2) *Discostella stelligera* (Cleve & Grunow) Houk & Klee, (3) *Aulacoseira ambigua* (Grunow) Simonsen, (4) *Hydrosera whampoensis* (A.F.Schwarz) Deby, (5) *Ulnaria ulna* (Nitzsch) P. Compère, (6) *Synedra ulna* var. *amphirhynchus* (Ehrenberg) Grunow, (7) *Synedra ulna* var. *subaequalis* Grunow, (8) *Synedra ulna* var. *spathulifera* Grunow, (9) *Eunotia repens* A. Berg, (10) *Diatoma mesodon* (Ehrenberg) Kuetzing, (11) *Encyonopsis microcephala* (Grunow) Krammer, (12) *Tabularia fasciculata* (C. Agardh) D.M. Williams & Round, (13) *Eunotia camelus* var. *arcuata* J. Frenguelli, (14) *Encyonema prostratum* (Berkeley) Kützing

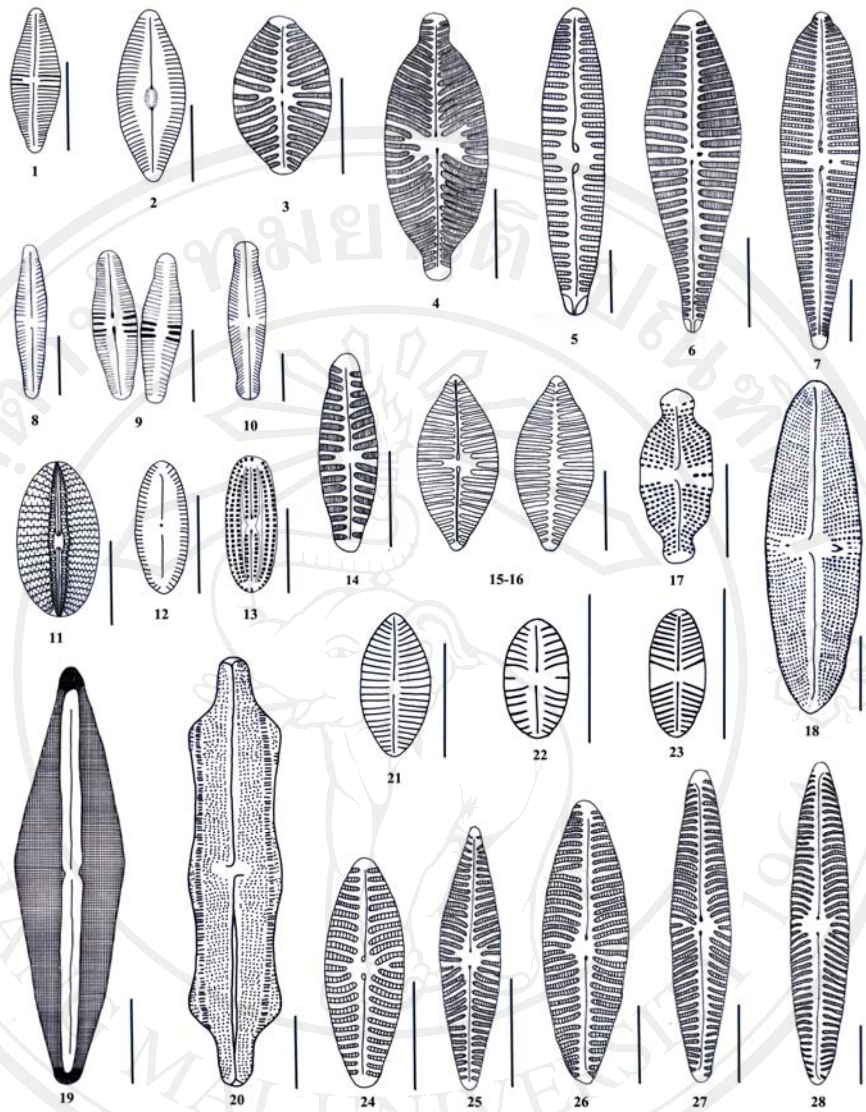


Figure 55 Hand drawing micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Geissleria punctifer* (Hustedt) Metzeltin, (2) *Diadesmis confervacea* Kützing, (3) *Placoneis gracilis* Metzeltin, Lange-Bertalot & Garcia-Rodriguez, (4) *Placoneis symmetrica* (Hustedt) Lange-Bertalot, (5) *Gomphoneis rhombica* (Fricke) V. Merino *et al.*, (6) *Gomphonema pseudoaugur* Lange-Bertalot , (7) *Gomphonema contraturris* Lange-Bertalot & Reichardt, (8) *Achnanthidium catenatum* (Bily & Marvan) Lange-Bertalot, (9) *Achnanthidium minutissimum* (Kützing) Czarnecki, (10) *Achnanthidium convergens* (H. Kobayasi) H. Kobayasi , (11) *Diploneis pseudovalis* Hustedt, (12) *Fallacia insociabilis* (Krasske) D.G. Mann, (13) *Fallacia meridionalis* Metzeltin, Lange-Bertalot and Garcia-Rodriguez, (14) *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski, (15) *Planothidium delicatulum* (Kützing) Round & L. Bukhtiyarova, (16) *Luticola nivalis* (Ehrenberg) D.G. Mann in Round, Crawford & Mann, (17) *Luticola peguana* (Grunow) D.G. Mann, (18) *Frustulia pararhomboides* var. *pararhomboides* H. Lange-Bertalot, (19) *Neidium floridanum* Reimer, (20-21) *Eolimna subminuscula* (Manguin) Gerd Moser, (22) *Eolimna minima* (Grunow) Lange-Bertalot, (23) *Eolimna tantula* (Hustedt) Lange-Bertalot, (24) *Navicula cryptotenelloides* Lange-Bertalot, (25) *Navicula phyllepta* Kützing, (26) *Navicula cinctaeformis* Hustedt, (27) *Navicula radiosafallax* Lange-Bertalot, (28) *Navicula kuseliana* Lange-Bertalot & U.Rumrich

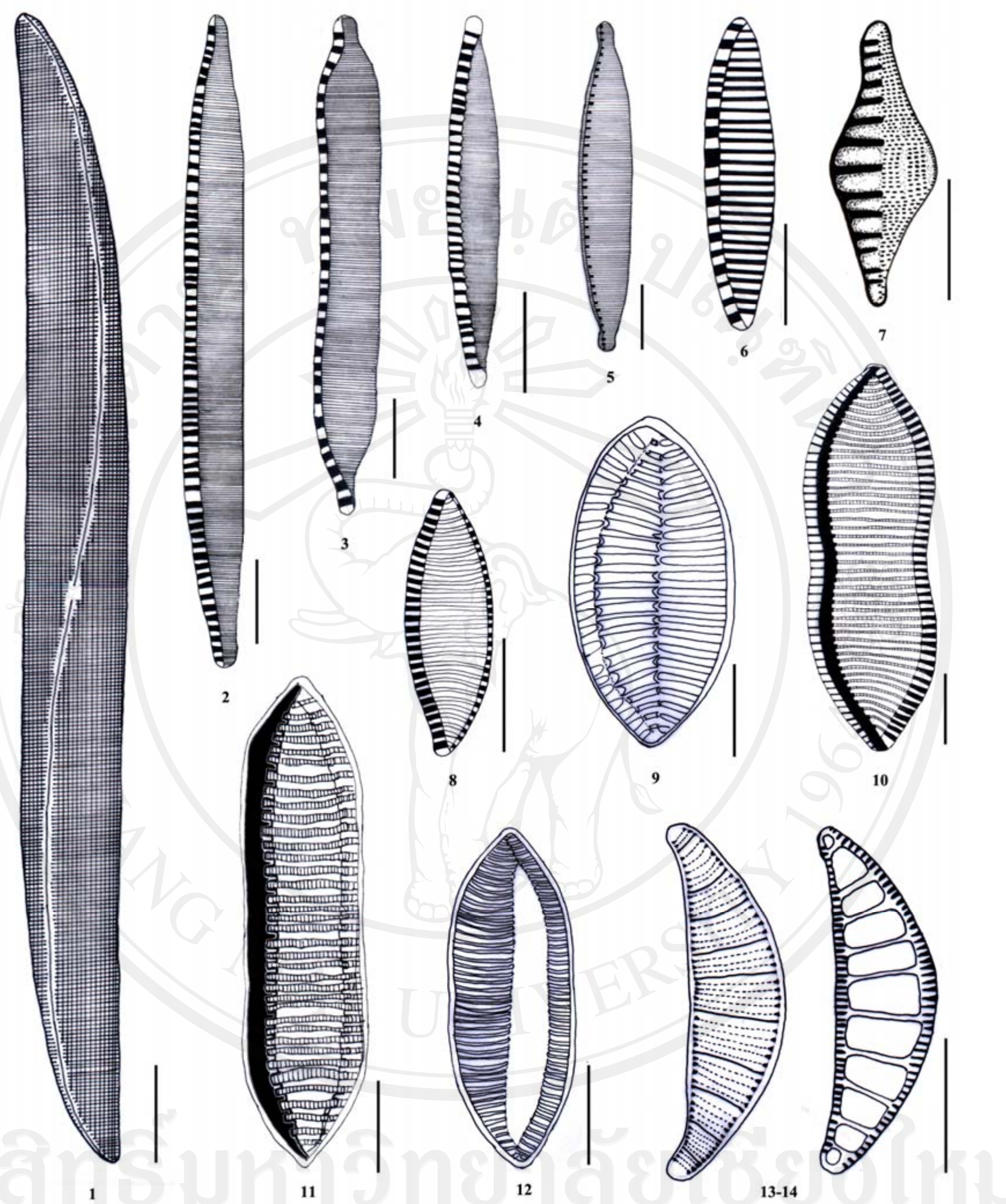


Figure 56 Hand drawing micrographs of cleaned diatoms in Mekong River and its tributaries in the part of Thailand (scale bar = 10 μm)

(1) *Gyrosigma obscurum* (W. Smith) J.W. Griffith & Henfrey, (2) *Nitzschia linearis* (Agardh ex.W. Smith)W.Smit var. *linearis*, (3) *Nitzschia terrestris* (J.B. Petersen) Hustedt, (4) *Nitzschia pseudofonticola* Hustedt, (5) *Nitzschia supralitorea* Lange-Bertalot, (6) *Nitzschia liebetruthii* Rabenhorst, (7) *Nitzschia tabellaria* (Grunow) Grunow, (8) *Tryblionella balatonis* (Grunow in Cleve & Grunow) D.G. Mann, (9) *Tryblionella levidensis* W. Smith, (10) *Tryblionella coarctata* (Grunow) D.G. Mann, (11) *Tryblionella acuminata* W. Smith, (12) *Tryblionella calida* (Grunow) D.G.Mann, (13-14) *Rhopalodia operculata* (Agardh) Håk

4.1.2 Diatom distribution and cell counting

A total of 135,859 benthic diatom cells were counted and identified from 830 samples. They were classified in Class Bacillariophyceae, Class Fragilariophyceae and Class Coscinodiscineae, respectively. An average amount of benthic diatoms and the number of benthic diatoms in each class from 14 sites in 6 times between July 2005 – April 2007 were showed in Figures 53-54 respectively. The highest amount of diatoms were observed at sampling site 2 (KO) in the second sampling time on December 2005 (cool dry season 1) (3,294 cells). Beside that, the lowest amount of diatoms were found in the first sampling time in July 2005 (rainy season 1) (at the same sampling site (94 cells).

At sampling site 3 (HK) where a sampling site in the Mekong River in Northern Thailand, there were generally the lowest amount of diatoms at all sampling times recorded, with the lowest amount at the fourth sampling in July 2006(rainy season 2) (Figure 58). An average amount of diatom cells at all sampling period were 559 cells (Figure 57).

At sampling site 13 (KP) where a sampling site in the tributaries of Mekong River in Northeastern Thailand, there were generally the highest amount of diatoms at all sampling times recorded except in the fourth and fifth sampling times on July 2006 (Rainy season 2) and December 2006 (cool dry season 2) with the highest amount at the second sampling in December 2005 (cool dry season 1) (Figure 58). An average amount of diatom cells at all sampling period were 2,416 cells (Figure 57).

Among two hundred and fifty two species of benthic diatoms discovered, it was found that 29 species were common species. The species list was shown in Table 10. Furthermore, the remaining 223 species were rare species.

The percentages of relative abundant of the common species in this study were also showed in Table 10. *Nitzschia palea* showed the highest percentage of relative abundant of 36.0% follow by *Mayamaea atomus* (35.4%), *Eolimna minima* (25.3%), *Navicula cryptotenelloides* (24.9%), *Cymbella* sp.1 (21.3%) and *Achnanthidium minutissimum* (20.5%), respectively.

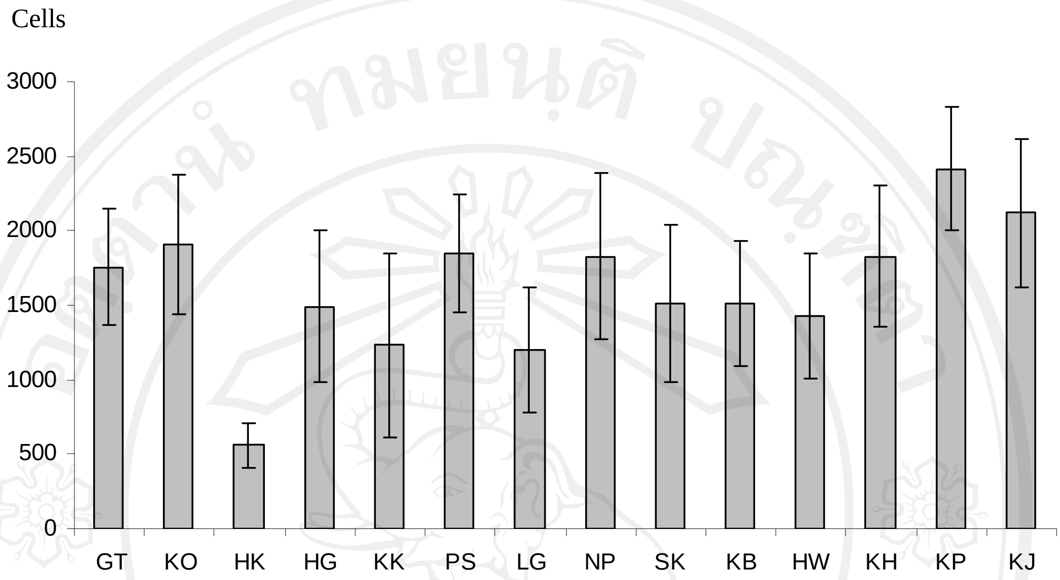


Figure 57 An average amount of benthic diatoms cells from 14 sampling sites between July 2005 – April 2007.

The histogram representing the pattern of common species distribution were show in Figures 59-62. It was found that *Mayamaea atomus* were highest distributed and frequency more than another species where as *Nitzschia microcephala* and *Frustulia undosa* were lowest distributed and frequency respectively.

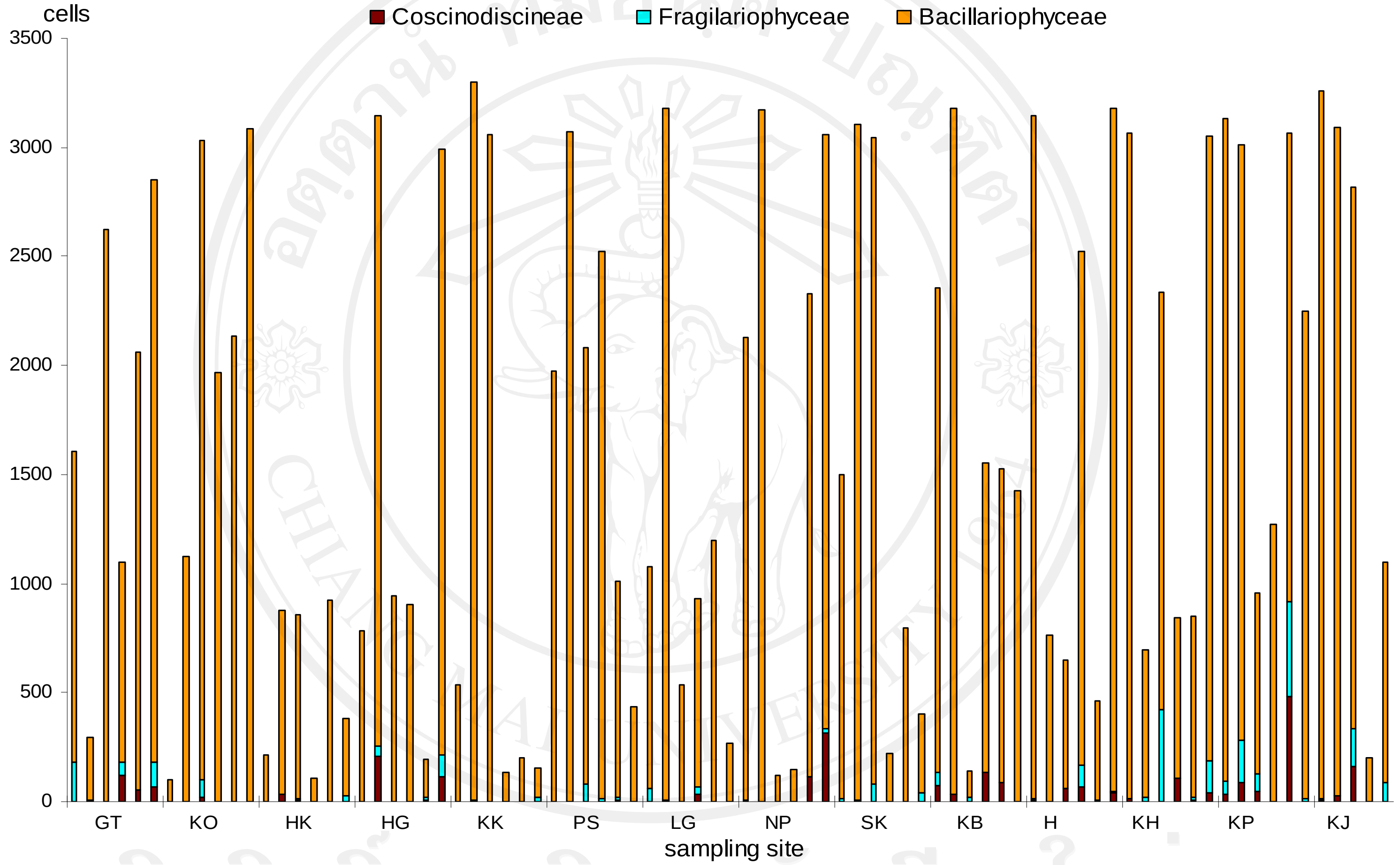


Figure 58 Number of benthic diatoms in the Mekong River and its tributaries of Thailand from 14 sampling sites at 6 times between July 2005 –April 2007

1 = July 2005 (rainy1)
2 = December 2005 (cool dry1)
3 = May 2006 (summer1)
4 = July 2006 (rainy 2)
5 = December 2006 (cool dry2)
6 = April 2007 (summer2)

Table 10 Twenty nine common species of benthic diatoms in the Mekong River and its tributaries of Thailand and the percentage of relative abundant

TAXA
Nitzschia palea (Kützing) W. Smith (36.0%)
Mayamaea atomus (Kützing) H. Lange-Bertalot (35.4%)
Navicula symmetrica R.M. Patrick (33.4%)
Eolimna minima (Grunow) Lange-Bertalot (25.3%)
Navicula cryptotenelloides Lange-Bertalot (24.9%)
Gomphonema lagenula Kützing (24.6%)
Cymbella sp.1 (21.3%)
Achnanthidium minutissimum (Kützing) Czarnecki (20.5%)
Navicula cryptotenella Lange-Bertalot (19.9%)
Nitzschia inconspicua Grunow (19.2%)
Nitzschia supralitorea Lange-Bertalot (17.2%)
Navicula rostellata Kützing (14.5%)
Encyonema sp.1 (14.3%)
Luticola goeppertiana (Bleisch) D.G.Mann in Round,Crawford&Mann(13.7%)
Nitzschia clausii Hantzsch (13.1%)
Planothidium frequentissimum (Lange-Bertalot)Round&L.Bukhtiyarova(11.9%)
Cymbella sumatrensis Hustedt (11.7%)
Nitzschia filiformis (W. Smith) Hustedt (11.4%)
Ulnaria ulna (Nitzsch) P. Compère (10.8%)
Eolimna subminuscula (Manguin) Gerd Moser (9.8%)
Fragilaria bidens Heiberg (9.0%)
Melosira varians C. Agardh (9.0%)
Navicula menisculus Schumann (6.9%)
Nitzschia dissipata (Kützing) Grunow (6.6%)
Geissleria decussis (Østrup) Lange-Bertalot&Metzeltin (5.9%)
Achnanthidium convergens (H. Kobayasi) H. Kobayasi (5.9%)
Frustulia undosa D. Metzeltin & H. Lange-Bertalot (4.7%)
Sellaphora pupula (Kützing) Mereschkovsky (3.1%)
Nitzschia microcephala Grunow (2.9%)

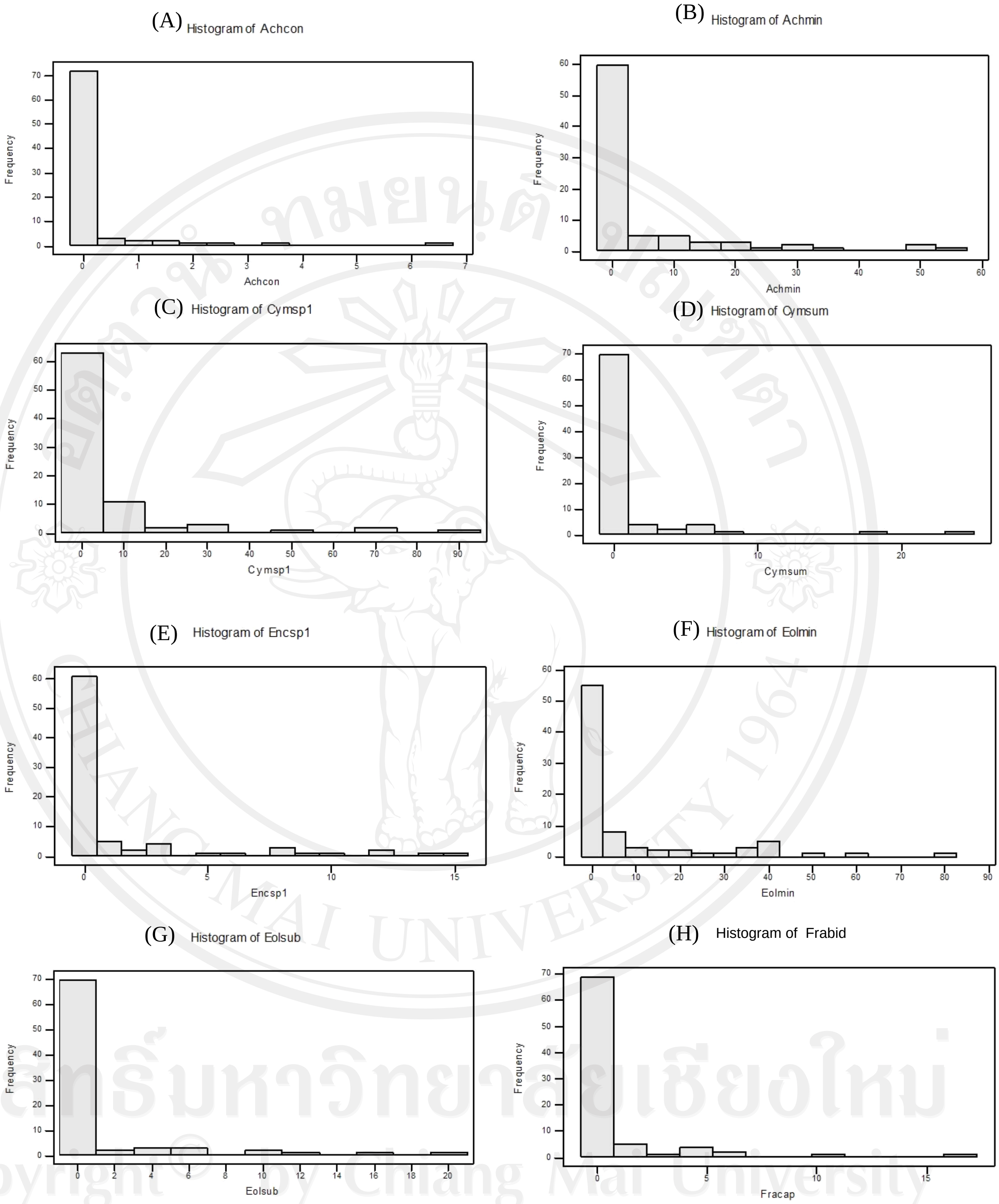


Figure 59 Histogram of common species of benthic diatom from Mekong River and its tributaries

(A) *Achnanthidium convergens* (H. Kobayasi) H. Kobayasi (Achcon)
(B) *Achnanthidium minutissimum* (Kützing) Czarnecki
(C) *Cymbella* sp.1
(D) *Cymbella sumatrensis* Hustedt
(E) *Encyonema* sp.1
(F) *Eolimna minima* (Grunow) Lange-Bertalot
(G) *Eolimna subminuscula* (Manguin) Gerd Moser
(H) *Fragilaria bidens* Heiberg

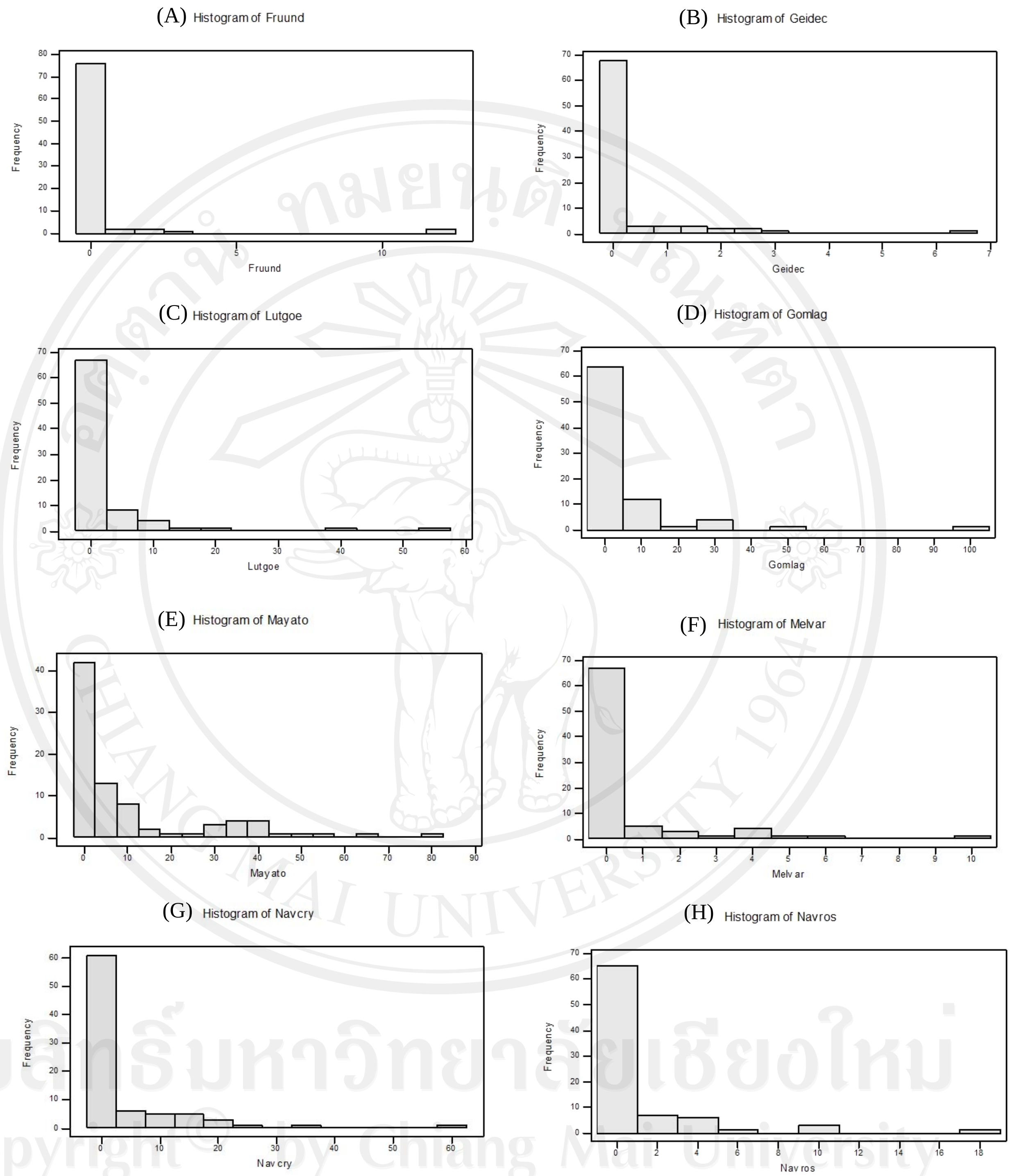


Figure 60 Histogram of common species of benthic diatom from Mekong River and its tributaries
(A) *Frustulia undosa* D. Metzeltin & H. Lange-Bertalot
(B) *Geissleria decussis* (Østrup) Lange-Bertalot&Metzeltin
(C) *Luticola goeppertiana* (Bleisch) D.G. Mann in Round, Crawford & Mann
(D) *Gomphonema lagenula* Kützing
(E) *Mayamaea atomus* (Kützing) H. Lange-Bertalot
(F) *Melosira varians* C. Agardh
(G) *Navicula cryptotenella* Lange-Bertalot
(H) *Navicula rostellata* Kützing

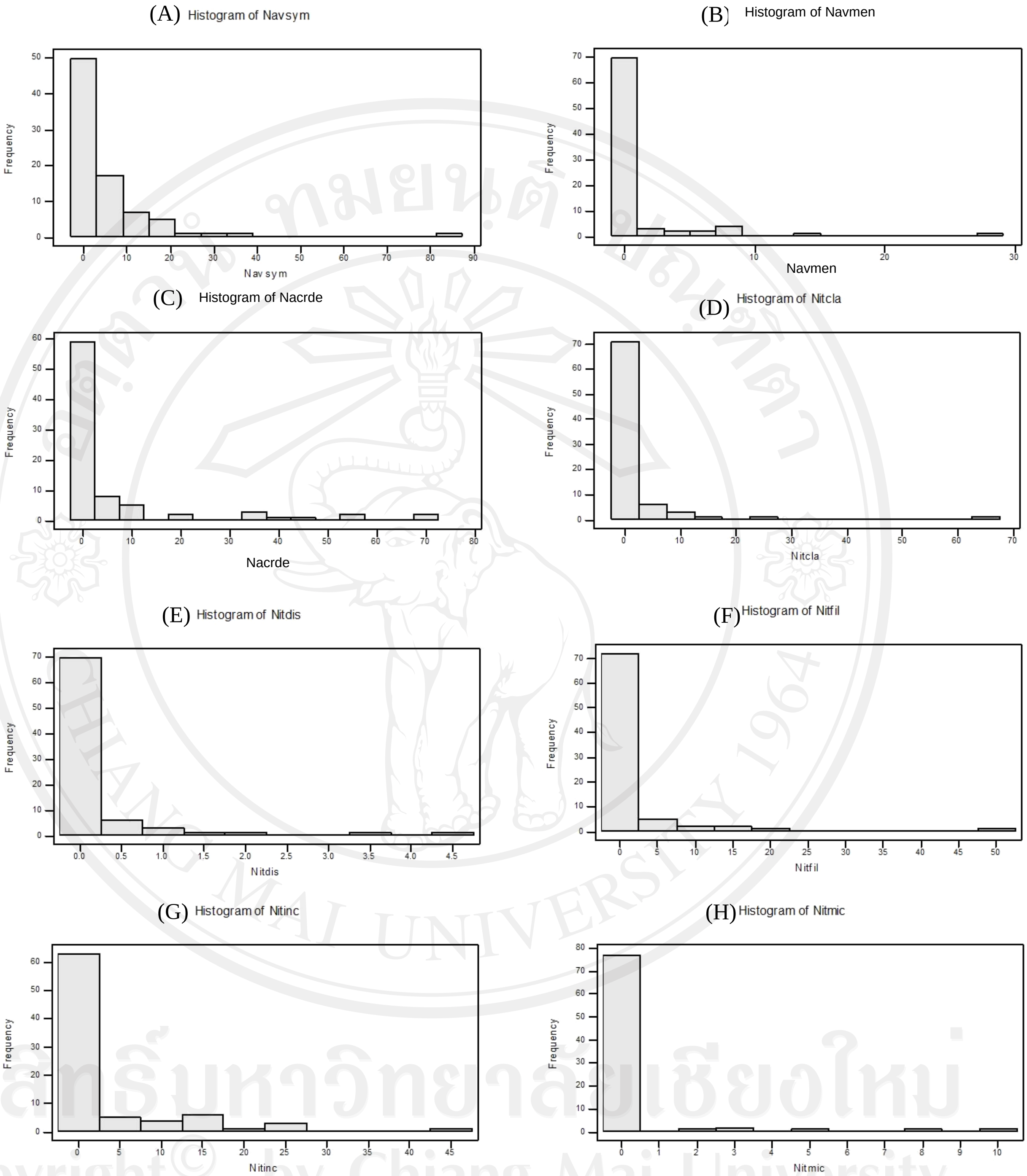


Figure 61 Histogram of common species of benthic diatom from Mekong River and its tributaries

(A) *Navicula symmetrica* R.M. Patrick
(B) *Navicula menisculus* Schumann
(C) *Navicula cryptotenelloides* Lange-Bertalot
(D) *Nitzschia clausii* Hantzsch
(E) *Nitzschia dissipata* (Kützing) Grunow
(F) *Nitzschia filiformis* (W. Smith) Hustedt
(G) *Nitzschia inconspicua* Grunow
(H) *Nitzschia microcephala* Grunow

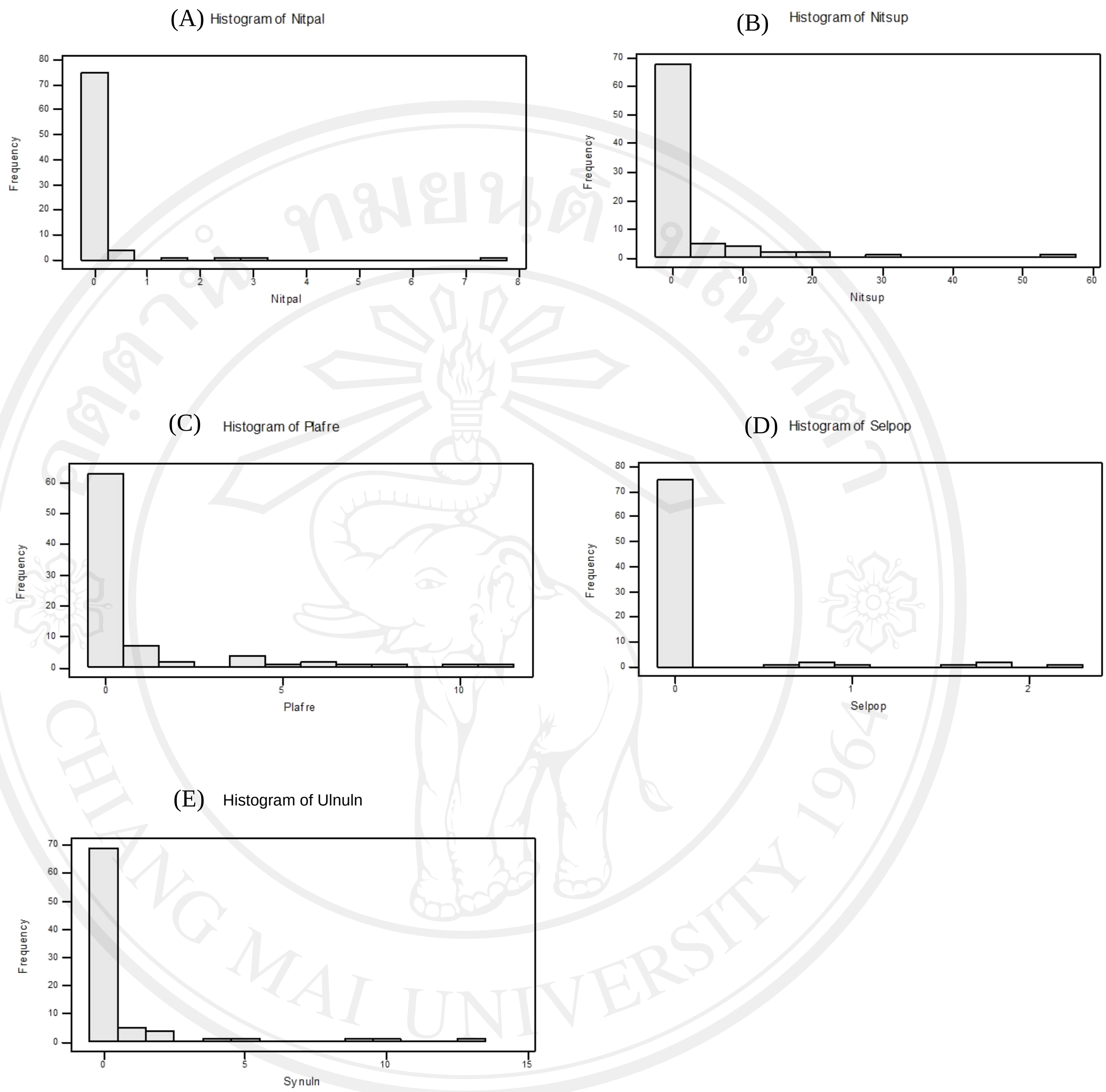


Figure 62 Histogram of common species of benthic diatom from Mekong River and its tributaries

(A) *Nitzschia palea* (Kützing) W. Smith
(B) *Nitzschia supralitorea* Lange-Bertalot
(C) *Planothidium frequentissimum* (Lange-Bertalot)Round&L.Bukhtiyarova
(D) *Sellaphora pupula* (Kützing) Mereschkovsky
(E) *Ulnaria ulna* (Nitzsch) P. Compère

4.1.3 Diversity index of benthic diatoms

Shannon's diversity index, evenness and number of diatoms species in each sampling site were shown in Table 11. The diversity index of benthic diatoms was ranged from 0.183 – 2.671, the evenness was ranged from 0.167-0.888 and number of species was ranged from 3- 38. The lowest values of diversity index was observed at sampling site 7 in May 2006 (summer1) (LG3) and the highest values at sampling site 9 in December 2006 (cool dry season 2) (SK5). The evenness values were lowest at sampling site 7 in May 2006 (summer1) (LG3) and showed the highest values in sampling site 9 in April 2007 (summer 2) (SK6). The highest numbers of species were recorded at sampling site 4 in December 2005 (cool dry season 1) (HG2) whereas the lowest value was at sampling site 7 in May 2006 (summer1)(LG3), sampling site 8 in July 2006 (rainy season 2) (NP4) and sampling site 9 in July 2006 (rainy season 2) (SK4). It was found that at sampling site 7 in May 2006 (summer1) (LG3) showed the lowest values of diversity index, evenness and number of species.

Table 11 Shannon's diversity index, evenness and numbers of diatoms species of 14 sampling sites in the Mekong River and its tributaries of Thailand

Sampling sites	Diversity Index	Evenness	Number of Species
SK5	**2.671**	0.810	27
HG2	2.614	0.718	**38**
KP1	2.581	0.732	34
KB3	2.548	0.837	21
KO3	2.494	0.713	33
KP3	2.436	0.843	18
KJ1	2.422	0.743	26
GT6	2.394	0.735	26
KB1	2.394	0.813	19
SK1	2.392	0.743	25
KH6	2.374	0.691	31
KO4	2.355	0.762	22
HW6	2.354	0.731	25
KP4	2.334	0.767	21
PS3	2.332	0.744	23
GT3	2.323	0.838	16
LG2	2.310	0.655	34
KO5	2.294	0.766	20
GT1	2.284	0.701	26
GT5	2.275	0.725	23
LG5	2.235	0.703	24
NP1	2.227	0.701	24
KH3	2.185	0.771	17
KJ4	2.169	0.702	22
PS1	2.164	0.764	17
HK3	2.148	0.676	24
NP6	2.128	0.806	14
KB6	2.049	0.739	16

Table 11 (continued)

Sampling sites	Diversity Index	Evenness	Number of Species
KP5	2.048	0.776	14
HK6	2.045	0.755	15
SK6	2.045	**0.888**	10
HG3	2.006	0.741	15
NP2	1.977	0.631	23
HK5	1.951	0.785	12
LG4	1.951	0.785	12
KH1	1.928	0.712	15
KP6	1.904	0.672	17
PS5	1.865	0.645	18
KK5	1.837	0.883	8
KO6	1.822	0.733	12
KJ6	1.821	0.829	9
GT4	1.819	0.689	14
HG4	1.748	0.759	10
LG1	1.734	0.589	19
SK2	1.677	0.551	21
HW5	1.676	0.763	9
KH5	1.674	0.618	15
KB5	1.673	0.618	15
NP5	1.661	0.629	14
KB2	1.638	0.530	22
PS4	1.608	0.773	8
HW1	1.573	0.683	10
KH4	1.573	0.716	9
HG1	1.565	0.578	15
KK2	1.560	0.530	19
KH2	1.516	0.524	18
KK6	1.513	0.778	7
SK3	1.476	0.545	15
KK1	1.426	0.649	9
HK2	1.423	0.731	7
KB4	1.334	0.829	5
GT2	1.310	0.546	11
KJ5	1.208	0.751	5
KP2	1.200	0.577	8
KJ3	1.110	0.400	16
KK3	1.090	0.560	7
PS2	1.080	0.421	13
NP3	1.009	0.563	6
KK4	1.007	0.626	5
KO2	0.976	0.393	12
KJ2	0.966	0.403	11
HK1	0.961	0.597	5
HG5	0.961	0.597	5
HW4	0.960	0.437	9
SK4	0.955	0.869	**3**
NP4	0.933	0.849	**3**
LG6	0.859	0.782	3
PS6	0.776	0.433	6
KO1	0.769	0.395	7
HG6	0.673	0.271	12
HK4	0.572	0.413	4
HW2	0.314	0.175	6
LG3	**0.183**	**0.167**	**3**

4.2 Water Quality

4.2.1 Water chemistry and other physical variables

The environmental parameters measured in the Mekong River and it tributaries between July 2005 to April 2007 were shown in Table 12. It was found that broad differences were apparent between sampling sites. An average water temperature in 14 sites ranged from 25.34 – 32.06 ^{o}C. The temperatures at sampling sites 1, 2 and 3 in Northern Thailand were lower than other sites in Northeastern. The highest turbidity value of 212.64 NTU was recorded at sampling site 3 whereas the lowest turbidity of 53.29 NTU was found at site 7. The velocity was highest at 8.30 m/s in sampling site 10 in the Mekong River.

Furthermore, all sampling sites showed a neutral pH. The highest value was 7.67 for sampling site 1 and lowest values was 6.75 at sampling site 9. An average alkalinity ranged from 23.3 – 67.8 mg.l^{-1} with the highest values at sampling site 5 and the lowest values in site 9. On the other hand, the highest values of conductivity was recorded for sampling site 9 which was a tributary of Mekong River in Northeastern Thailand.

The highest DO and BOD values were observed in sampling site 2 (KO) which was a tributary of Mekong River in Northern Thailand. Besides that, the highest values of average nitrate nitrogen (1.57 mg.l^{-1}) and soluble reactive phosphorus concentrations (0.24 mg.l^{-1}) were also observed in this site. The highest ammonium nitrogen of 0.53 mg.l^{-1} was recorded at site 13 and the lowest value of 0.21 mg.l^{-1} at sampling site 1.

Table 12 Environmental parameters of the Mekong River and its tributaries at fourteen sampling sites between July 2005 to April 2007 (average values and min – max values, n=14)

	Temp (°C)	Velo (m/s)	pH	Cond (µs/cm)	Turbid (NTU)	Alk (mg/L as $CaCO_3$)	DO (mg/L)	BOD (mg/L)	NO_3 (mg/L)	NH_4 (mg/L)	SRP (mg/L)
Site1	25.6 (18.1-30.8)	5.44 (1.80-9.20)	7.67 (7.30-7.98)	218.8 (153.0-312.0)	137.1 (54.0-301.0)	55.7 (9.9-103.0)	8.0 (5.4-10.0)	2.6 (1.8-4.1)	0.78 (0.10-1.90)	0.21 (0.04-0.47)	0.14 (0.06-0.55)
Site2	26.0 (20.5-29.2)	5.86 (4.00-7.80)	7.15 (6.88-7.78)	138.5 (78.9-198.2)	199.1 (57.0-305.0)	41.05 (6.9-70.2)	8.2 (5.2-11.0)	3.1 (2.0-5.0)	1.57 (0.80-3.00)	0.37 (0.29-0.46)	0.24 (0.10-1.19)
Site3	25.3 (18.5-29.8)	7.86 (3.00-12.30)	7.56 (7.20-8.10)	221.0 (162.0-270.0)	212.6 (48.0-419.0)	60.8 (17.6-97.0)	7.8 (5.2-9.8)	1.5 (0.2-3.1)	1.55 (0.20-3.40)	0.31 (0.13-0.67)	0.15 (0.02-0.67)
Site4	30.2 (23.3-35.8)	6.70 (0.50-14.30)	7.61 (7.19-8.10)	180.4 (64.0-389.0)	82.5 (3.0-438.0)	57.8 (19.0-101.0)	7.0 (4.2-8.4)	2.7 (0.4-6.4)	0.88 (0.00-1.60)	0.42 (0.15-0.72)	0.22 (0.10-0.61)
Site5	28.9 (23.9-32.8)	3.52 (0.06-5.60)	7.61 (7.01-8.70)	192.8 (49.0-325.0)	205.2 (105.0-453.0)	67.8 (35.0-104.0)	5.9 (4.8-8.6)	2.3 (0.0-5.6)	1.20 (0.20-2.00)	0.28 (0.14-0.43)	0.19 (0.14-0.29)
Site6	30.0 (26.0-33.0)	2.74 (0.00-6.20)	7.43 (7.01-7.81)	249.7 (147.0-349.0)	183.4 (96.0-367.0)	65.8 (25.0-107.0)	5.6 (4.4-8.2)	1.2 (0.2-4.4)	1.12 (0.60-1.80)	0.38 (0.16-0.58)	0.19 (0.07-0.26)
Site7	31.5 (26.5-34.1)	1.38 (0.00-6.25)	7.15 (6.36-8.11)	292.0 (146.0-401.0)	53.3 (12.0-125.0)	36.0 (8.0-85.0)	4.4 (2.6-5.8)	1.3 (0.1-3.0)	0.79 (0.50-1.10)	0.41 (0.20-0.74)	0.20 (0.07-0.40)
Site8	30.6 (25.1-32.9)	1.39 (0.00-4.40)	7.44 (6.74-7.83)	195.7 (91.0-263.0)	127.4 (28.0-266.0)	61.2 (20.5-95.0)	5.7 (4.0-8.2)	1.7 (0.2-4.9)	0.76 (0.00-1.30)	0.36 (0.17-0.55)	0.13 (0.00-0.33)
Site9	31.4 (27.0-34.8)	3.67 (0.10-10.40)	6.75 (6.00-7.51)	341.1 (127.0-759.0)	70.1 (10.0-288.0)	23.3 (4.1-45.0)	4.6 (2.2-7.0)	1.6 (0.0-3.6)	0.99 (0.20-1.80)	0.40 (0.18-0.73)	0.09 (0.01-0.20)
Site10	30.4 (24.5-32.6)	8.30 (2.04-16.50)	7.53 (6.83-7.98)	193.2 (133.5-255.0)	134.1 (23.0-271.0)	51.4 (17.0-92.0)	6.0 (4.6-8.4)	1.9 (0.3-4.6)	0.68 (0.10-1.90)	0.30 (0.14-0.54)	0.15 (0.04-0.29)
Site11	31.0 (27.1-34.8)	6.86 (0.05-14.90)	7.44 (6.76-7.93)	166.3 (66.0-255.0)	136.0 (16.0-303.0)	49.2 (18.5-87.0)	6.1 (4.6-8.6)	1.1 (0.0-4.9)	0.55 (0.10-1.20)	0.31 (0.10-0.60)	0.15 (0.00-0.37)
Site12	30.3 (22.4-36.4)	2.73 (0.03-7.10)	7.52 (6.79-7.84)	134.9 (43.0-250.0)	144.1 (22.0-325.0)	52.5 (20.0-90.0)	5.89 (4.00-8.40)	1.40 (0.10-4.80)	0.55 (0.10-1.10)	0.31 (0.16-0.61)	0.17 (0.00-0.70)
Site13	32.1 (28.0-36.0)	5.20 (0.09-8.80)	6.89 (6.17-7.90)	175.7 (80.0-265.0)	72.6 (13.0-119.0)	43.9 (10.0-73.2)	4.86 (3.60-7.20)	1.44 (0.00-5.20)	0.65 (0.00-1.90)	0.53 (0.17-0.85)	0.10 (0.02-0.30)
Site14	31.5 (27.0-34.8)	1.67 (0.00-4.70)	7.49 (6.60-8.20)	141.8 (44.0-243.0)	119.9 (14.0-260.0)	59.8 (21.0-85.0)	6.29 (4.60-8.50)	2.36 (0.60-5.10)	0.68 (0.00-1.30)	0.40 (0.11-1.07)	0.14 (0.01-0.34)

4.2.2 Correlation between environmental variables

There were significant positive and negative correlations between some of physico – chemical parameters from 14 sites in Mekong River and its tributaries between July 2005 to April 2007 as shown in Table 13. Significant positively correlation between soluble reactive phosphorus concentrations and nitrate nitrogen concentrations were found ($P<0.001$). The pH values were positively correlated with nitrate nitrogen ($P<0.01$), ammonium nitrogen ($P<0.001$) and soluble reactive phosphorus ($P<0.001$).

The conductivity was significantly correlated positively with nitrate nitrogen ($P<0.05$), soluble reactive phosphorus ($P<0.05$) and pH ($P<0.01$). The alkalinity was positively correlated with nitrate nitrogen ($P<0.01$), soluble reactive phosphorus ($P<0.001$), pH ($P<0.001$) and conductivity ($P<0.001$), there was also negative correlation with ammonium nitrogen ($P<0.001$).

The dissolved oxygen values were negatively correlated with ammonium nitrogen ($P<0.001$) and also correlated positively with pH ($P<0.001$) and alkaline ($P<0.001$). The biochemical oxygen demand was correlated positively with nitrate nitrogen ($P<0.001$), soluble reactive phosphorus ($P<0.001$), pH ($P<0.001$), alkalinity ($P<0.001$) and DO ($P<0.001$). There was also negatively correlated with ammonium nitrogen ($P<0.05$).

The water temperature was significantly correlated negatively with pH ($P<0.001$), DO ($P<0.001$) and BOD ($P<0.001$) but positively correlated with ammonium nitrogen ($P<0.001$). The velocity was significantly correlated positively with soluble reactive phosphorus ($P<0.05$) and DO($P<0.05$).

The turbidity was negatively correlated with pH ($P<0.01$), conductivity ($P<0.001$), alkalinity ($P<0.001$) and DO ($P<0.05$), but it was positively correlated with ammonium nitrogen ($P<0.05$).

Table 13 Pearson’s correlation coefficients (r) between each Water chemistry and other physical variables at fourteen sites in the Mekong River and its tributaries. Significant values of r: $P < 0.05$ = *, $P < 0.01$= **, $P < 0.001$ = ***, n=194

	NO3	*NH4*	*SRP*	*pH*	*Cond*	*Alk*	*DO*	*BOD*	*Temp*	*Velo*	*Turbid*
NO3	1										
NH4	−0.040	1									
SRP	0.360 (***)	−0.032	1								
pH	0.200 (**)	0.446 (***)	0.353 (***)	1							
Cond	0.146 (*)	−0.072	0.162 (*)	0.206 (**)	1						
Alk	0.212 (**)	−0.311 (***)	0.313 (***)	0.644 (***)	0.260 (***)	1					
DO	0.069	−0.495 (***)	0.005	0.492 (***)	0.046	0.349 (***)	1				
BOD	0.293 (***)	−0.178 (*)	0.265 (***)	0.382 (***)	0.047	0.310 (***)	0.360 (***)	1			
Temp	−0.09	0.515 (***)	0.017	−0.337 (***)	−0.053	−0.090	−0.716 (***)	−0.233 (***)	1		
Velo	0.004	0.041	0.165 (*)	0.057	0.024	0.006	0.149 (*)	0.102	−0.020	1	
Turbid	0.129	0.177 (*)	−0.032	−0.219 (**)	−0.305 (***)	−0.325 (***)	−0.139 (*)	−0.079	−0.078	0.079	1

4.2.3 Seasonal changes in physico-chemical parameters

4.2.3.1 Water temperature

The water temperature in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 18.2 – 35.6 ^{o}C (Table 12). The lowest temperature was recorded in December 2006 (cool dry season 2) at site 1 ($F_{3, 11}$ = 1503.4, $p < 0.001$). The highest temperature was observed in July 2006 (rainy season 2) at site 4 ($F_{3, 11}$ = 50.4, $p < 0.001$) (Figure 63). The water temperature of all sampling sites in the Northern region (site 1-3, Figure 63) were generally lower than other sampling sites.

There were large differences in water temperature over the two years between the seasons (July 2005 – April 2007) (Figure 63). The average percentages of difference between each season were 109%, 102% and 92% in rainy season, cool dry season and summer, respectively. One hundred and thirty two percents difference between each season were recorded in rainy season at sampling site 4 which showed the highest values with the lowest values of 86% in summer at sampling site 9. Similar temperature was observed at sampling sites 1, 2 and 3 in Northern Thailand which were lower than those from sampling sites in the North-Eastern Thailand (site 4-14). Furthermore in summer, the observed temperature was high at all sites (Figure 63C).

The seasonal changes in water temperature at 14 sites were shown in Figure 62. The seasonal pattern of water temperature in each sampling site was different between Northern (site 1-3, Figure 64A) and North-Eastern (site 4-14, Figure 64B-E) regions of Thailand. At Northern Thailand sites, the water temperature was lowered down in July 2006 (rainy season 2, weeks 51). However, the temperature was increased in all North-Eastern sites during the same period of time. There was a significant difference in the water temperature at all sites except for site 12 that was not significant over the last 4 sampling times of the study.

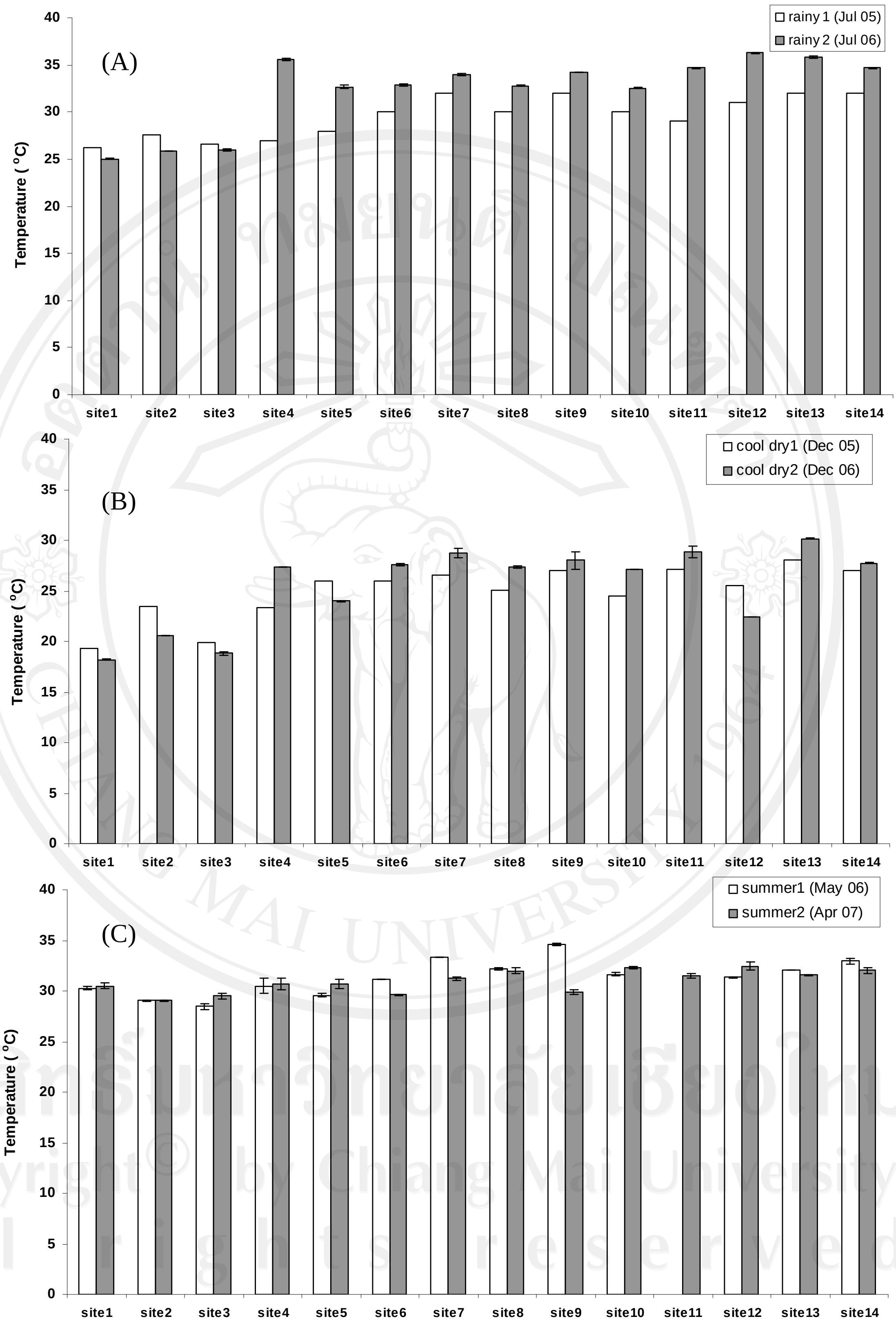


Figure 63 Seasonal changes in water temperature at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

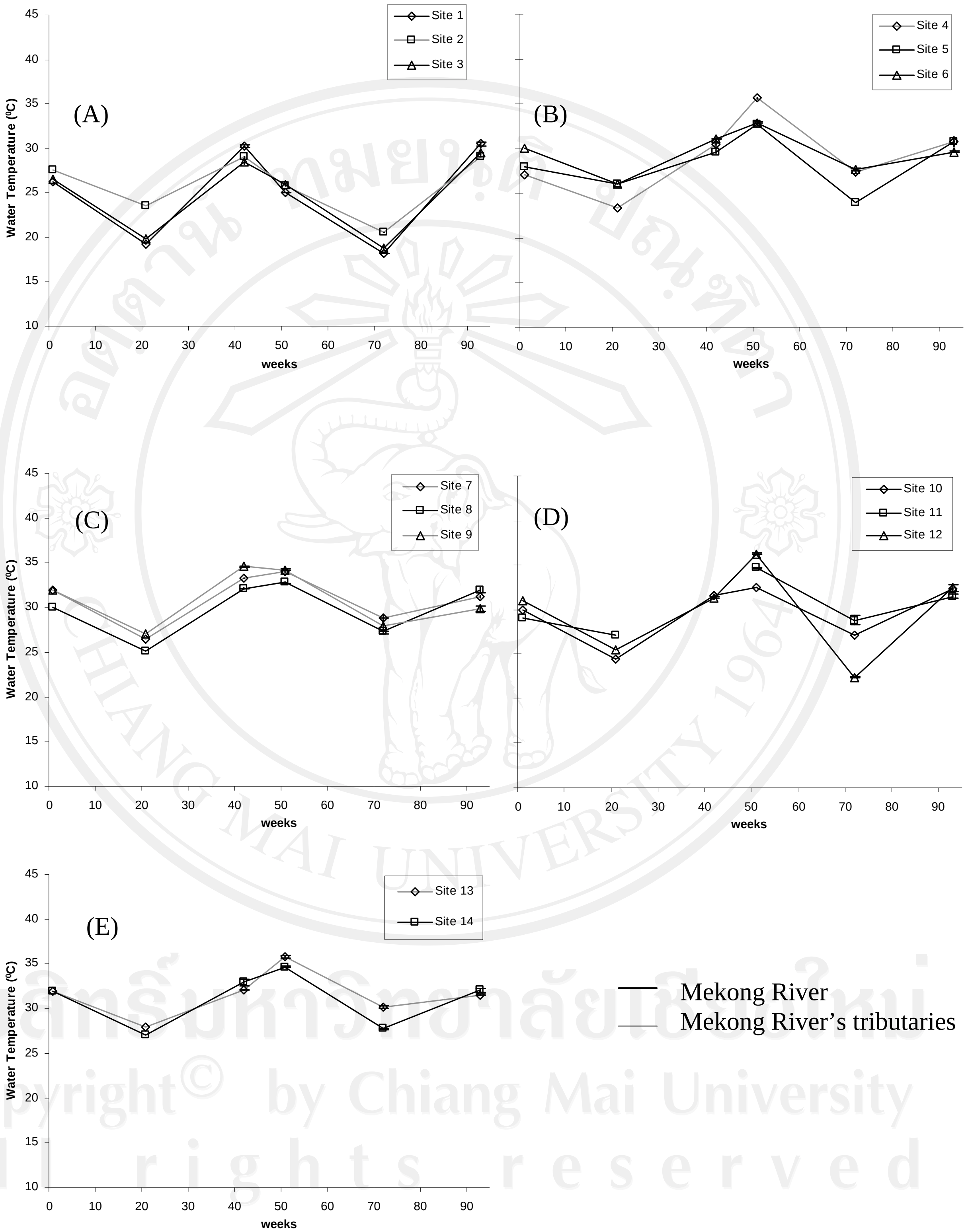


Figure 64 Seasonal changes in water temperature at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.2 Turbidity

The turbidity in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 4 – 453 NTU (Table 12). The lowest values were recorded in December 2006 (cool dry season 2) at site 4. The highest turbidity were observed in July 2005 (rainy season1) at site 5 (Figure 65). The turbidity in two rainy seasons samples were the highest turbidity among all sampling sites recorded, with the highest values in site 5, except for site 7 and 9.

There were differences in turbidity over the two year period between the seasons (July 2005 – April 2007). The average percentages of difference between each season were 117%, 108% and 79% in cool dry season, rainy season and summer, respectively. Four hundred and fifty one percents of different between each season were recorded in cool dry season at sampling site 3 which showed the highest values whereas the lowest values of 3% was found in cool dry season at sampling site 4.

The turbidity in two summer were the lowest turbidity of all sampling sites recorded except for sampling site 1 in April 2007 (hot2). It was found that the turbidity values at sampling site 2, 4, 7 9 and 13 that were a tributary of Mekong River was lower than sampling site 1, 3, 5, 6, 8, 10, 11 12 and 13 that were Mekong River except for site 4 in July 2005 (rainy season1) .

The seasonal changes in turbidity at 14 sites are shown in Figure 66. The turbidity was high in July 2005 (rainy season 1, weeks 1) then decreased in December 2005 (cool dry season 1, weeks 21) and remained low until May 2006 (summer1, weeks 42), then increased to the highest level in December 2006 (cool dry season 2, weeks 51). The highest turbidity was observed for sampling site 5 ($F_{3, 11} = 486.7$, $p < 0.001$), then decreased in December 2006 (cool dry season 2, weeks 72) and remained low until April 2007 (summer2, weeks 93). An exception for this pattern was site 2 ($F_{3, 11} = 327.6$, $p < 0.001$), site 4 ($F_{3, 11} = 927.2$, $p < 0.001$) and site 9 ($F_{3, 11} = 26.2$, $p < 0.001$). There was significant difference in turbidity at all sampling sites over the last 4 sampling times of the study.

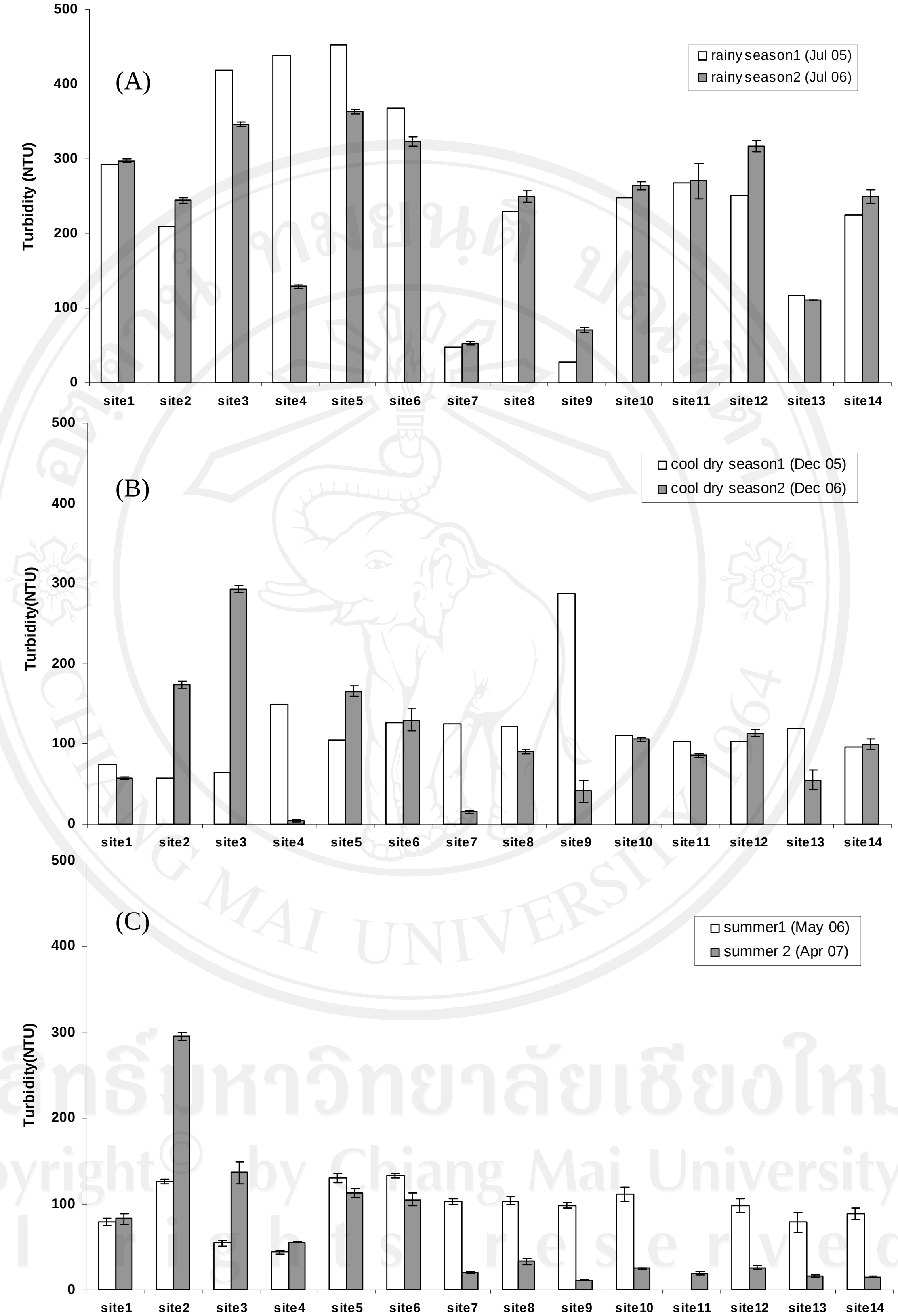


Figure 65 Seasonal changes in turbidity at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

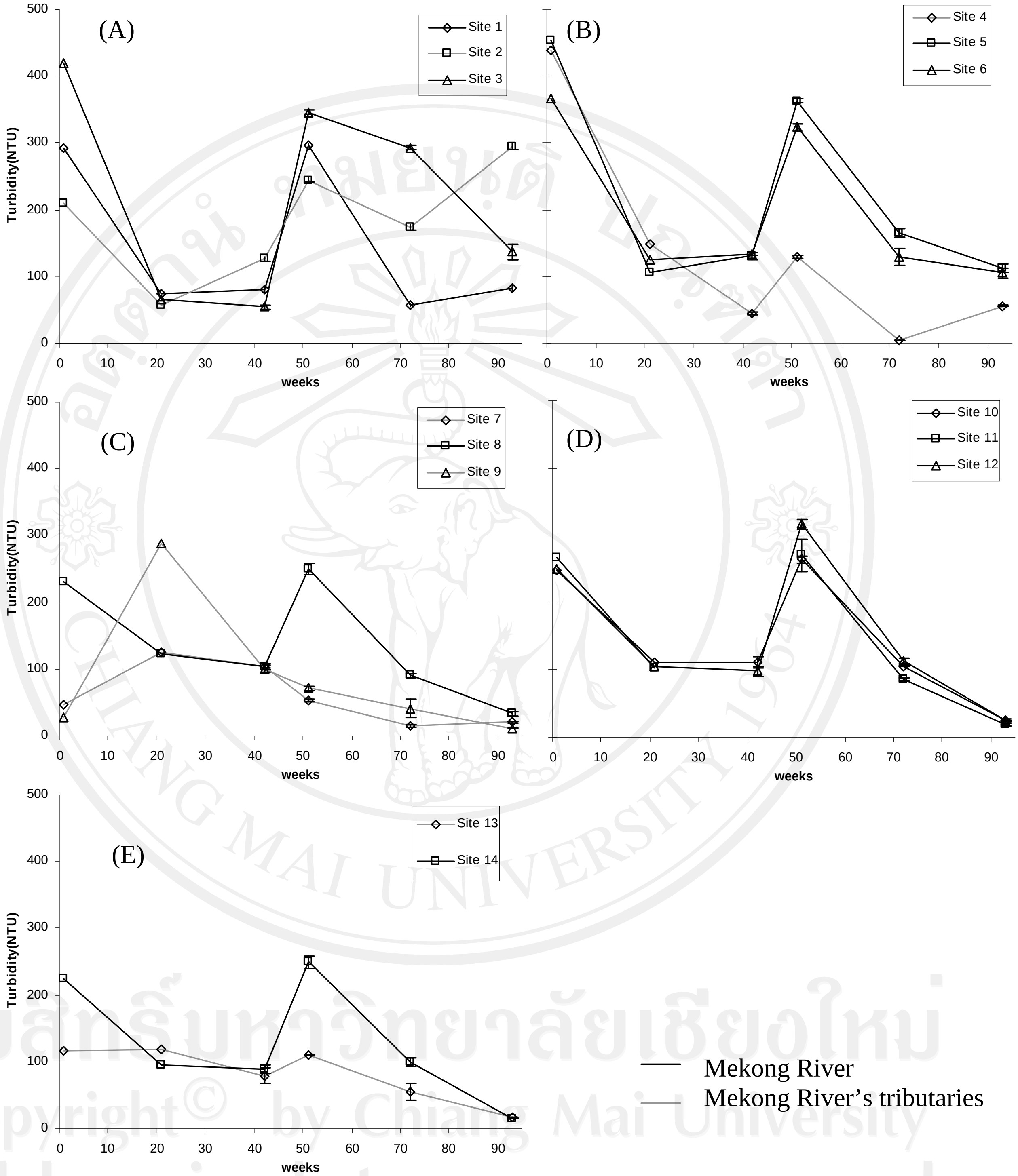


Figure 66 Seasonal changes in turbidity at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean $\pm$ standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.3 Conductivity

The conductivity in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 43.0 – 759.0 μS.cm^{-1} (Table 12). The lowest values were detected in December 2006 (cool dry season 2) at site 12. The highest values were observed in December 2006 (cool dry season 2) at site 9 (Figure 67). The conductivity in two rainy seasons (July 2005 (rainy season 1) and July 2006 (rainy season 2)) were generally the lowest concentrations among all sampling sites recorded, with the lowest concentration in site 11($F_{3, 11}$ = 242.3, $p < 0.001$). Beside that the conductivity in July 2005 (rainy season 1) was higher than July 2006 (rainy season 2). In addition, there was very high conductivity at sampling site 9 in two cool dry season (December 2005 (cool dry season 1) and December 2006 (cool dry season 2) in comparison with other sampling sites at the same time.

There were differences in conductivity between the seasons (July 2005 – April 2007) over the two years of study. The average percentages of difference between each season were 137%, 84% and 63% in summer, cool dry season and rainy season, respectively. Two hundred and thirteen percents of difference between each season were observed in summer at sampling site 4 which showed the highest value whereas the lowest value of 26% was found in cool dry season at the same site.

The seasonal changes in conductivity at 14 sites were shown in Figure 68. At sampling site 1, 2 and 3 in Northern Thailand, the conductivity was increased in December 2005 (cool dry season 1, weeks 21) and decreased in May 2006 (summer1, weeks 42) and remained low at rainy season 2. The lowest conductivity was found at sampling site 2 ($F_{3, 11}$ = 168.9, $p < 0.001$) then increased in December 2006 (cool dry season 2, weeks 72) and remained high in April 2007 (summer2, weeks 93). An exception to this pattern was in site 2 in May 2006 (summert1, weeks 42) (Figure 68A).

The lowest values of the sampling period was observed at sampling site 4, 5, 12, 13 and 14 in North-Eastern Thailand in December 2006 (cool dry season 2, weeks 72). In April 2007 (summer2, weeks 93), the highest conductivity of the sampling period for all sampling sites in North-Eastern Thailand was recorded except for site 9 that shown highest values in December 2006 (cool dry season 2, weeks 72) ($F_{3, 11}$ = 10110.6, $p < 0.001$). There were also a significant difference in conductivity at all sampling sites over the last 4 sampling times of the study.

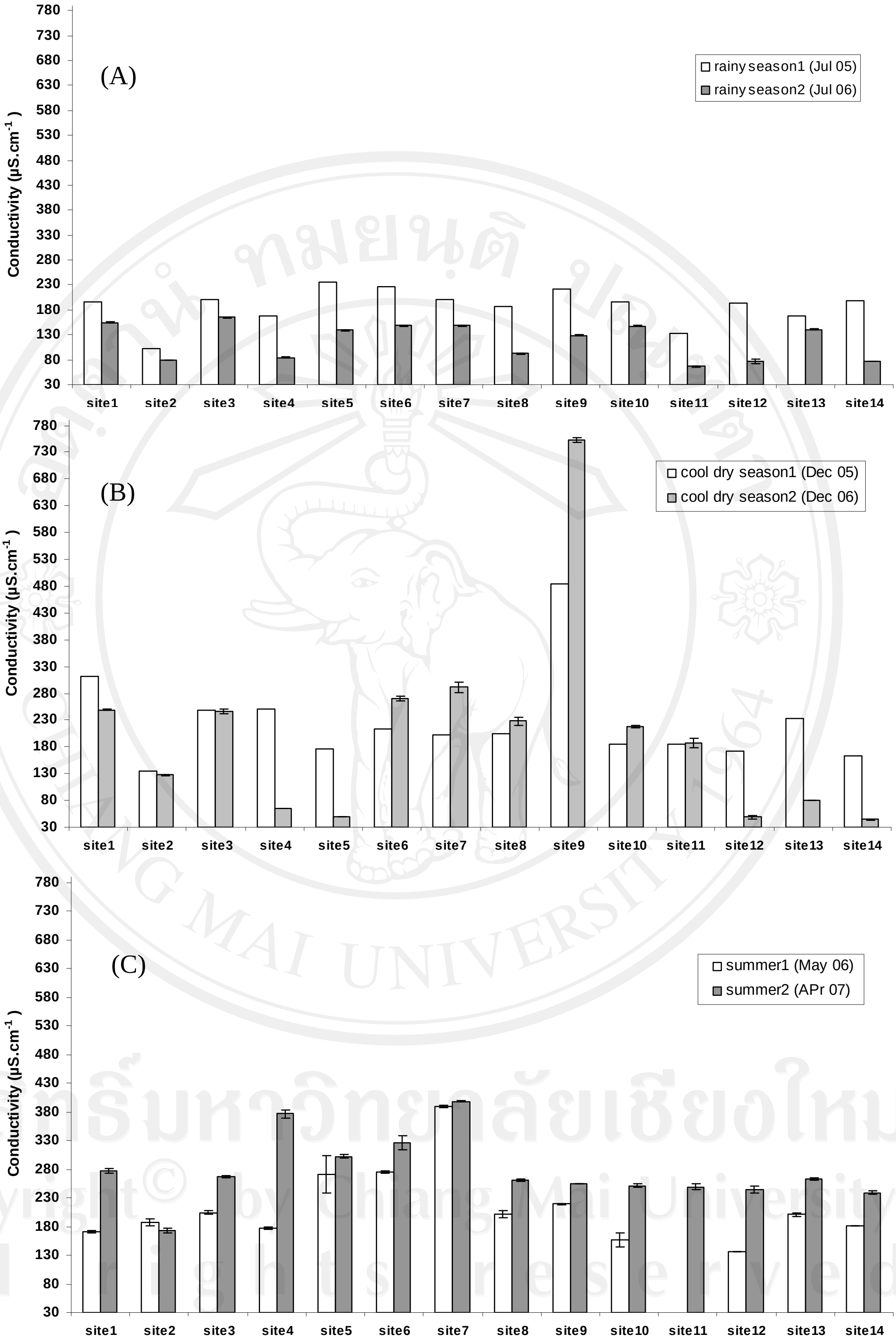


Figure 67 Seasonal changes in conductivity at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except July and December 2005, when n = 1.

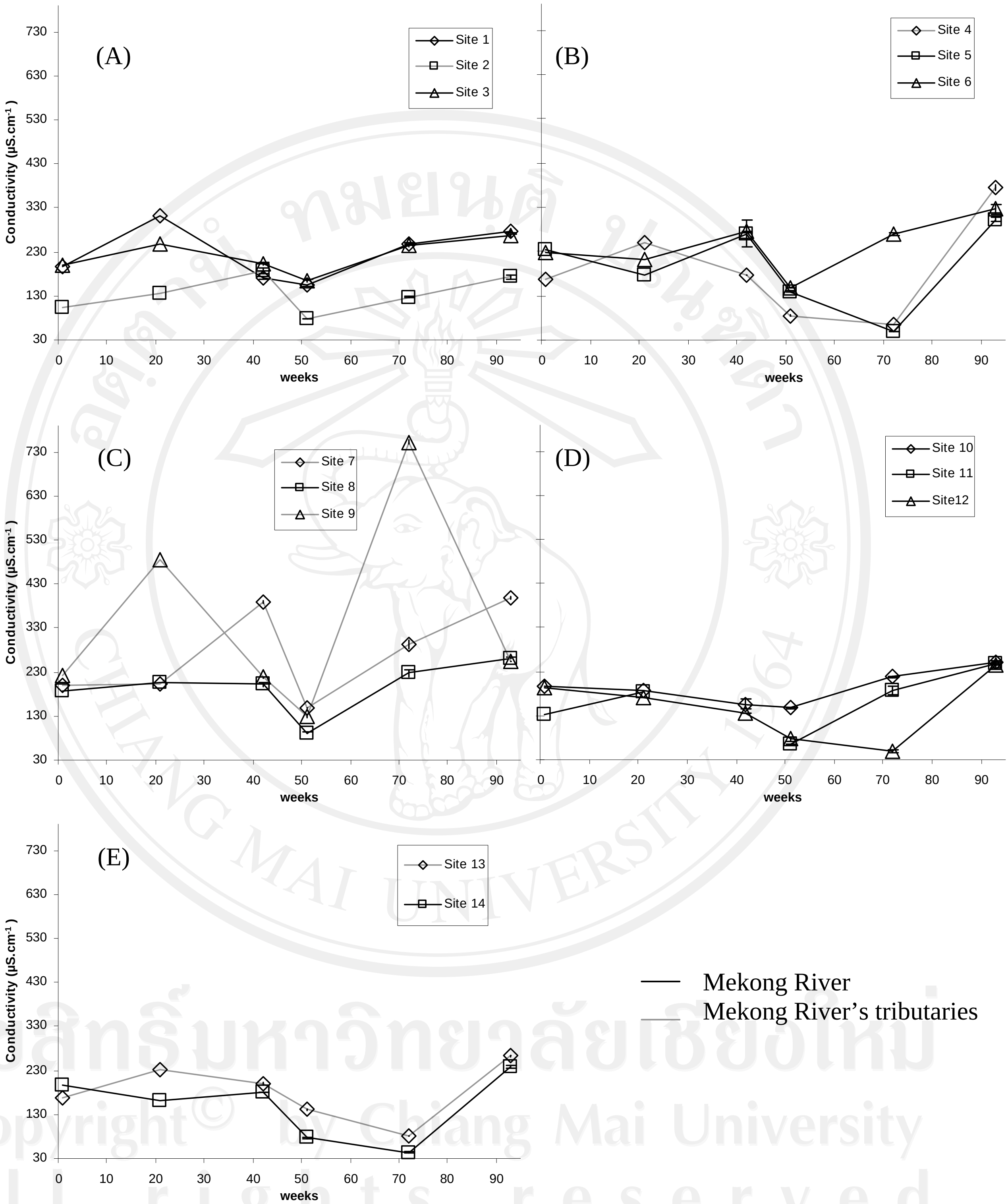


Figure 68 Seasonal changes in conductivity at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.4 pH

The pH value in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 6.00- 8.70 (Table 12). The lowest values were observed in July 2005 (rainy season1) at site 9 and the highest values in December 2005 (cool dry season 1) at site 5 (Figure 69). At sampling site 9 in two rainy seasons (July 2005 (rainy season 1) and July 2006 (rainy season 2), there was very low pH values compared with other sampling sites at the same time.

There were differences in pH values between seasons over the two years (July 2005 – April 2007). The average percentages of difference between each season were 104%, 99% and 93% in summer, cool dry season and rainy season, respectively. One hundred and nineteen percents of difference between each season were observed in cool dry season at sampling site 7 which presented the highest value whereas the lowest value of 85% was found in cool dry season at sampling site 5.

The seasonal changes in pH at 14 sites were shown in Figure 70. At site 1, 2 and 3 in Northern Thailand, similar pH was found throughout the sampling period and there was no significant differences over the last 4 sampling times of the study at site 3. On the other hand, there were significant differences in site 1 ($F_{3, 11} = 47.65$, $p < 0.001$) and 2 ($F_{3, 11} = 10.61$, $p < 0.01$).

In tributaries of the Mekong River in North-Eastern Thailand, at site 7, 9 and 13, the pH values were lower than those from other sampling sites in the Mekong River (site 5, 6, 8, 10, 11, 12 and 14) except for site 7 in December 2006 (cool dry season 2, weeks 72) which showed the highest pH. Beside that, the lowest pH was observed in July 2006 (rainy season 2, weeks 51) throughout the sampling period at all sampling sites in North-Eastern Thailand. In addition, there was a significant difference in pH at all sampling sites over the last 4 sampling times of the study except for site 3.

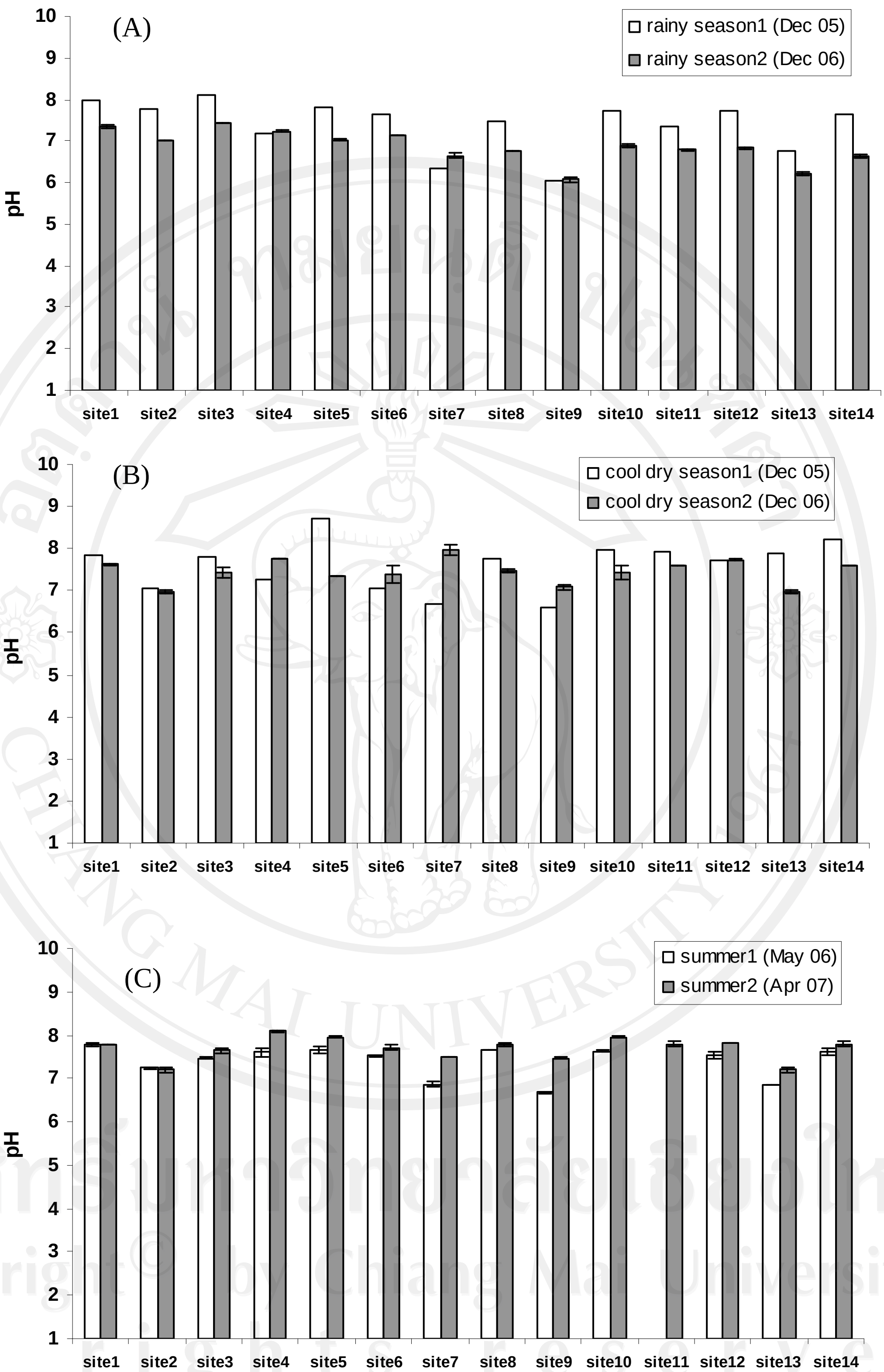


Figure 69 Seasonal changes in pH concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

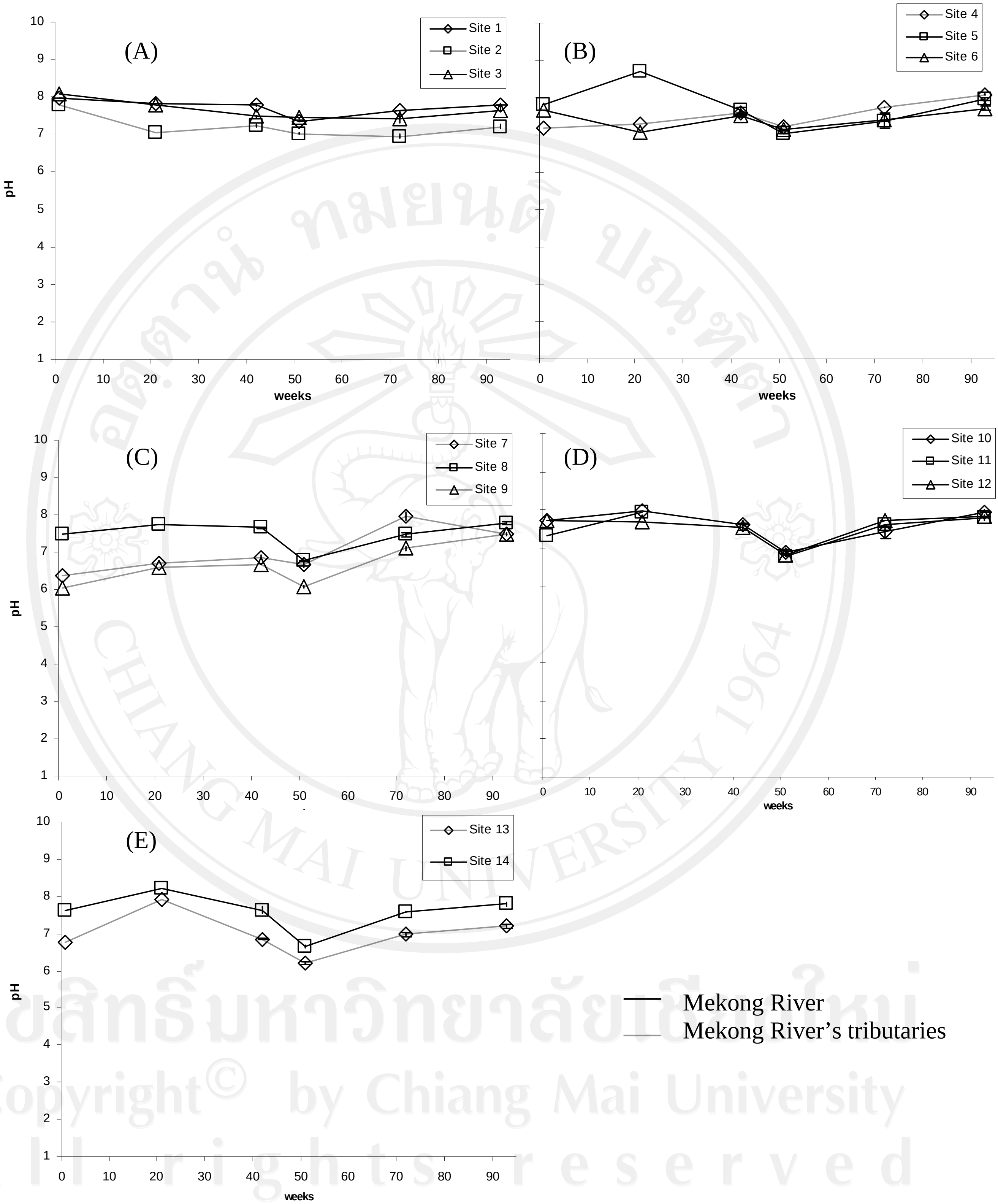


Figure 70 Seasonal changes in pH concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.5 Alkalinity

The alkalinity in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 14 - 107 mg.L^{-1} (Table 12). The lowest value was recorded in December 2006 (cool dry season 2) at site 9 and the highest value in April 2007 (summer2) at site 6 (Figure 67). The alkalinity in site 7 and site 9 were very low in comparison with other sampling sites in all time except for April 2007 (summer2) at site 7 that shown high values. Further more, the alkalinity was generally high in two summer for all sampling sites.

There were differences in alkalinity between the seasons over the two years period (July 2005 – April 2007). The average percentages of difference between each season were 150%, 75% and 37% in cool dry season, rainy season and summer, respectively. Two and thirty six percents of difference between each season were observed in summer at sampling site 10 which showed the highest value whereas the lowest value of 14% was found in rainy season at sampling site 1.

The seasonal changes in alkalinity at 14 sites were shown in Figure 68. The seasonal pattern in alkalinity in each sampling site was different between Northern (site 1-3, Figure 72A) and North-Eastern (site 4-14, Figure 72B-E) Thailand. For sampling sites in Northern Thailand, at sampling site 1 and 3 in Mekong River, the alkalinity was decreased in December 2006 (cool dry season 2, weeks 72) and increased in May 2006 (summer1, weeks 42). This value was then decreased down again in July 2006 (rainy season 2, weeks 51) to the lowest value, and increased to the highest values of all sites in April 2007 (summer2, weeks 93) . An exception to this pattern was in site 2 ($F_{3, 11} = 602.17$, $p < 0.001$).

At sites in North-Eastern Thailand, alkalinity was increased in December 2005 (cool dry season 1, weeks 21) and decreased down until July 2006 to the lowest values at all sampling sites (rainy season 2, weeks 51). This value was then increased up until April 2007 (summer2, weeks 93) that shown the highest values. An exception to this pattern was for site 7 ($F_{3, 11} = 722.02$, $p < 0.001$), site 9 ($F_{3, 11} = 220.76$, $p < 0.001$) and site 13 ($F_{3, 11} = 1059.88$, $p < 0.001$) which were a tributaries of Mekong River. In addition, there was a significant difference in alkalinity at all sampling sites over the last 4 sampling times of the study.

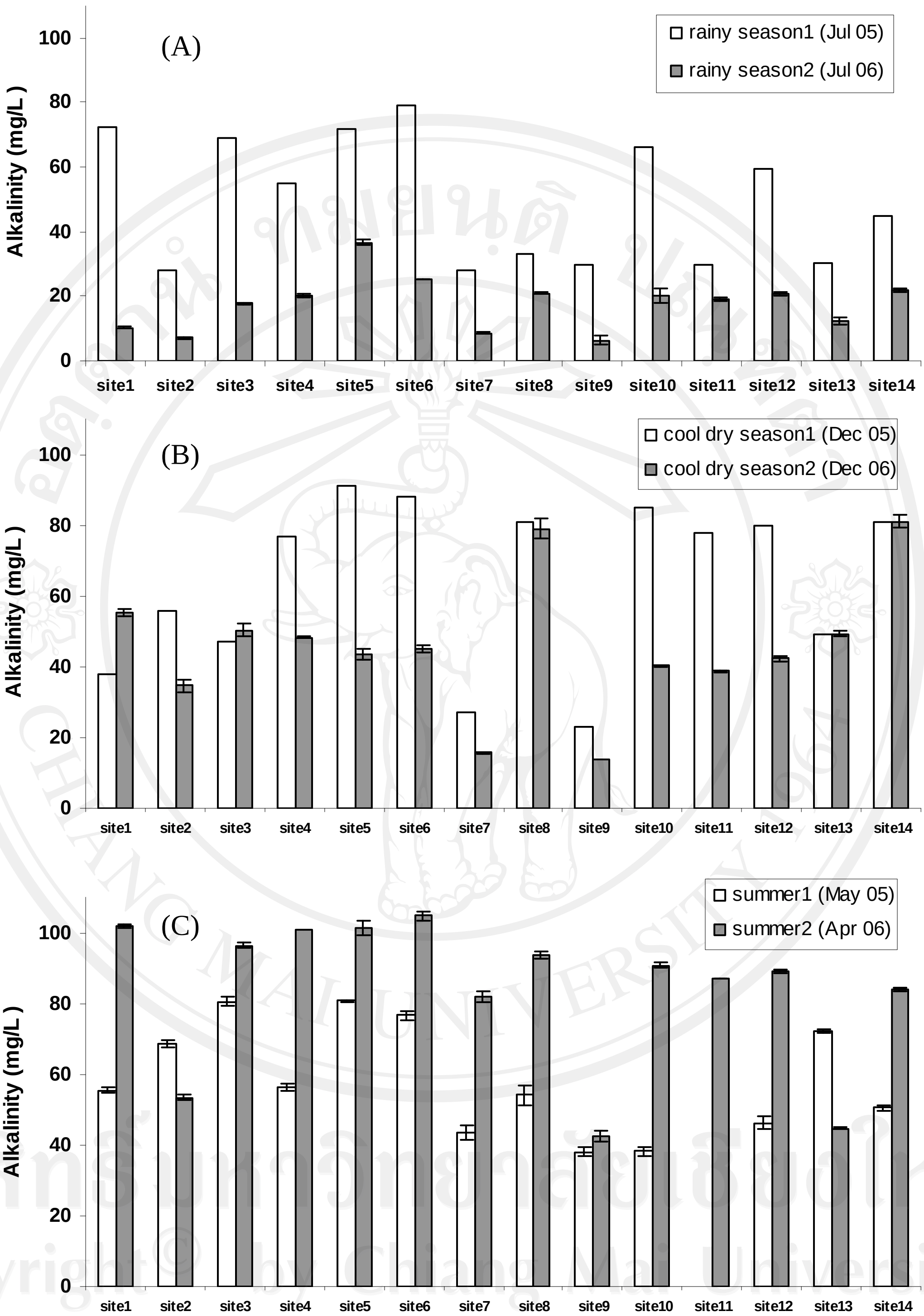


Figure 71 Seasonal changes in alkalinity concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean <u>+</u> standard error, n = 3, except weeks 1 & 21, when n = 1.

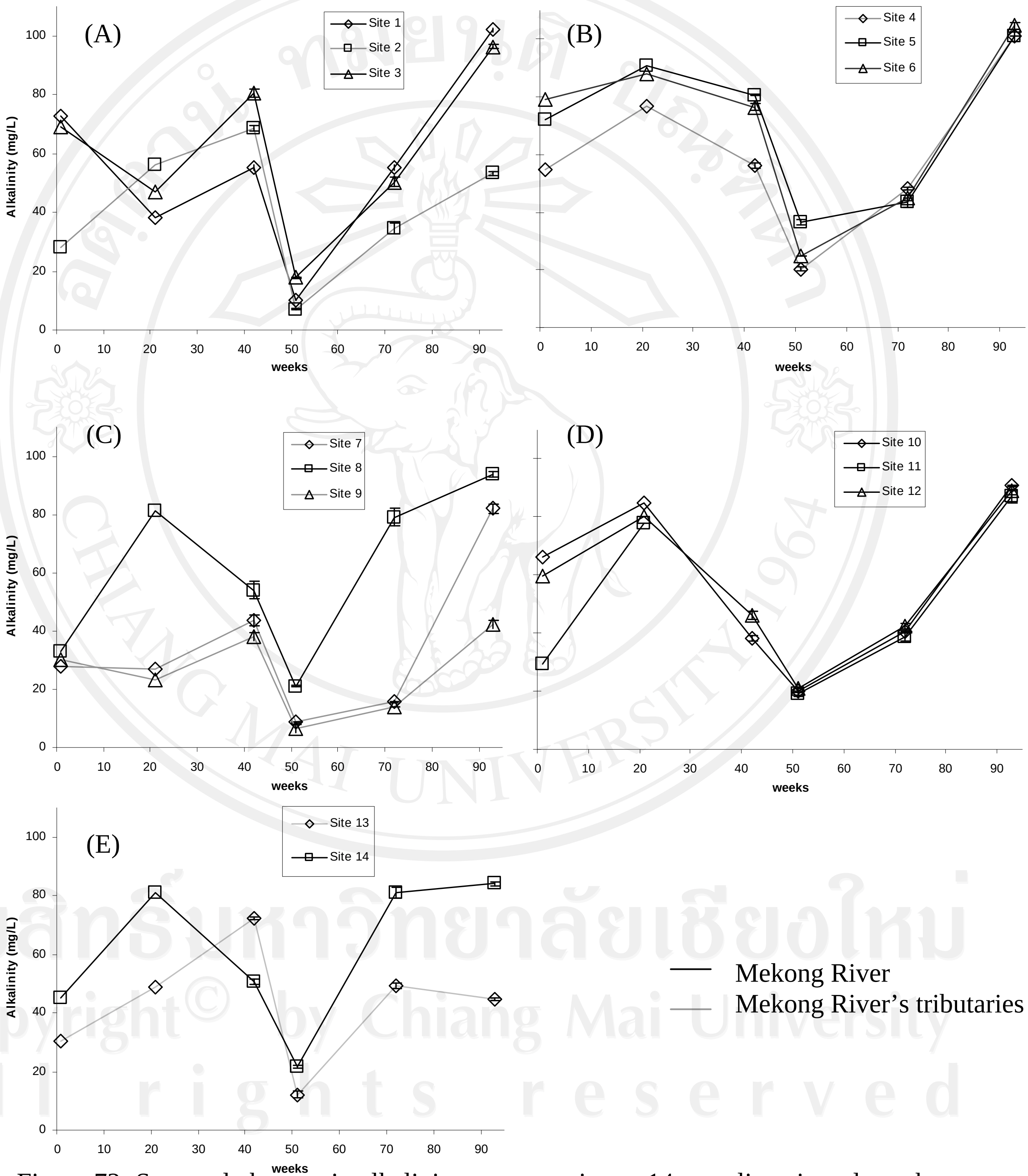


Figure 72 Seasonal changes in alkalinity concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.6 Dissolved oxygen

The dissolved oxygen concentrations in the Mekong River and its tributaries between July 2005 to April 2007 were ranged from 2.20 – 10.93 $mg.L^{-1}$ (Table 12). The lowest value was measured in July 2005 (rainy season 1) at site 9. The highest concentration was observed in December 2006 (cool dry season 2) at site 2 (Figure 73). The dissolved oxygen concentrations in two rainy seasons sampling were generally the lowest concentrations among all sampling sites recorded, with the lowest concentration in site 9. In two cool dry seasons, there were generally the highest of all sampling sites except for site 7.

There were differences in dissolved oxygen concentrations over the two years period (July 2005 – April 2007). The average percentages of difference between each season were 113%, 110% and 98% in rainy season, summer and cool dry seasons, respectively. One hundred and seventy four percents of difference between each season were determined in cool season at sampling site 7 that presented the highest values whereas the lowest value of 83% was found in rainy season at sampling site 3 and 10.

High oxygen concentrations were recorded at sampling sites 1, 2 and 3 in Northern Thailand for all seasons. In tributaries of the Mekong River in North-Eastern Thailand, at site 7, 9 and 13, lower oxygen concentrations were observed these value were lower than those of sampling sites 5, 6, 8, 10, 11, 12 and 14 in the main river.

The seasonal changes in dissolved oxygen concentrations at 14 sites are shown in Figure 69. The lowest oxygen concentrations in rainy season and remained high until cool dry seasons except in December 2005 (cool dry season 1, weeks 21) at site 7 ($F_{3, 11} = 276.18$, $p < 0.001$). oxygen concentrations decreased in summer, except for April 2007 (summer2, weeks 93) at site 3 ($F_{3, 11} = 21.95$, $p < 0.001$) and site 4 ($F_{3, 11} = 157.41$, $p < 0.001$). Sampling site 10 ($F_{3, 11} = 332.85$, $p < 0.001$), site 11($F_{3, 11} = 1163.4$, $p < 0.001$) and site 12 ($F_{3, 11} = 425.92$, $p < 0.001$) (Figure 74D) showed the same spatial pattern of dissolved oxygen throughout the sampling period.

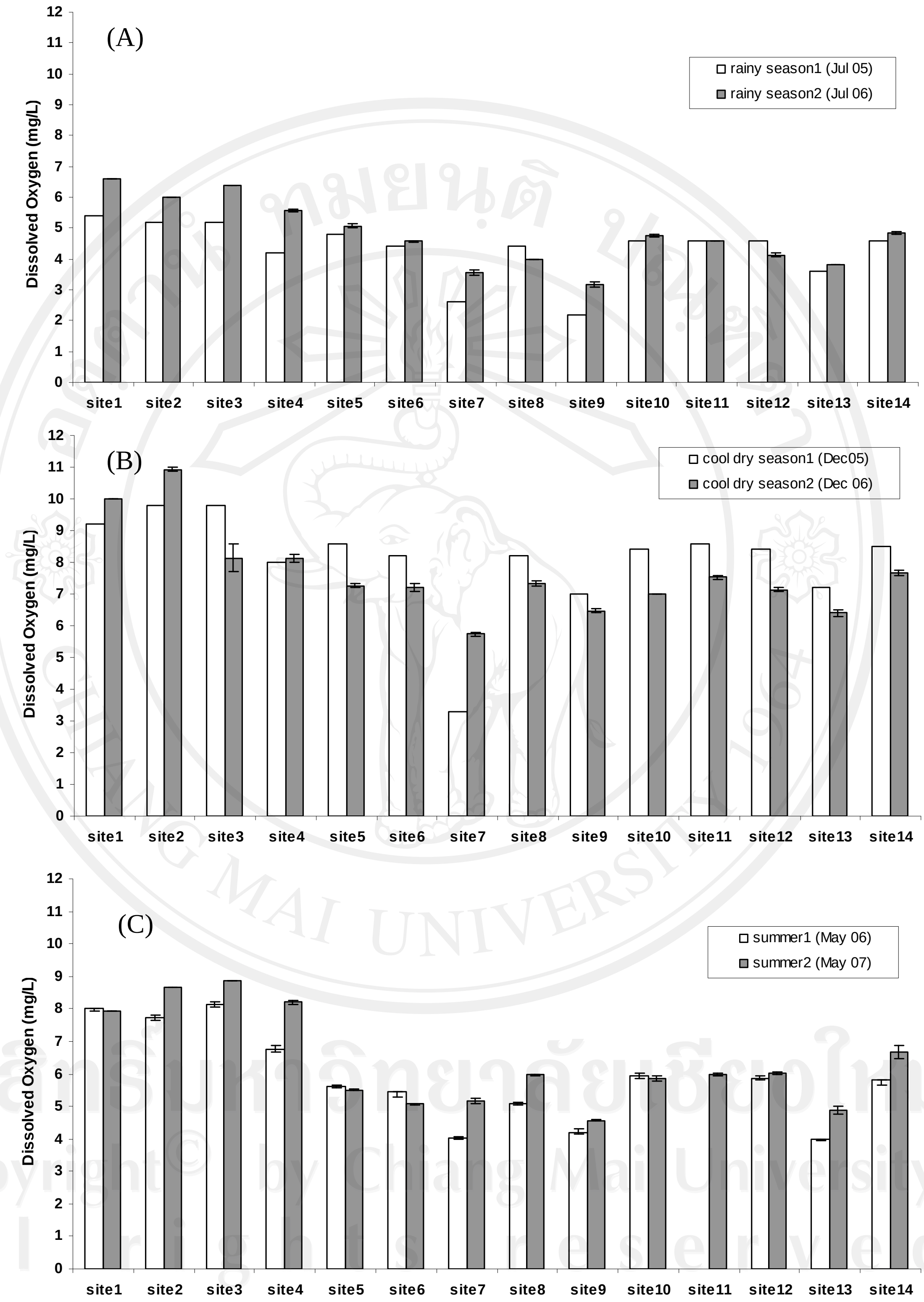


Figure 73 Seasonal changes in dissolved oxygen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean $\pm$ standard error, n = 3, except July and December 2005, when n = 1.

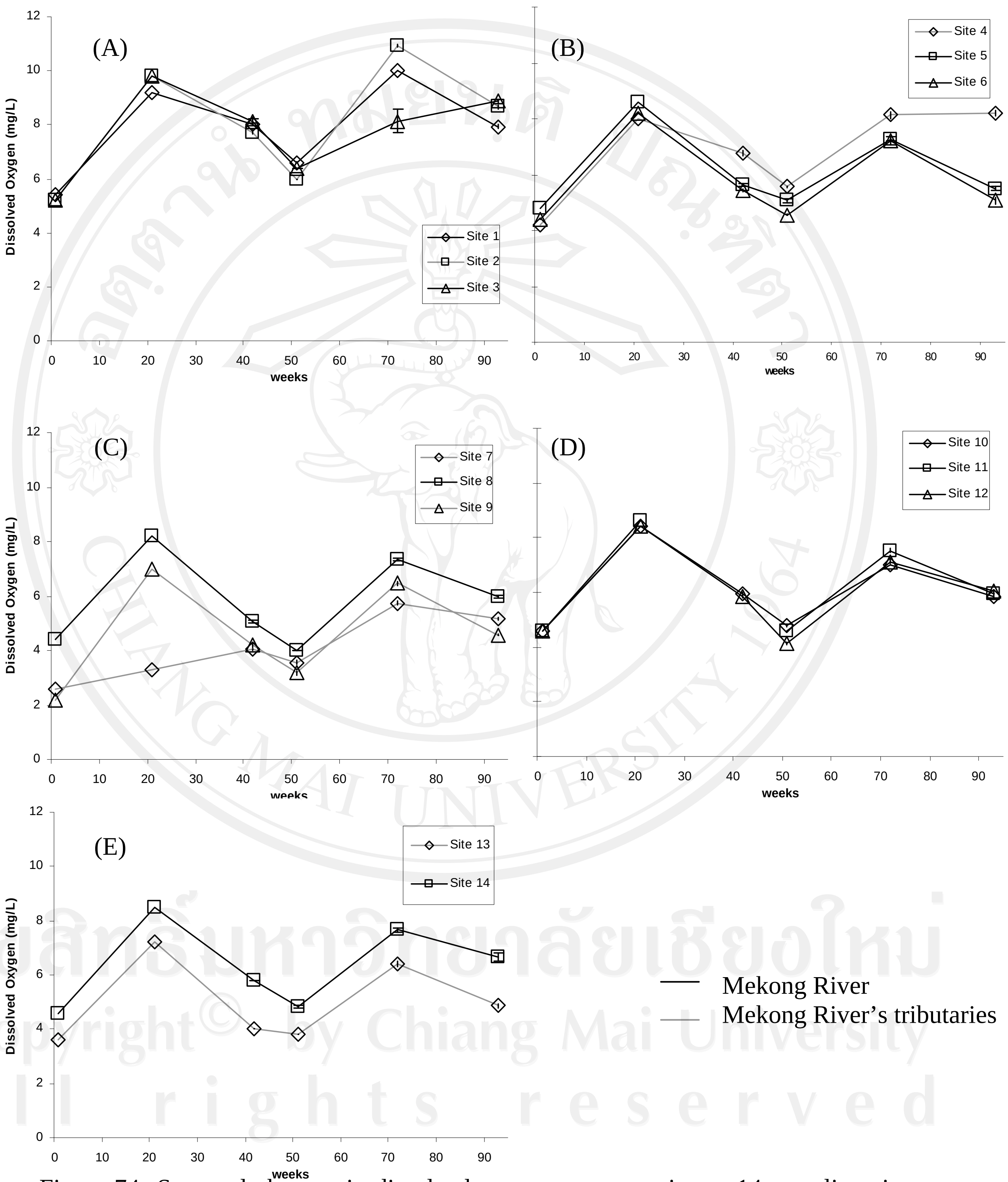


Figure 74 Seasonal changes in dissolved oxygen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.7 Biochemical Oxygen Demand

The biochemical oxygen demand in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 0.07 – 5.50 mg.L^{-1} per 5 days (Table 12). The highest of BOD was observed in April 2006 (summer2) at site 5 with the lowest values in July 2006 (rainy season 2) at site 13 (Figure 75).

There were large differences in biochemical oxygen demand over the two year period between the seasons (July 2005 – April 2007). The average percentages of difference between each season were 69%, 54% and 34% in hot, cool dry season and rainy season, respectively. Four hundred and six percents difference were observed in cool dry season at sampling site 4 which presented the highest values whereas the lowest values of 4% was recorded in rainy season at sampling site 13.

It was found that the values in July 2006 – April 2007 were generally higher than other comparable seasons during July 2005 – April 2006 except in rainy season at sampling site 1 and 2, cool dry seasons at sampling site 4 and summer at sampling site 1, 2 , 4, 5 and 14.

The biochemical oxygen demand in rainy season (July 2006) were the lowest value from all sampling sites recorded except for sampling site 1 and 2. It was found that the BOD value at sampling site 2, a tributary of Mekong River, was higher than sampling site 1 and 3, Mekong River in Northern Thailand, except in two rainy seasons.

The seasonal changes in biochemical oxygen demand at 14 sites are shown on Figure 76. Similar concentrations of BOD was observed at site 2 throughout the sampling period and showed no significant difference over the last 4 sampling times of the study.

At sites in North-Eastern Thailand, BOD was increased in December 2005 (cool dry season 1, weeks 21) then decreased in May 2006 (summer1, week 42) and remained low until July 2006 (rainy season 2, week 51) which was the lowest concentration. An exception to this pattern was site 4 and site 7 ($F_{3, 11} = 31.84$, $p < 0.001$) and sampling site 4 ($F_{3, 11} = 6.70$, $p < 0.05$).

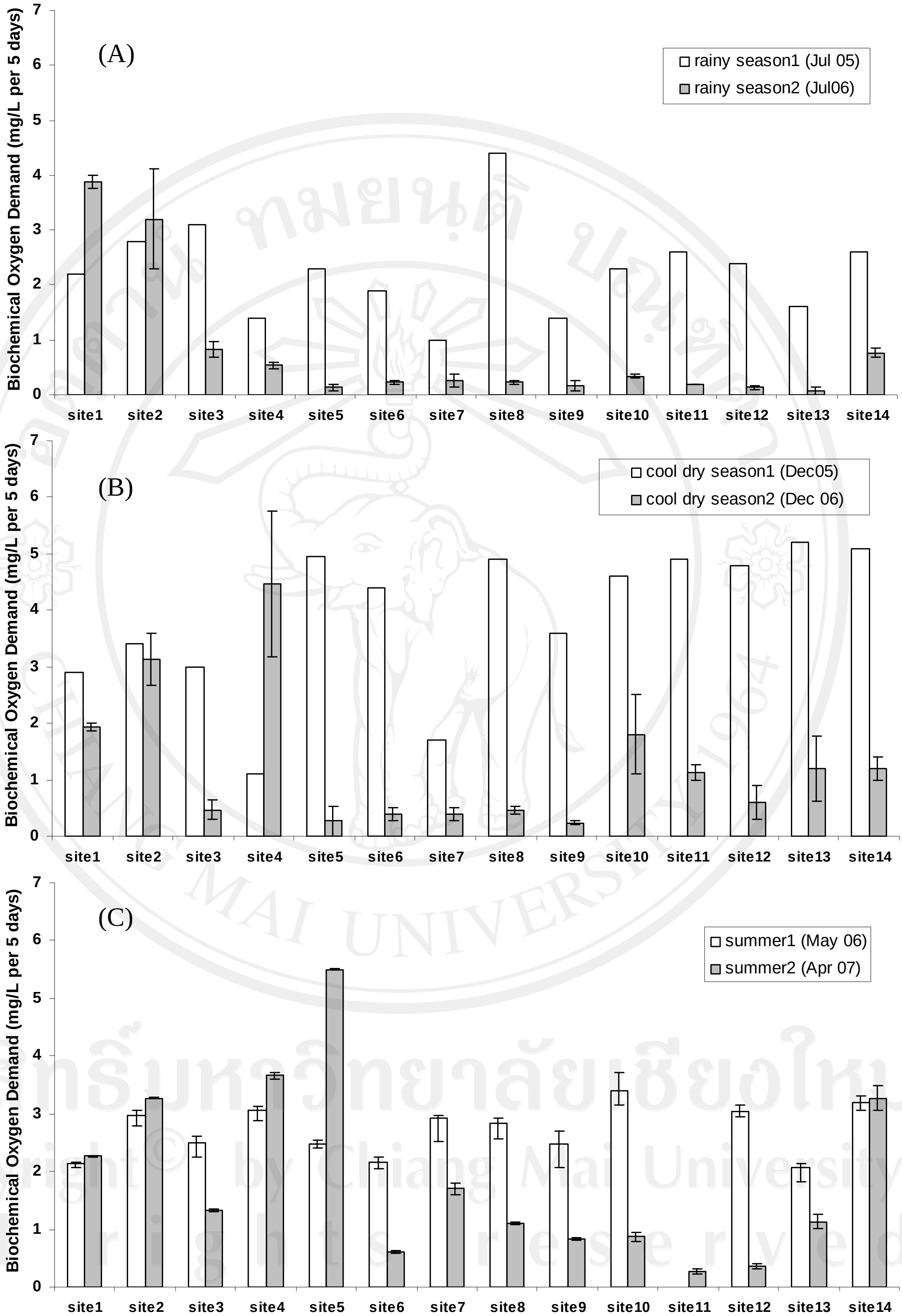


Figure 75 Seasonal changes in biochemical oxygen demand concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean <u>+</u> standard error, n = 3, except July and December 2005, when n = 1.

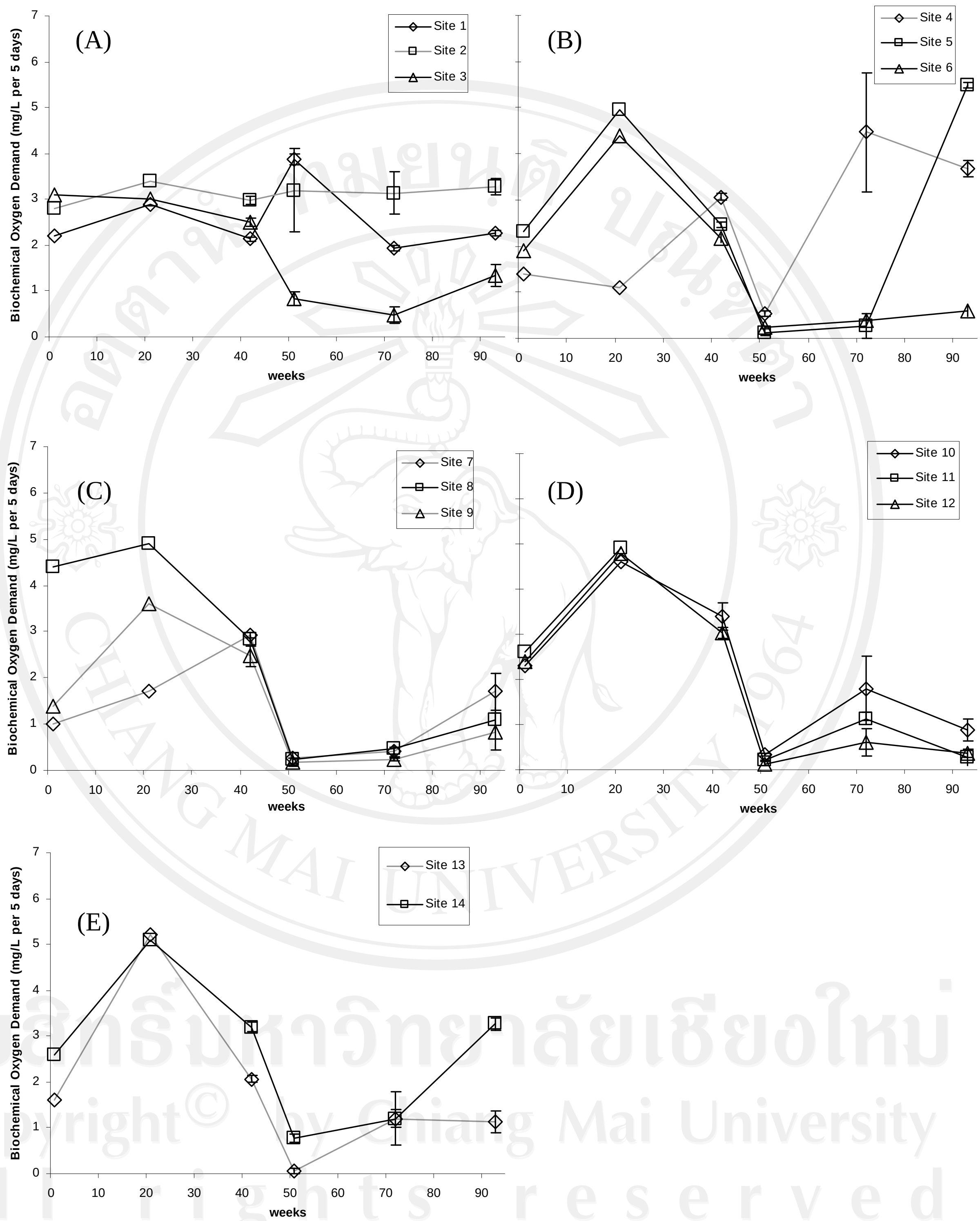


Figure 76 Seasonal changes in biochemical oxygen demand concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007.
Values mean $\pm$ standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.8 Nitrate nitrogen

The nitrate concentrations in Mekong River and their tributaries between July 2005 to April 2007 ranged from 0.13 – 3.00 $mg.L^{-1}$(Table 12) (Figure 77) with the highest values in May 2006 (summer1) at site 10 and in December 2006 (cool dry season 2) at site 1. The lowest concentrations were observed in July 2005 at site 2. The nitrate concentrations in July 2006 (rainy season 2) were lower than another season at all sampling sites. During rainy season, the values were similar to that observed at all site except for site 2, 3, 5 and 13 in July 2005 (rainy season 1) that had higher values and site 4 and 11 in July 2006 which showed lower values. It was found that at sampling site 2, a tributary of Mekong River in the Northern Thailand had higher values than those from sampling site 1 and site 3 twice during cool dry seasons (Figure 77B)

There were large differences in nitrate nitrogen concentrations over these two year between the seasons (July 2005 – April 2007). The average percentage of difference between each season were 173%, 92% and 37% in summer, cool dry season and rainy season, respectively. Eight hundred and seventy five percents difference between each season were observed in summer at sampling site 10 that presented the highest values whereas the lowest values of 10% were found in rainy season at sampling site 2.

In Figure 74, the seasonal pattern of nitrate concentrations was changed in all season except at site 7, 11, 12 and 13 that exhibited similar values during each season and showed no significant difference over the last 4 sampling times of the study.

Similar pattern was observed twice in each season at sampling sites 1, 2 and 3 in Northern Thailand. Nitrate concentrations were high in rainy season and decreased in cool dry season with higher nitrate concentrations in summer (Figure 78A). An exceptional was in site 2 ($F_{3, 11} = 5.16$, $p < 0.05$) in December 2006 (cool dry season 2, week 72).

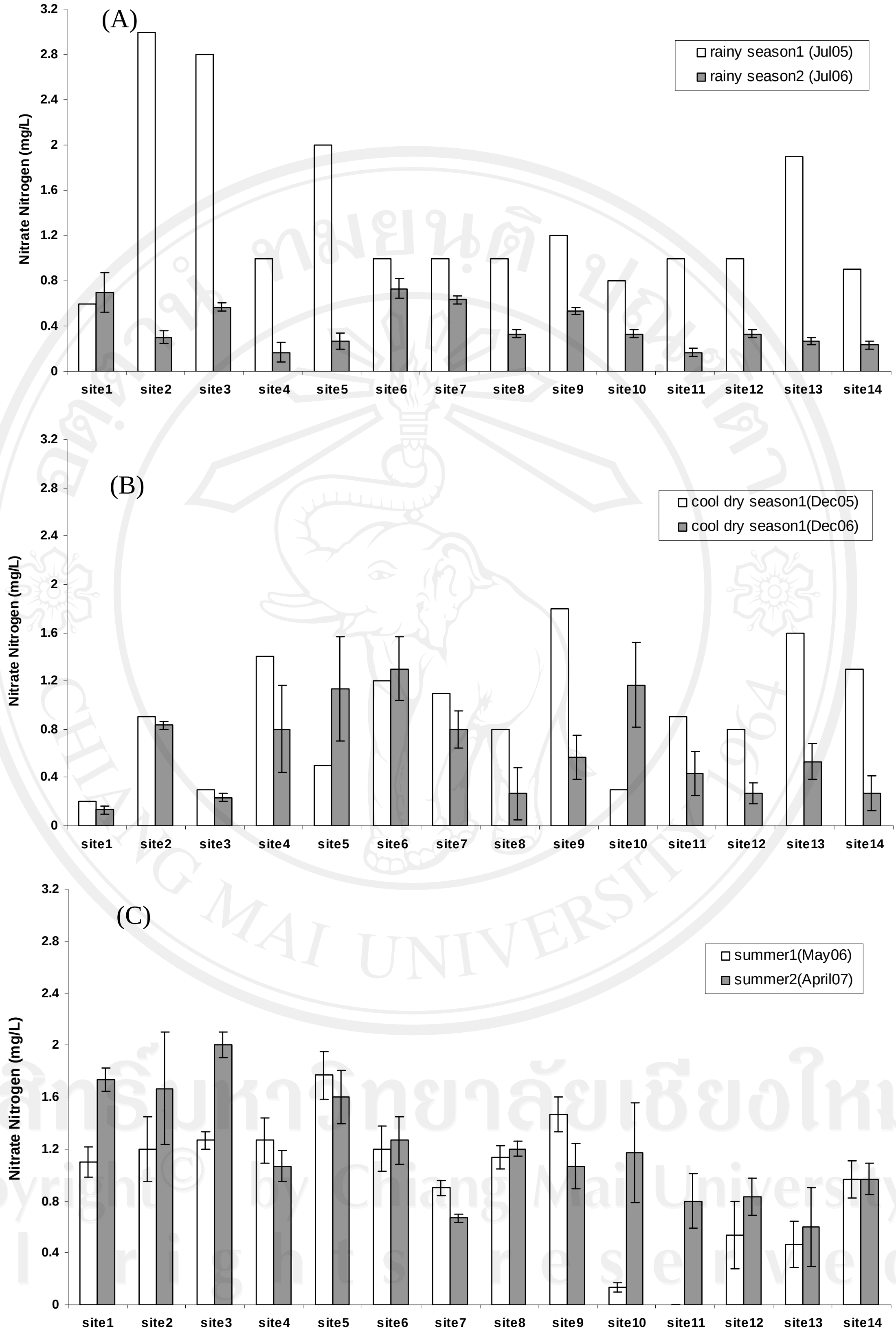


Figure 77 Seasonal changes in nitrate nitrogen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean $\pm$ standard error, n = 3, except July and December 2005, when n = 1.

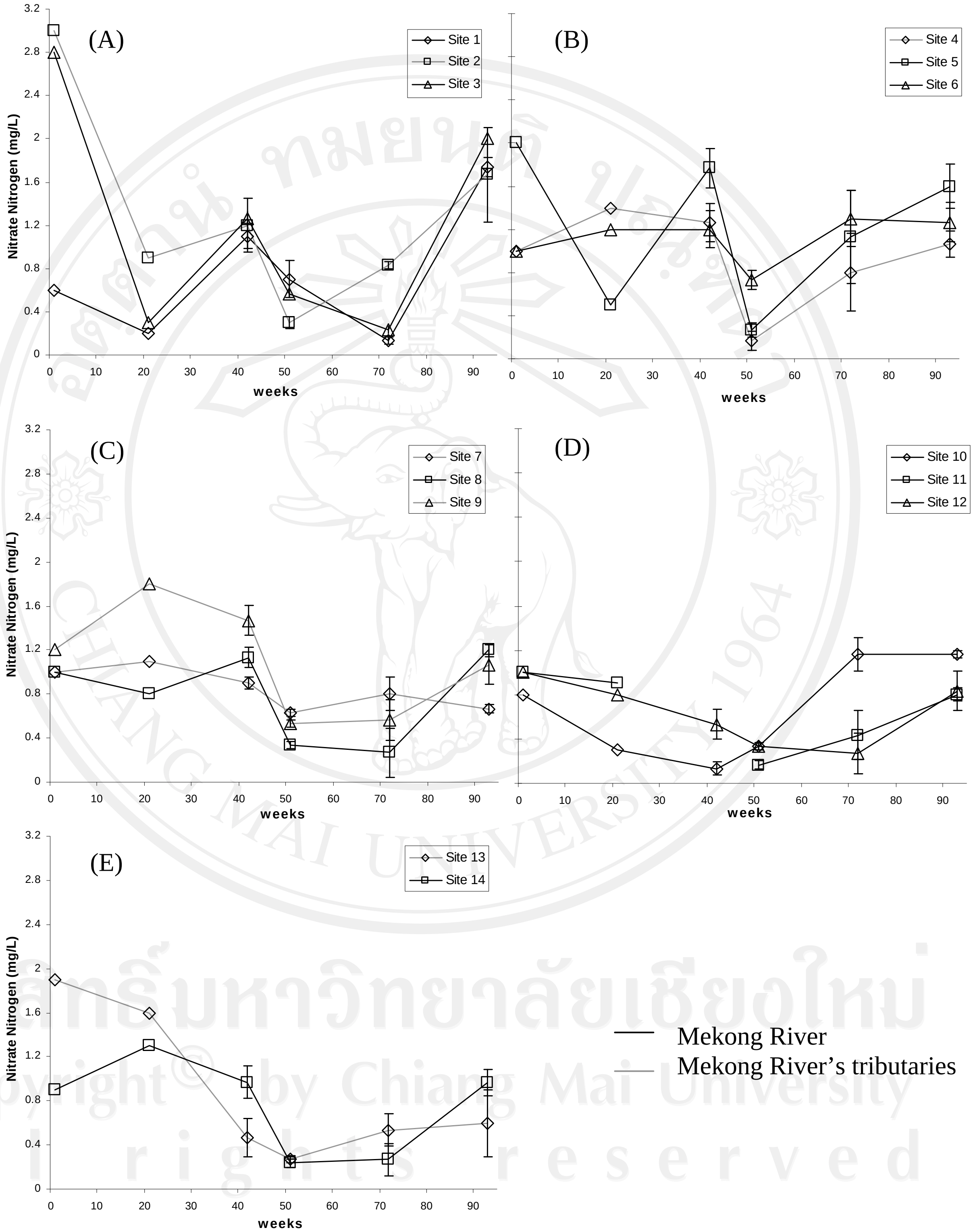


Figure 78 Seasonal changes in nitrate nitrogen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.9 Ammonium nitrogen

The concentrations of ammonium nitrogen in the Mekong River and its tributaries between July 2005 to April 2007 were ranged from 0.04 – 1.07 $mg.L^{-1}$ (Table 12). The lowest values were recorded in December 2006 (cool dry season 2) at site 1. The highest values were observed in July 2006 (rainy season 2) at site 13 (Figure 79). The concentrations of ammonium nitrogen in two cool dry seasons (December 2005 (cool dry season 1) and December 2006 (cool dry season 2)) were the lowest concentrations among all sampling sites recorded, with the lowest concentration in site 1($F_{3, 11}$ = 33.04, $p < 0.001$). It was found that the concentrations of ammonium nitrogen in July 2005 (rainy season 1) were lower than July 2006 (rainy season 2) at all sampling sites except for site 1.

There were large differences in concentrations of ammonium nitrogen over these two years between the seasons (July 2005 – April 2007). The average percentage of difference between each season were 183%, 116% and 97% for rainy season, summer and cool dry seasons, respectively. Three hundred and eighty three percentage of difference between each time were observed in rainy season at sampling site 7 that presented the highest value whereas the lowest value of 40% was recorded in cool dry season at sampling site 1.

The seasonal changes in ammonium nitrogen concentrations at 14 sites are shown in Figure 80. There was little differences in spatial changes in site 2 ($F_{3, 11}$ = 6.51, $p < 0.05$) which is a tributary of Mekong River in Northern Thailand.

All sampling sites in Mekong River (sites 1, 3, 5, 6, 8, 10, 11, 12 and 14) showed the same pattern in all seasons. Ammonium nitrogen concentrations were high in July 2005 (rainy season 1, week 1) and decreased in December 2006 (cool dry season 2, week 72) and increased in April 2007 (summer2, week 93) - July 2006 (rainy season 2, week 51). The concentration was then decreased in December 2006 (cool dry season 2, week 72) and remained high until April 2007 (summer2, week 93). There was a significant difference in ammonium nitrogen concentrations at all sampling sites over the last 4 sampling times of the study.

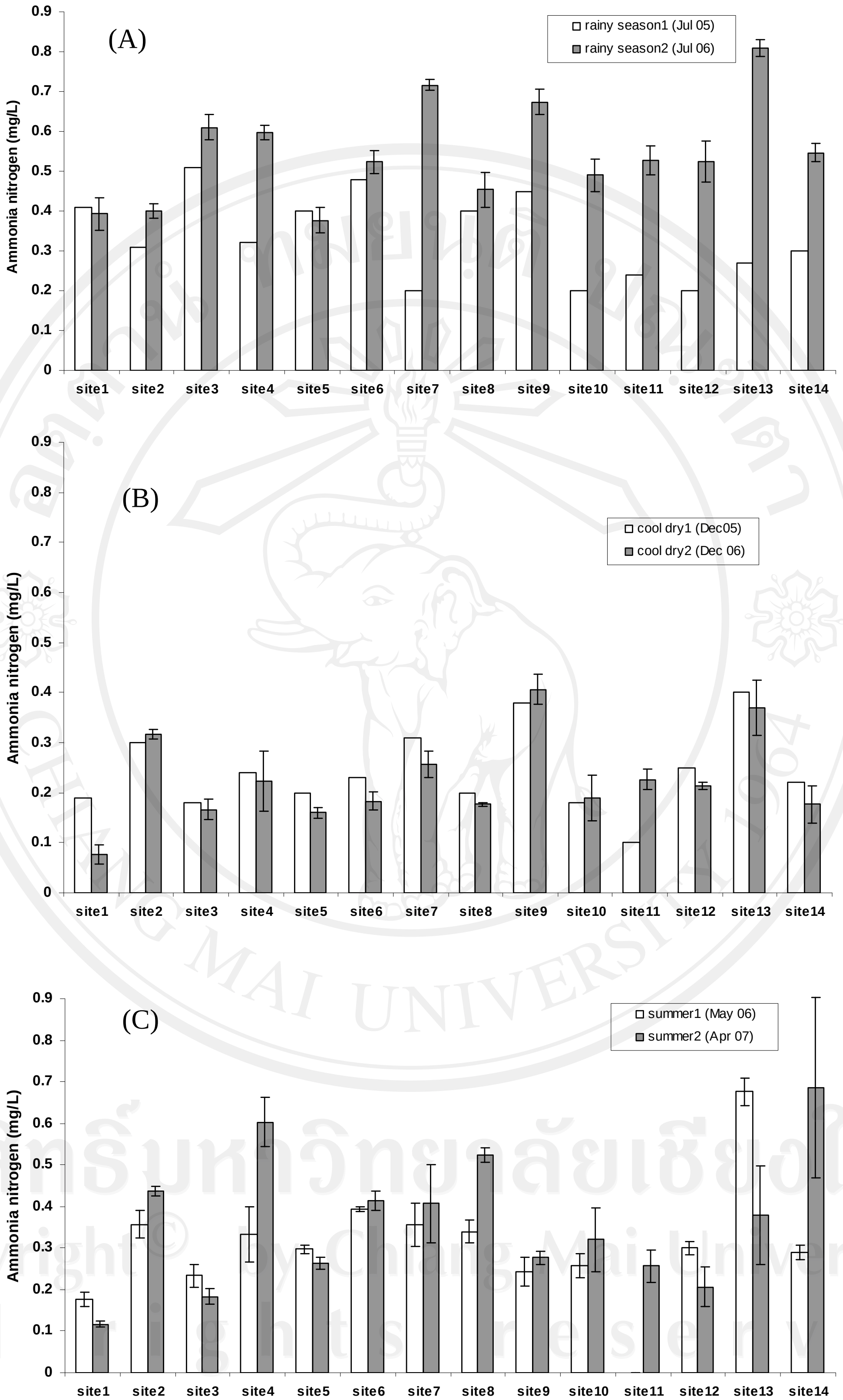


Figure 79 Seasonal changes in ammonia nitrogen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

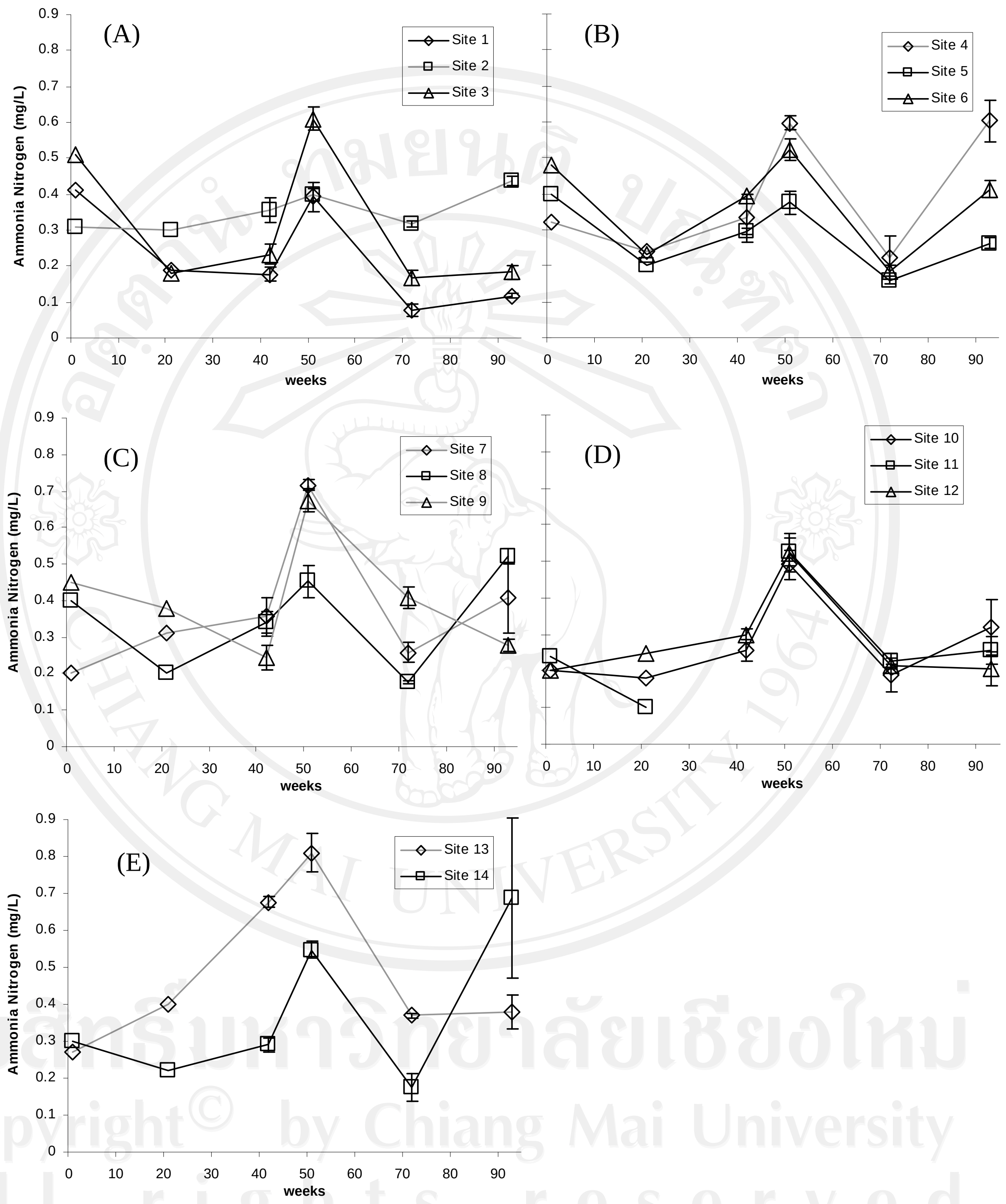


Figure 80 Seasonal changes in ammonia nitrogen concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.3.10 Soluble Reactive Phosphorus (SRP)

The SRP concentration in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from 0.003 – 0.47 $mg.L^{-1}$ (Table 12). The lowest values were recorded in December 2006 (cool dry season 2) at site 11 and site 12. The highest concentrations were observed in April 2007 (summer2, week 93) at site 4 (Figure 81). The SRP concentrations in July 2006 (rainy season 2) were generally the lowest concentrations among all sampling sites recorded, with the lowest concentration in site 9.

There were large differences in SRP concentrations over the two year (July 2005 – April 2007). Forty five percents of difference between each season were observed in rainy season that presented the lowest values whereas the highest values were 135% in summer. During rainy season and cool dry seasons, the values were different between two sets of measurement in each season over two years except for site 4, 5 and 7. It was found that the values in July 2005 – April 2006 were generally higher than in July 2006 – April 2007 except for site 4 in rainy season and site 4, 5 and 7 in the cool dry season. During the two summer samplings, most sites had similar SRP concentrations except for sites 4 and 12, where the 2007 values were 353% and 285%, respectively compared to a 2006 observation.

The seasonal changes in SRP concentrations at 14 sites are shown in Figure 80. The seasonal pattern in each sampling site was different between Northern (site 1-3, Figure 82A) and North-Eastern (site 4-14, Figure 82B-E) Thailand. At sites in Northern Thailand, it was similar to that observed at site 1, 2 and 3 except in December 2005 (rainy season 1, weeks 1) at site 3. SRP concentrations decreased down throughout July 2005 (rainy season 1, week 1) – December 2006 (cool dry season 2, week 72) and increased in April 2007 (summer2, week 93). Beside that, it was found that SRP concentrations in site 2 tributary was higher than that in the main river (site 1 and 3) in all season.

In North-Eastern Thailand, SRP concentrations shown different spatial changes between the Mekong River and its tributaries. In the tributaries, concentrations at site 7 and 9 were decreased in July 2005 (rainy season 1, week 1), then increased in May 2006 (summer1, week 42) and remained high until April 2007 (summer2, week 93). Similar concentrations of SRP was observed at sampling site 4 and 13 throughout the sampling period except in April 2007 (summer2, week 93) at site 4 and in July 2005 (rainy season 1, week 1) at site 13 that were very high concentrations. There was a significant difference in concentrations of SRP at site 4 ($F_{3, 11} = 14.040$, $p < 0.001$) and non- significant at site 13 over the last 4 sampling times of the study.

At sampling site 6, 8, 11, 12 and 14 in the Mekong River, SRP concentrations were increased in December 2005 (cool dry season 1, week 21), then declined until December 2006 (cool dry season 2, week 72) except for site 6. There were a sharp increase in SRP concentrations in all sites during April 2007 (summer2, week 93). Similar concentrations of SRP were observed throughout the sampling period except in July 2005 (rainy season 1, week 1) at site 5 and 10.

Beside that SRP concentrations decreased in July 2006 (rainy season 2, week 51) and remained low until December 2006 (cool dry season 2, week 72) in all sampling sites except for site 7 and 10. It was found no significant difference pattern of change throughout the sampling period in site 5, 7, 10 and 13.

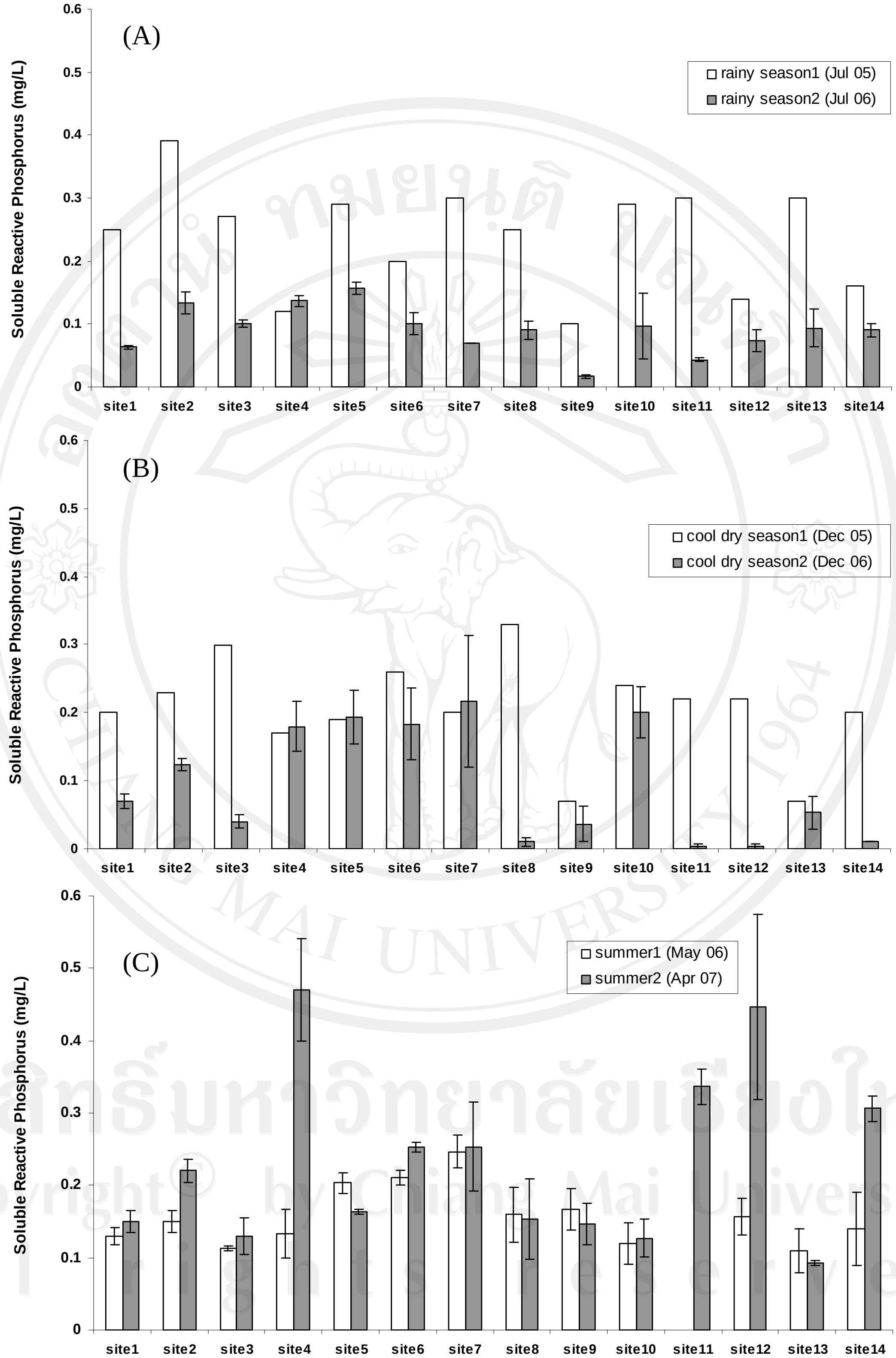


Figure 81 Seasonal changes in soluble reactive phosphorus concentration at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007.
Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

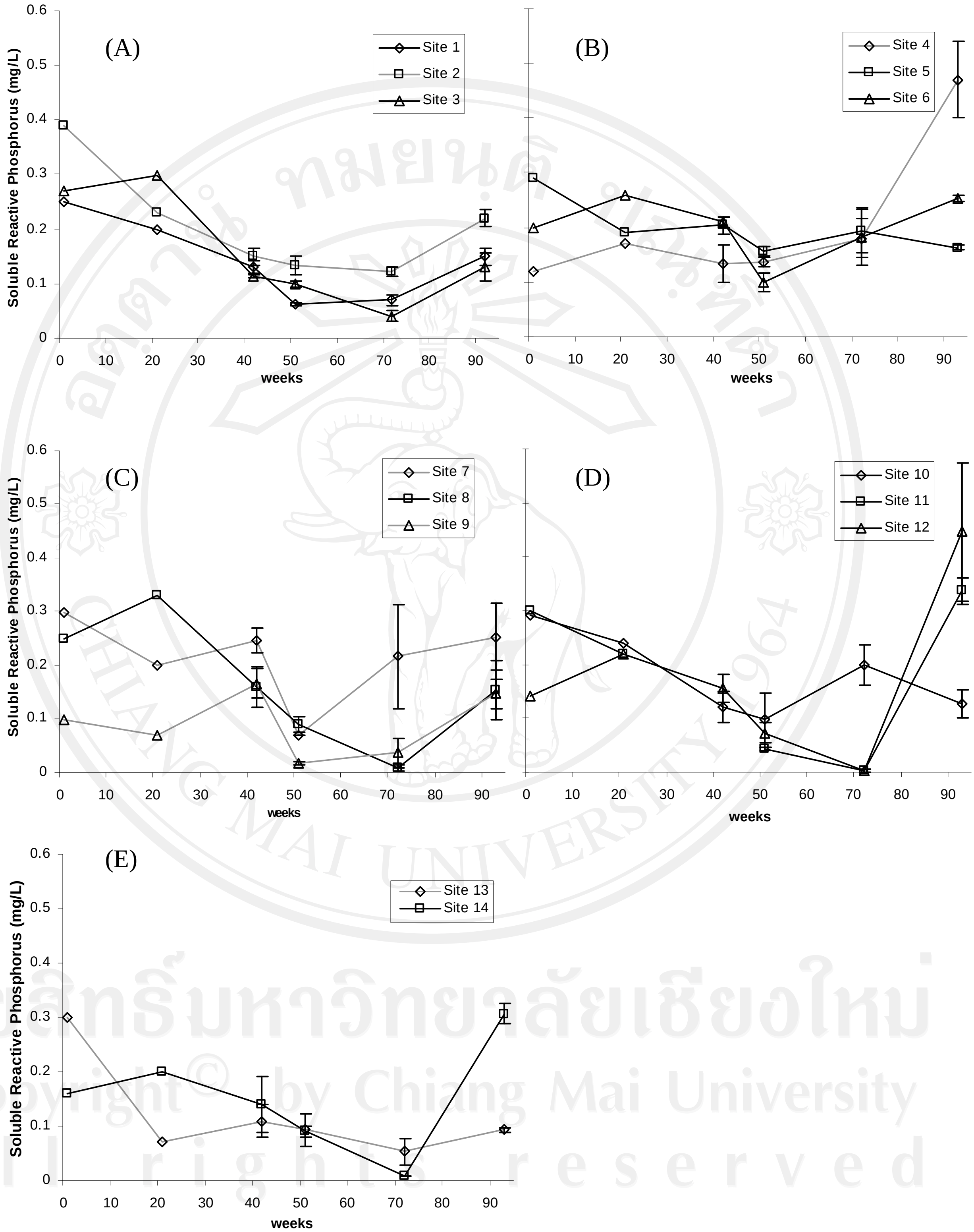


Figure 82 Seasonal changes in soluble reactive phosphorus concentrations at 14 sampling sites along the Mekong River and its tributaries during three different seasons between July 2005 and April 2007. Values mean ± standard error, n = 3, except weeks 1 & 21, when n = 1.

4.2.4 Cluster analysis of the water chemical and physical properties in each samples

At 80% similarity, the dendrogram divided sampling sites into eleven distinct clusters of characteristic water assemblage type, group A- I_2 (Figure 83 and Table 14). It was found that all sampling sites in Group A (n=3), B (n=9) and some of Group C (n=3) were sampling sites in Mekong River and its tributaries in December 2006 (cool dry season 2). In group E, the biggest group (n=54) was composed of sampling sites in the Mekong River and its Tributaries Thailand in May 2006 (summer1) and some sites in two cool dry seasons.

Most sampling sites in group F_1 (n=30) and F_2 (n=31) were sampling sites in Mekong River and its tributaries Thailand in two times of summer, some of them were in April 2007 (summer2) and December 2006 (cool dry season 2). Sampling site 9 (SK) In group G (n=1) was a tributary of Mekong River in North - Eastern Thailand in December 2005 (cool dry season1).

Group H (n=4) were sampling sites in tributaries of Northern Thailand in July 2005 (rainy season1) and December 2006 (cool dry season2). Some sampling sites in the Mekong River and its tributaries Thailand in July 2006 (rainy season 2) were assigned to group I_1(n=15). Finally, group I_1(n=31) was composed of the sampling sites in Mekong River and its tributaries in two time of rainy season seasons and some of December 2006 (cool dry season 2) and April (summer2).

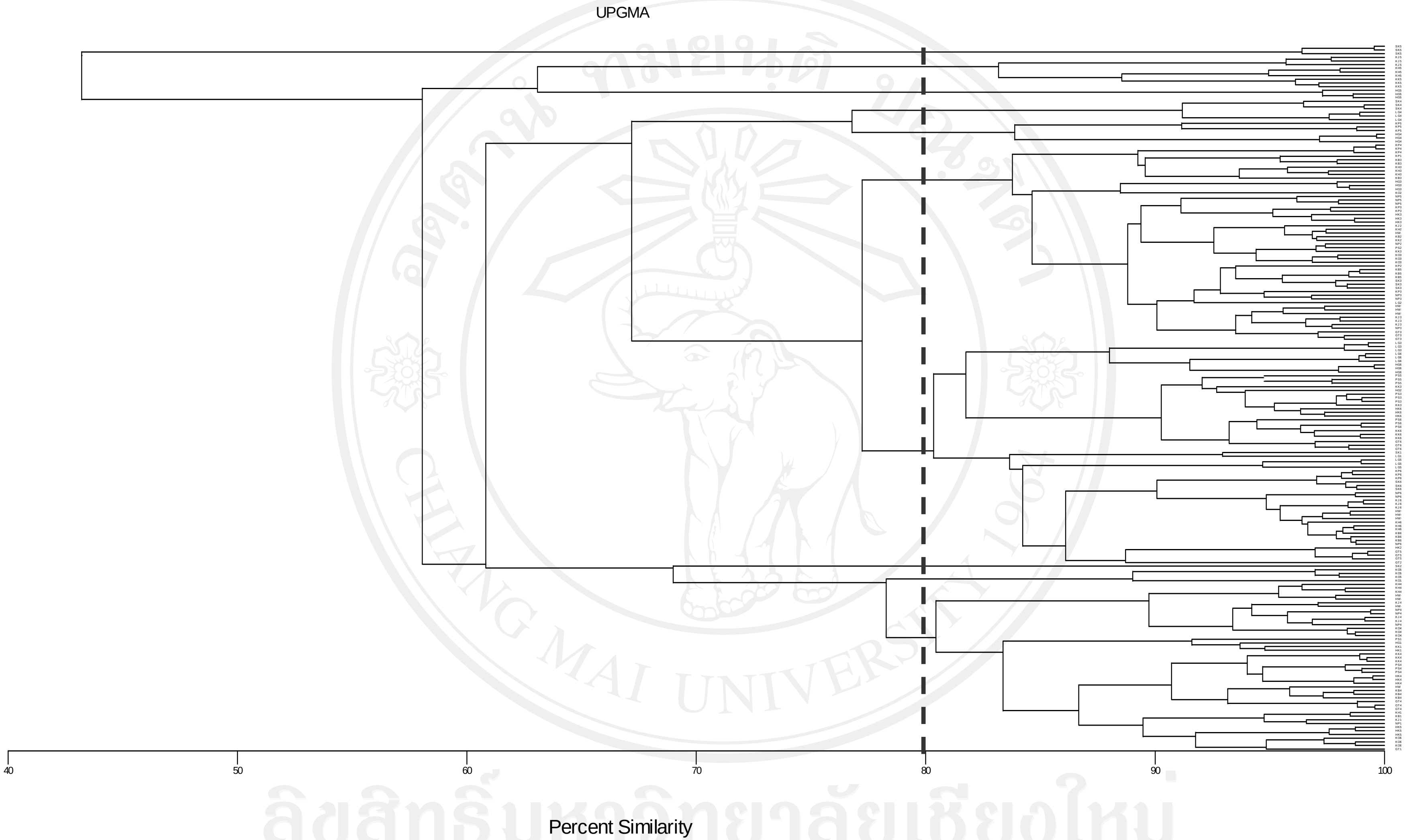


Figure 83 Dendrogram of similarities between investigated sites of the Mekong River and its tributaries according to physico-chemical parameters of water quality; 252 case 11 variables

Table 14 Groups of sampling sites detected by cluster analysis of physico-chemical parameters of water quality at 80% similarity

Group	Sampling site	Description
A	SK5.1, SK5.2, SK5.3	Tributaries of North-Eastern Thailand in cool dry season(2)
B	KK5.1, KK5.2, KK5.3, KH5.1, KH5.2, KH5.3, KJ5.1, KJ5.2, KJ5.3	Mekong River of North-Eastern Thailand in cool dry season(2)
C	HG5.1, HG5.2, HG5.3	Tributaries of North-Eastern Thailand in cool dry season(2)
D	HG4.1, HG4.2, HG4.3, LG4.1, LG4.2, LG4.3, SK4.1, SK4.2, SK4.3, KP5.1, KP5.2, KP5.3	Tributaries of North-Eastern Thailand in summer(1) and cool dry season(2)
E	GT3.1, GT3.2, GT3.3, KO2, KO3.1, KO3.2, KO3.3, HK3.1, HK3.2, HK3.3, HG3.1, HG3.2, HG3.3,KK2, KK3.2, PS2, LG2, NP2, NP3.1, NP3.2,NP3.3, NP5.1, NP5.2, NP5.3, SK3.1, SK3.2, SK3.3, KB2, KB3.1, KB3.2, KB3.3, KB5.1, KB5.2, KB5.3,HW2, HW5.1, HW5.2, HW5.3, KH2, KH3.1, KH3.2, KH3.3, KP1, KP2, KP3.1, KP3.2, KP3.3, KP4.1, KP4.2, KP4.3, KJ2, KJ3.1, KJ3.2, KJ3.3	Mekong River and its tributaries, Thailand in summer(1) and some of two cool dry seasons
F1	GT6.1, GT6.2, GT6.3, HK6.1, HK6.2, HK6.3, HG2, HG6.1, HG6.2, HG6.3, KK3.1, KK3.3, K6.1, KK6.2, KK6.3, PS3.1, PS3.2, PS3.3,PS5.1,PS5.2, PS5.3, PS6.1, PS6.2, PS6.3,LG3.1, LG3.2, LG3.3, LG6.1, LG6.2, LG6.3	Mekong River and its tributaries, Thailand in two summer
F2	GT2, GT5.1, GT5.2, GT5.3, HK2, LG1, LG5.1, LG5.2, LG5.3, NP6.1, NP6.2, NP6.3, SK1, SK6.1, SK6.2, SK6.3, KB6.1, KB6.2, KB6.3, HW6.1, HW6.2, HW6.3, KH6.1, KH6.2, KH6.3, KP6.1, KP6.2, KP6.3, KJ6.1, KJ6.2,KJ6.3	Mekong River and its tributaries, Thailand in summer(2) and some of cool dry season (2)
G	SK2	Tributary of North-Eastern Thailand in cool dry season(1)
H	KO1, KO5.1, KO5.2, KO5.3	Tributaries of North Thailand in rainy season(1) and cool dry season(2)
I1	KO4.1, KO4.2, KO4.3, NP4.1, NP4.2, NP4.3, HW4.1, HW4.2, HW4.3, KH4.1, KH4.2, KH4.3, KJ4.1, KJ4.2, KJ4.3	Mekong River and its tributaries, Thailand in rainy season (2)
I2	GT1, GT4.1, GT4.2, GT4.3, KO6.1, KO6.2, KO6.3, HK1, HK4.1, HK4.2, HK4.3, HK5.1, HK5.2, HK5.3, HG1, KK1, KK4.1, KK4.2, KK4.3, PS1, PS4.1, PS4.2, PS4.3, NP1,KB1, KB4.1, KB4.2, KB4.3, HW1, KH1, KJ1	Mekong River and its tributaries, Thailand in two rainy seasons and some of cool dry season (2) and summer(2)

4.2.5 The significant correlation between group A-I_1 with physico-chemical parameters

The physico-chemical parameters in each group were calculated by Minitab program to find the significant difference and significant correlation of group A- I_2, as shown in Figure 84-94 and Table 15-16.

It was found that the sampling sites in group A, C, G and H showed no significant correlation with nitrate nitrogen concentrations (Figure 84). All sampling sites in group F_1 showed high concentration of nitrate nitrogen than group E, F_2, I_1, B and D ($P < 0.05$). In Figure 85, all sampling sites in group D ($P<0.05$) were high in ammonia nitrogen concentrations with an average value of 0.59 $mg.l^{-1}$. There was no-significant correlation in group A ($P<0.05$) for ammonia nitrogen concentrations.

In addition, there was significantly high concentrations of soluble reactive phosphorus in group H ($P<0.05$) of 0.39 $mg.l^{-1}$ with an average of soluble reactive phosphorus, and showed non-significant in group C and G with the same parameter (Figure 86). The pH value showed non-significant in group A and H, but significantly high pH (7.75) was found in group C ($P<0.05$) and low pH (6.59) in group G ($P<0.05$) (Figure 87).

There were significantly differences in conductivity in all groups ($P<0.05$) as showed in Figure 88. All sampling sites in group A showed high conductivity whereas low conductivity was observed in group B, also in group I_2 that shown low conductivity. Figure 89, there were high values of alkalinity in group F_1 ($P<0.05$).

The dissolved oxygen was non-significant in group A and G. High DO was observed in group H with an average of 9.50 $mg.l^{-1}$, as showed in Figure 90. For biochemical oxygen demand, there was non-significant in group G and high BOD in group C with an average value of 4.47 $mg.l^{-1}$ (Figure 91).

In addition, there were non-significant in group A and G for water temperature. All sampling sites in group D ($P<0.05$) and I_1 ($P<0.05$) had high water temperature with low values in group H ($P<0.05$) (Figure 92).

There were significant differences in turbidity for all group ($P<0.05$) as showed in Figure 93. The lowest turbidity was recorded for group C with an average value of 4.33 NTU.

One-way ANOVA: NO3 versus code

```
Analysis of Variance for NO3
Source     DF        SS        MS        F        P
code       10    12.419     1.242     3.37    0.000
Error     182    67.008     0.368
Total     192    79.427
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  --+---------+---------+---------+----
 A          3    0.5667    0.3215   (------*------)
 B          9    0.5556    0.5918      (---*---)
 C          3    0.8000    0.6245     (------*------)
 D         12    0.4667    0.2270     (---*--)
 E         54    0.8759    0.5288           (-*)
 F1        30    1.3300    0.4481               (-*-)
 F2        31    0.8194    0.4362          (-*-)
 G          1    1.8000    0.0000          (-----------*-----------)
 H          4    1.3750    1.0844            (-----*-----)
 I1        15    0.6800    0.8898        (--*--)
 I2        31    1.0355    0.8503            (-*--)
                                   --+---------+---------+---------+----
Pooled StDev =   0.6068            0.0       1.0       2.0       3.0
```

Figure 84 The significant correlation between each group with nitrate nitrogen concentrations

One-way ANOVA: NH4 versus code

```
Analysis of Variance for NH4
Source     DF        SS        MS        F        P
code       10    1.5276    0.1528     6.32    0.000
Error     182    4.4007    0.0242
Total     192    5.9284
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  --------+---------+---------+--------
 A          3    0.4067    0.0513           (--------*--------)
 B          9    0.1833    0.0418    (----*----)
 C          3    0.2233    0.1021  (--------*--------)
 D         12    0.5892    0.1484                          (---*----)
 E         54    0.3111    0.1723             (--*-)
 F1        30    0.3193    0.1512             (--*--)
 F2        31    0.3216    0.2069             (--*--)
 G          1    0.3800    0.0000    (-------------*-------------)
 H          4    0.3150    0.0129        (------*------)
 I1        15    0.4900    0.0788                    (--*---)
 I2        31    0.4081    0.1305                 (-*--)
                                   --------+---------+---------+--------
Pooled StDev =   0.1555                  0.20      0.40      0.60
```

Figure 85 The significant correlation between each group with ammonia nitrogen concentrations

One-way ANOVA: SRP versus code

```
Analysis of Variance for SRP
Source     DF         SS         MS        F        P
code       10     0.7759     0.0776     4.93    0.000
Error     182     2.8661     0.0157
Total     192     3.6421
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N       Mean      StDev  ---------+---------+---------+-------
 A          3     0.0367     0.0462      (------*------)
 B          9     0.0689     0.0994          (---*----)
 C          3     0.1800     0.0624             (------*------)
 D         12     0.0692     0.0493           (--*---)
 E         54     0.1407     0.0780                (-*-)
 F1        30     0.2320     0.1096                    (--*-)
 F2        31     0.2094     0.1409                   (-*--)
 G          1     0.0700     0.0000  (------------*-----------)
 H          4     0.3900     0.5335                        (-----*------)
 I1        15     0.0860     0.0362            (--*--)
 I2        31     0.1710     0.1426                 (--*-)
                                   ---------+---------+---------+-------
Pooled StDev =    0.1255                  0.00      0.20      0.40
```

Figure 86 The significant correlation between each group with soluble reactive phosphorus concentrations

One-way ANOVA: pH versus code

```
Analysis of Variance for pH
Source     DF         SS         MS        F        P
code       10     14.977      1.498     9.51    0.000
Error     182     28.669      0.158
Total     192     43.647
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N       Mean      StDev  --------+---------+---------+--------
 A          3     7.0933     0.1050               (-----*------)
 B          9     7.5611     0.1662                        (---*---)
 C          3     7.7467     0.0058                        (------*-----)
 D         12     6.7333     0.4610             (--*--)
 E         54     7.4039     0.4950                        (-*)
 F1        30     7.5997     0.3449                           (-*-)
 F2        31     7.6216     0.4467                           (-*-)
 G          1     6.5900     0.0000   (----------*---------)
 H          4     7.1625     0.4168                 (----*-----)
 I1        15     6.8080     0.1325              (--*--)
 I2        31     7.3571     0.3109                       (-*-)
                                   --------+---------+---------+--------
Pooled StDev =    0.3969                 6.30      7.00      7.70
```

Figure 87 The significant correlation between each group with pH

One-way ANOVA: Cond versus code

```
Analysis of Variance for Cond
Source     DF        SS        MS        F        P
code       10   2128104    212810   212.29    0.000
Error     182    182443      1002
Total     192   2310547
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  ---------+---------+---------+-------
 A          3    753.00      8.72                               (*-)
 B          9     47.78      3.99  (*)
 C          3     64.17      0.15  (-*)
 D         12    110.86     30.37     *)
 E         54    186.81     27.95        *)
 F1        30    316.44     52.21             (*
 F2        31    254.71     21.64           *)
 G          1    484.00      0.00                     (-*--)
 H          4    121.45     12.42     (*)
 I1        15     78.42      9.10   (*)
 I2        31    175.96     34.59        *
                                   ---------+---------+---------+-------
Pooled StDev =    31.66                   250       500       750
```

Figure 88 The significant correlation between each group with conductivity

One-way ANOVA: Alk versus code

```
Analysis of Variance for Alk
Source     DF        SS        MS        F        P
code       10     76647      7665    17.69    0.000
Error     182     78836       433
Total     192    155484
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  -------+---------+---------+---------
 A          3      4.25      0.20   (------*-------)
 B          9     55.56     19.20                     (----*---)
 C          3     48.33      0.76               (-------*-------)
 D         12     21.17     17.91          (---*---)
 E         54     55.89     20.43                        (-*)
 F1        30     83.17     22.20                                (--*-)
 F2        31     62.90     27.45                          (-*-)
 G          1     23.00      0.00   (-------------*------------)
 H          4     33.00      4.16            (------*------)
 I1        15     17.95      5.74          (---*---)
 I2        31     39.41     20.68                   (-*--)
                                   -------+---------+---------+---------
Pooled StDev =    20.81                  0        30        60
```

Figure 89 The significant correlation between each group with alkalinity

One-way ANOVA: DO versus code

```
Analysis of Variance for DO
Source     DF        SS        MS        F        P
code       10    139.23     13.92     5.57    0.000
Error     182    454.82      2.50
Total     192    594.05
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Group       N      Mean     StDev  --+---------+---------+---------+----
 A          3     6.467     0.115       (--------*--------)
 B          9     7.356     0.260                (----*----)
 C          3     8.133     0.231                (---------*--------)
 D         12     4.675     1.414   (---*----)
 E         54     6.480     1.676              (-*--)
 F1        30     6.383     1.586             (--*--)
 F2        31     6.155     1.913            (--*--)
 G          1     7.000     0.000   (---------------*---------------)
 H          4     9.500     2.868                      (-------*------)
 I1        15     4.713     0.738    (---*---)
 I2        31     5.787     1.509         (--*--)
                                   --+---------+---------+---------+----
Pooled StDev =    1.581              4.0       6.0       8.0      10.0
```

Figure 90 The significant correlation between each group with dissolved oxygen

One-way ANOVA: BOD versus code

```
Analysis of Variance for BOD
Source     DF        SS        MS        F        P
code       10    131.86     13.19     8.13    0.000
Error     182    295.08      1.62
Total     192    426.93
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Group       N      Mean     StDev  -------+---------+---------+---------
 A          3     0.233     0.058   (------*------)
 B          9     0.689     0.567        (---*----)
 C          3     4.467     2.248                      (------*-------)
 D         12     0.542     0.611        (---*--)
 E         54     2.618     1.344                   (-*-)
 F1        30     2.258     1.488                 (-*--)
 F2        31     1.252     1.007            (-*--)
 G          1     3.600     0.000             (------------*------------)
 H          4     3.050     0.681                 (-----*------)
 I1        15     0.907     1.352         (---*--)
 I2        31     1.698     1.426              (-*--)
                                   -------+---------+---------+---------
Pooled StDev =    1.273                  0.0       2.0       4.0
```

Figure 91 The significant correlation between each group with biochemical oxygen demand

One-way ANOVA: Temp versus code

```
Analysis of Variance for Temp
Source     DF        SS        MS        F        P
code       10     858.5      85.9     7.18    0.000
Error     182    2175.8      12.0
Total     192    3034.3
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  ---+---------+---------+---------+---
 A          3    28.000     1.559             (-------*-------)
 B          9    24.711     2.362          (---*----)
 C          3    27.300     0.000            (-------*------)
 D         12    33.492     2.110                          (---*---)
 E         54    29.956     3.021                     (-*-)
 F1        30    30.167     1.970                     (-*--)
 F2        31    29.332     4.861                   (--*-)
 G          1    27.000     0.000     (-------------*-------------)
 H          4    22.325     3.517   (------*-----)
 I1        15    32.833     3.818                          (---*--)
 I2        31    28.406     4.207                 (--*-)
                                   ---+---------+---------+---------+---
Pooled StDev =    3.458            20.0      25.0      30.0      35.0
```

Figure 92 The significant correlation between each group with water temperature

One-way ANOVA: Turbid versus code

```
Analysis of Variance for Turbid
Source     DF        SS        MS        F        P
code       10   1892904    189290   166.11    0.000
Error     182    207403      1140
Total     192   2100307
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Group       N      Mean     StDev  ---+---------+---------+---------+---
 A          3     41.00     24.33     (--*---)
 B          9    126.33     31.43            (-*)
 C          3      4.33      1.53  (--*---)
 D         12     65.78     16.61        (*-)
 E         54     95.35     23.36           (*)
 F1        30    101.60     38.77           (*)
 F2        31     28.06     17.52     (*)
 G          1    288.00      0.00                     (-----*-----)
 H          4    183.00     19.20               (--*--)
 I1        15    265.80     33.46                        (*-)
 I2        31    314.16     56.80                            (*)
                                   ---+---------+---------+---------+---
Pooled StDev =    33.76             0       120       240       360
```

Figure 93 The significant correlation between each group with turbidity

Table 15 An average, standard error and the significant correlation between group A-E with physico-chemical parameters ($P<0.05$)

Parameters	A	B	C	D	E
NO_3	$\bar{X}$ = 0.57 se = 0.19 n = 3 sig ns	$\bar{X}$ = 0.56 se = 0.20 n = 9 sig $B<F_1$	$\bar{X}$ = 0.80 se = 0.36 n = 3 sig ns	$\bar{X}$ = 0.47 se = 0.07 n = 12 sig $D<F_1, H, I_2$	$\bar{X}$ = 0.88 se = 0.07 n = 54 sig $E< F_1$
NH_4	$\bar{X}$ = 0.41 se = 0.03 n = 3 sig ns	$\bar{X}$ = 0.18 se = 0.01 n = 9 sig $B<D,I_1,I_2$	$\bar{X}$ = 0.22 se = 0.06 n = 3 sig $C<D,I_1$	$\bar{X}$ = 0.59 se = 0.04 n = 12 sig $D>B,E,F_1,F_2,H,I_2$	$\bar{X}$ = 0.32 se = 0.02 n = 54 sig $E<D,I_1$
SRP	$\bar{X}$ = 0.04 se = 0.03 n = 3 sig $A<F_1,H$	$\bar{X}$ = 0.07 se= 0.03 n=9 sig $B<F_1,F_2,H$	$\bar{X}$ = 0.18 se= 0.04 n=3 sig ns	$\bar{X}$ = 0.07 se = 0.01 n = 12 sig $D< F_1,F_2,H$	$\bar{X}$ = 0.14 se = 0.01 n = 54 sig $E< F_1,H$
pH	$\bar{X}$ = 7.09 se = 0.06 n = 3 sig ns	$\bar{X}$ = 7.56 se= 0.06 n=9 sig $B>D,I_1$	$\bar{X}$ = 7.75 se= 0 n=3 sig $C>D,I_1$	$\bar{X}$ = 6.73 se = 0.13 n = 12 sig $D<B,C,E,F_1,F_2,I_2$	$\bar{X}$ = 7.40 se = 0.07 n = 54 sig $E> D,I_1$
Conductivity	$\bar{X}$ = 753.00 se = 5.03 n = 3 sig $A>B,C,D,E,F_1,F_2,G,H,I_1,I_2$	$\bar{X}$ = 47.78 se= 1.33 n=9 sig $B<A,D,E,F_1,F_2,G,H,I_2$	$\bar{X}$ = 65.17 se= 0.09 n=3 sig $C<A,E,F_1,F_2,G,H,I_2$	$\bar{X}$ = 110.86 se = 8.77 n = 12 sig $B<D<A,E,F_1,F_2,G,I_2$	$\bar{X}$ = 186.81 se = 3.80 n = 54 sig $B,C,D,H,I_1<E=I_2<A,F_1,F_2,G$
Alkalinity	$\bar{X}$ = 4.25 se = 0.12 n = 3 sig $A<B,D,F_1,F_2,I_2$	$\bar{X}$ = 55.56 se= 6.40 n=9 sig $A,D,I_1<B<F_1$	$\bar{X}$ = 48.33 se= 0.44 n=3 sig $C<F_1$	$\bar{X}$ = 21.17 se =5.17 n = 12 sig $D<B,E,F_1,F_2,I_2$	$\bar{X}$ = 55.89 se = 2.78 n = 54 sig $A,D,I_1,I_2<E< F_1$
DO	$\bar{X}$ = 6.47 se = 0.07 n = 3 sig ns	$\bar{X}$ = 7.36 se= 0.09 n=9 sig $B> D,I_1,I_2$	$\bar{X}$ = 8.13 se= 0.13 n=3 sig $C> D,I_1,I_2$	$\bar{X}$ = 4.67 se= 0.41 n=12 sig $D<E,F_1,F_2,H$	$\bar{X}$ = 6.48 se = 0.23 n = 54 sig $D,I_1<E<H$
BOD	$\bar{X}$ = 0.23 se = 0.03 n = 3 sig $A<C,E,F_1,H$	$\bar{X}$ = 0.69 se= 0.19 n=9 sig $B<C,E,F_1,H$	$\bar{X}$ = 4.47 se= 1.30 n=3 sig $C>A,B,D,E,F_1,F_2,I_1,I_2$	$\bar{X}$ = 0.54 se = 0.18 n = 12 sig $D<C,E,F_1,F_2,H,I_2$	$\bar{X}$ = 2.62 se = 0.18 n = 54 sig $E>A,B,D,F_2,I_1,I_2$
Temperature	$\bar{X}$ = 28.00 se = 0.90 n = 3 sig ns	$\bar{X}$ = 24.71 se= 0.79 n=9 sig $B<D,E,F_1,F_2,I_1,I_2$	$\bar{X}$ = 27.30 se= 0 n=3 sig $C<D,I_1$	$\bar{X}$ = 33.49 se = 0.61 n = 12 sig $D>B,C,E,F_1,F_2,H,I_1,I_2$	$\bar{X}$ = 29.96 se = 0.41 n = 54 sig $B,H<E<D,I_1$
Turbidity	$\bar{X}$ = 41.00 se = 14.05 n = 3 sig $A<B,E,F_1,G,H,I_1,I_2$	$\bar{X}$ = 126.33 se= 10.48 n=9 sig $A,C,D,E,F_1,F_2<B<G,H,I_1,I_2$	$\bar{X}$ = 4.33 se= 0.88 n=3 sig $C<B,D,E,F_1,G,H,I_1,I_2$	$\bar{X}$ = 65.78 se = 4.79 n = 12 sig $C,F_2<D<B,E,F_1,G,H,I_1,I_2$	$\bar{X}$ = 95.35 se = 3.18 n = 54 sig $A,C,D,F_2<E=F_1<B,G,H,I_1,I_2$

Table 16 An average, standard error and the significant correlation between group F_1 - I_2 with physico-chemical parameters (P<0.05)

Parameters	F_1	F_2	G	H	I_1	I_2
NO_3	$\bar{X}$ = 1.33 se = 0.08 n = 30 sig $F_1>B,D,E,F_2,I_1$	$\bar{X}$ = 0.82 se = 0.08 n = 31 sig $F_2 < F_1$	$\bar{X}$ = 1.80 se = 0 n = 1 sig ns	$\bar{X}$ =1.38 se = 0.54 n=4 sig ns	$\bar{X}$ =0.68 se = 0.23 n=15 sig $I_1 < F_1$	$\bar{X}$ =1.04 se=0.15 n=31 sig $I_2>D$
NH_4	$\bar{X}$ = 0.32 se = 0.03 n = 30 sig $F_1=F_2<D,I_1$	$\bar{X}$ = 0.32 se = 0.04 n = 31 sig $F_2= F_1<D,I_2$	$\bar{X}$ = 0.38 se = 0 n = 1 sig ns	$\bar{X}$ = 0.32 se = 0.01 n = 4 sig H< D	$\bar{X}$ = 0.49 se = 0.02 n = 15 sig $I_1>B,C,E,F_1,F_2$	$\bar{X}$ = 0.41 se = 0.02 n = 31 sig $B,E<I_2<D$
SRP	$\bar{X}$ = 0.23 se = 0.02 n = 30 sig $F_1> A,B,D,E,I_1$	$\bar{X}$ = 0.21 se = 0.03 n = 31 sig $B,D,I_1<$F2<H	$\bar{X}$ = 0.07 se = 0 n = 1 sig ns	$\bar{X}$ = 0.39 se = 0.27 n = 4 sig $H>A,B,D,E,F_2,I_2$	$\bar{X}$ = 0.09 se = 0.01 n = 15 sig $I_2<F_1,F_2,H$	$\bar{X}$ = 0.17 se = 0.03 n = 31 sig $I_2<H$
pH	$\bar{X}$ = 7.60 se = 0.06 n = 30 sig $F_1=F_2>D,E,G,I_1$	$\bar{X}$ = 7.63 se = 0.08 n = 31 sig $F_2=F_1>D,E,G,I_1$	$\bar{X}$ = 6.59 se = 0 n = 1 sig $G<F_1,F_2$	$\bar{X}$ = 7.16 se = 0.21 n = 4 sig ns	$\bar{X}$ = 6.81 se = 0.03 n = 15 sig $I_1<B,C,E,F_1,F_2,I_2$	$\bar{X}$ = 7.36 se = 0.06 n = 31 sig $D,I_1<F_1,F_2$
Conductivity	$\bar{X}$ = 316.44 se = 9.53 n = 30 sig $B,C,D,E,F_2,H,I_1,I_2<F_1<A,G$	$\bar{X}$ = 254.71 se = 3.89 n = 31 sig $B,C,D,E,H,I_1,I_2<F_2<A,F_1,G$	$\bar{X}$ = 484.00 se = 0 n = 1 sig $B,C,D,E,F_1,F_2,H,I_1,I_2<E<A$	$\bar{X}$ = 121.45 se = 6.21 n = 4 sig $B,C,I_1<H<A,E,F_1,F_2,G,I_2$	$\bar{X}$ = 78.42 se = 2.35 n = 15 sig $I_1>A,E,F_1,F_2,G,H,I_2$	$\bar{X}$ = 175.96 se = 6.21 n = 31 sig $B,C,D,H,I_1<I_2=E<A,F_1,F_2,G$
Alkalinity	$\bar{X}$ = 83.17 se = 4.05 n = 30 sig $F_1>A,B,C,D,E,F_2,G,H,I_1,I_2$	$\bar{X}$ = 62.90 se = 4.93 n = 31 sig $A,D,I_1,I_2<F_2<F_1$	$\bar{X}$ = 23.00 se = 0 n = 1 sig $G<F_1$	$\bar{X}$ = 33.00 se = 2.08 n = 4 sig $H<F_1,F_2$	$\bar{X}$ = 17.95 se = 1.48 n = 15 sig $I_1< B,E,F_1,F_2,I_2$	$\bar{X}$ = 39.41 se = 3.71 n = 31 sig $D,I_1<I_2< E,F_1,F_2$
DO	$\bar{X}$ = 6.38 se = 0.29 n = 30 sig $D,I_1<F_1<H$	$\bar{X}$ = 6.16 se = 0.34 n = 31 sig $D,I_1<F_2<H$	$\bar{X}$ = 7.00 se = 0 n = 1 sig ns	$\bar{X}$ = 9.50 se = 1.43 n = 4 sig $H>D,E,F_1,F_2,I_1,I_2$	$\bar{X}$ = 4.71 se = 0.19 n = 15 sig $I_1<B,E,F_1,F_2,H$	$\bar{X}$ = 5.79 se = 0.27 n = 31 sig $I_2<B,C,H$
BOD	$\bar{X}$ = 2.26 se = 0.27 n = 30 sig $A,B,D,F_2,I_1<F_1<C$	$\bar{X}$ = 1.25 se = 0.18 n = 31 sig $F_2<C,H$	$\bar{X}$ = 3.60 se = 0 n = 1 sig ns	$\bar{X}$ = 3.05 se = 0.34 n = 4 sig $H>A,B,D,F_2,I_1$	$\bar{X}$ = 0.91 se = 0.35 n = 15 sig $I_1< C,E,F_1,H$	$\bar{X}$ = 1.70 se = 0.26 n = 31 sig $D<I_2<C,H$
Temperature	$\bar{X}$ = 30.17 se = 0.36 n = 30 sig $B,H<F_1<D$	$\bar{X}$ = 29.33 se = 0.87 n = 31 sig $B,H<F_2<D,I_1$	$\bar{X}$ = 27.00 se = 0 n = 1 sig ns	$\bar{X}$ = 22.33 se = 1.76 n = 4 sig $H<D,E,F_1,F_2,I_1,I_2$	$\bar{X}$ = 32.83 se = 0.99 n = 15 sig $I_1>B,C,E,F_2,H,I_2$	$\bar{X}$ = 28.41 se = 0.76 n = 31 sig $B,H<I_2<D,I_1$
Turbidity	$\bar{X}$ = 101.60 se = 7.08 n = 30 sig $A,C,D,F_2<F_1=E<B,G,H,I_1,I_2$	$\bar{X}$ = 28.06 se = 3.15 n = 31 sig $F_2<B,D,E,F_1,G,H,I_1,I_2$	$\bar{X}$ = 288.00 se = 0 n = 1 sig $G>A,B,C,D,E,F_1,F_2,H$	$\bar{X}$ = 183.00 se = 9.60 n = 4 sig $A,B,C,D,E,F_1,F_2<H<G,I_1,I_2$	$\bar{X}$ = 265.80 se = 8.64 n = 15 sig $A,B,C,D,E,F_1,F_2,H<I_1<I_2$	$\bar{X}$ = 314.16 se = 10.20 n = 31 sig $I_1>A,B,C,D,E,F_1,F_2,H,I_2$

4.2.6 The evaluation of water quality in Mekong River and its tributaries by AARL PC Score (Peerapornpisal *et al*., 2004)

The water quality in Mekong River and its tributaries were evaluated by AARL PC Score (Peerapornpisal *et al*., 2004). The method was modified from Wetzel (1983), Lorraine and Vollenweider (1981) and Kelly (2000). The standard justified the water quality category using alkalinity, conductivity, nitrate nitrogen, ammonia nitrogen and soluble reactive phosphorus. The water quality was shown in Figure 94.

The water quality in the Mekong River and its tributaries between July 2005 to April 2007 was ranged from oligo-mesotrophic to meso-eutrophic status depending on sampling sites and seasons. Mesotrophic status was recorded for many sampling sites in each season over the two year period, except for July 2005 (rainy season) which was mesotrophic status at site 2(KK) and 3(HK). During July to December 2006 (rainy season to cool season), oligo-mesotrophic status was found in all sites except for site 2 (KO), 7 (LG), 9 (SK) and 10 (KB) that shown mesotrophic status. Furthermore, mesotrophic status was observed at all sampling sites in December 2005 (cool dry season) except for site 1 (GT) , 3 (HK) and 5 (KK) that shown oligo-mesotrophic status.

It was found that site 1 (GT) was oligo-mesotrophic during these two year s except in July 2005 and July 2006, and summer in April 2007 which were mesotrophic. Site 11 (HW) showed mesotrophic status only in July 2005 (rainy season) and April 2007 (summer).

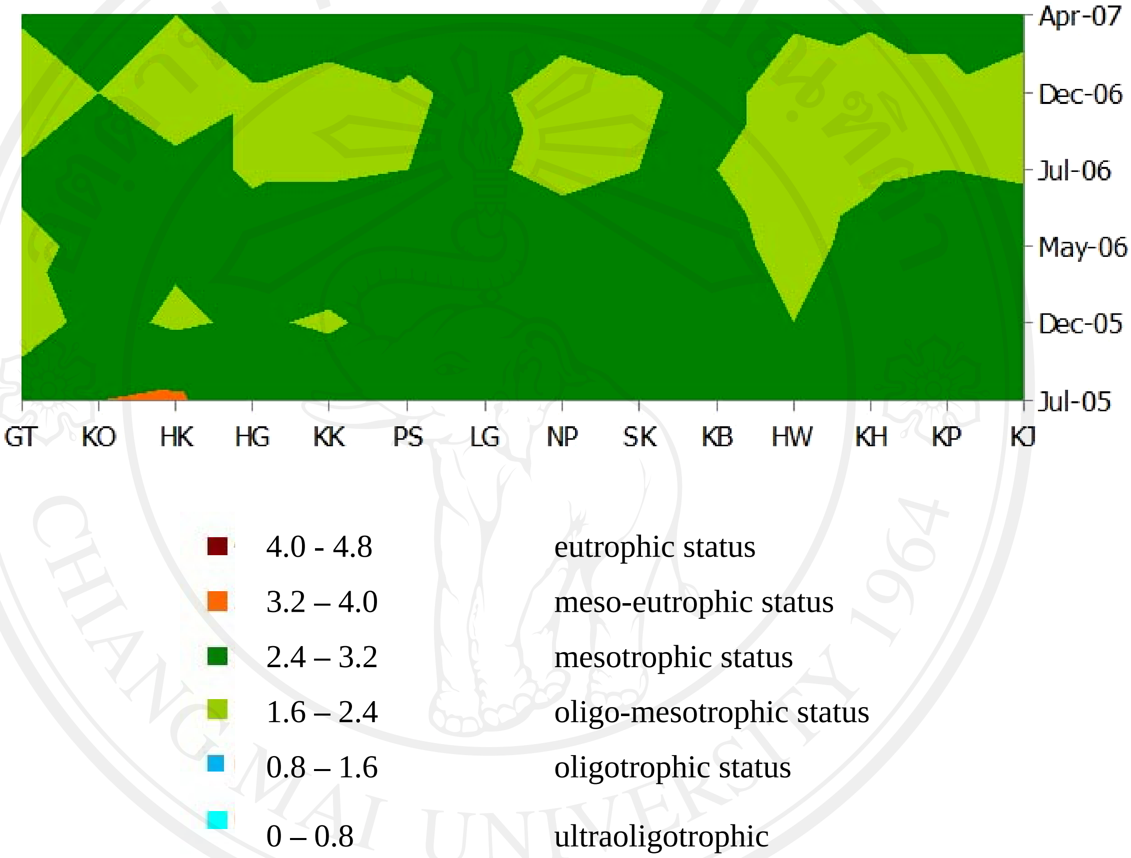


Figure 94 Water quality estimation in Mekong River and its tributaries based on the trophic standard of AARL PC Score (Peerapornpisal *et al*., 2004)

4.3 Relationship between diatom species and environment variables

4.3.1 CCA of physico-chemical parameters and diatom species

Twenty nine common species of benthic diatoms were put into MVSP statistical program. Canonical Correspondence Analysis (CCA) was used to find the relationship between physico-chemical parameters and diatom species. The results of CCA were shown in Figure 95.

It was found that *Navicula symmetrica* (Navsym) was correlated with velocity. *Navicula* cf. *menisculus* (Navmen) was correlated with alkalinity. *Fragilaria bidens* (Frabid) and *Achnanthidium minutissimum* (Achmin) were correlated with conductivity.

In addition, *Nitzschia clausii* (Nitcla) was correlated with soluble reactive phosphorus (SRP). *Luticola goeppertiana* (Lutgeo), *Achnanthidium convergens* (Achcon), *Eolimna minima* (Eolmin) and *Ulnaria ulna* (Ulnuln) were correlated with nitrate nitrogen (NO_3).

Sixty nine rare species of benthic diatoms were put into MVSP statistical program. Canonical Correspondence Analysis (CCA) was used to find the relationship between physico-chemical parameters and diatom species. The results of CCA were shown in Figure 96.

It was found that *Frustulia* sp.1(Frusp1) and *Nitzschia nana* (Nitnan) were correlated with conductivity (Cond). *Nitzschia acidoclinata* was correlated with nitrate nitrogen (NO3). *Naviculadicta nanogomphonema* was correlated with alkalinity (Alk). *Navicula viridula* var. *viridula* was correlated with soluble reactive phosphorus (SRP).

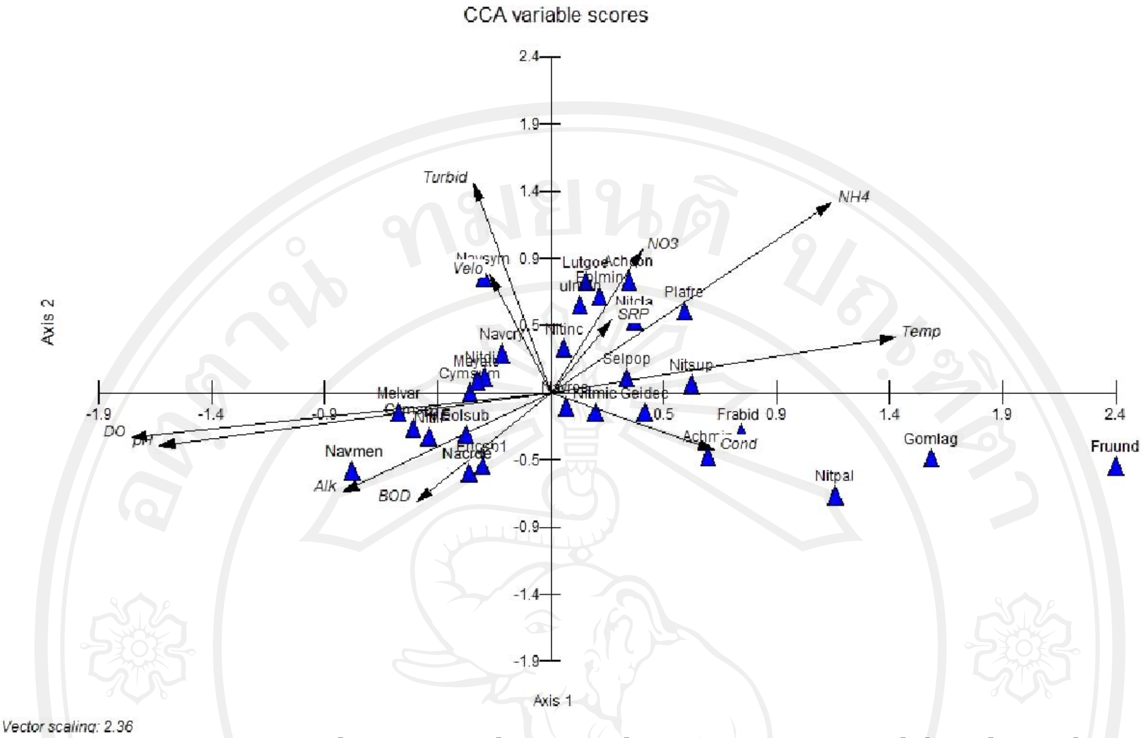


Figure 95 Canonical Correspondence Analysis (CCA) presented the relationship between water quality and common species of diatom (% of relative abundance > 1).

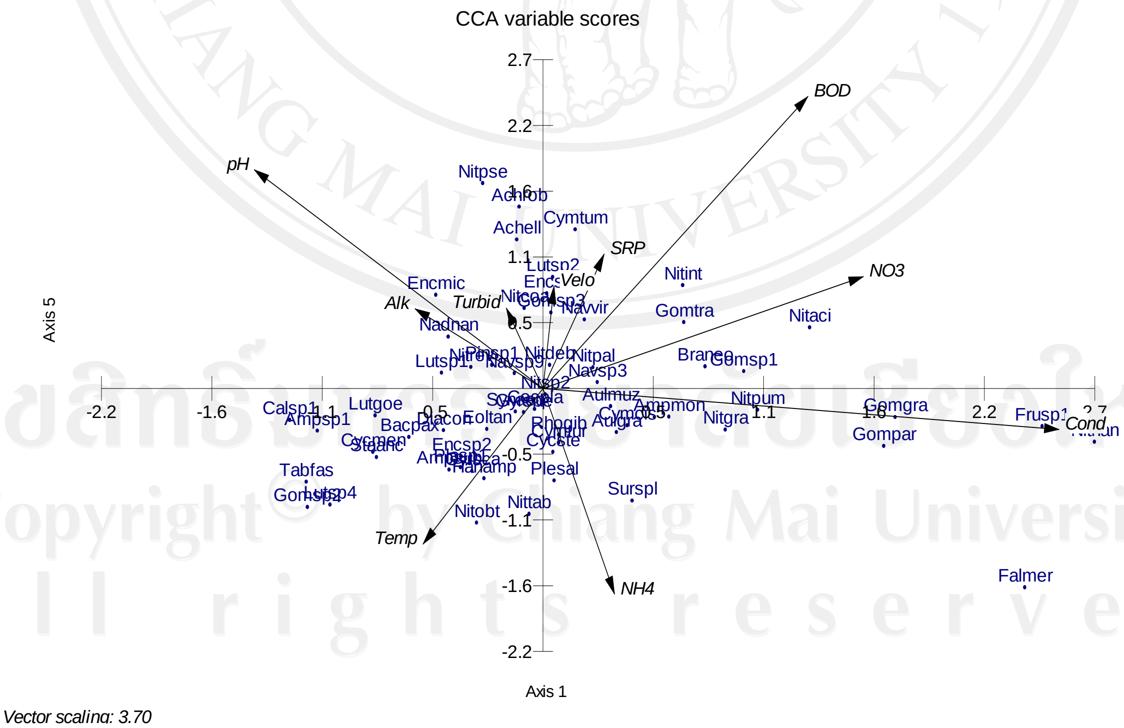


Figure 96 Canonical Correspondence Analysis (CCA) presented the relationship between water quality and rare species of diatom (% of relative abundance > 1).

4.3.2 Species of benthic diatoms that indicated physico-chemical of water quality

Twenty nine of common diatom species were arranged according to groups of sampling sites detected by cluster analysis of physico-chemical parameters of water quality at 80% similarity (from Figure 79 and Table 14). Benthic diatoms in each group were calculated by Minitab program to find the significant difference and significant correlation of groups A- I_2.

It was found that only 4 species from 29 species had significant correlation, as shown in Figures 92-95. In Figure 92, there was significant correlation between *Luticola goeppertiana* with Group I_2 ($P \leq 0.05$) in most sampling sites in wet seasons. From Figure 79 and Table 14, they showed significant with low conductivity in Group I_2. Therefore, *Luticola goeppertiana* could be used to indicate low conductivity.

There was significant correlation between *Eolimna minima* with group H ($P \leq 0.05$) (a tributary in North Thailand) in wet seasons. It was evident from Figure 79 and Table 14 that they showed significant with high soluble reactive phosphorus in group H. Therefore, *Eolimna minima* could be used to indicate high concentrations of soluble reactive phosphorus, as show in Figure 93. Further more, there was significant correlation between *Mayamaea atomus* and *Ulnaria ulna* with Group C ($P \leq 0.05$, a tributaries in North-Eastern Thailand) in cool seasons that showed significantly high BOD. Therefore, *Mayamaea atomus* and *Ulnaria ulna* could be indicators for high BOD, as show in Figures 94-95.

One-way ANOVA: Lutgoe versus code

```
Analysis of Variance for Lutgoe
Source     DF        SS        MS        F        P
code       10    1093.2     109.3     1.92    0.050
Error      72    4109.6      57.1
Total      82    5202.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
 A          1     0.000     0.000   (--------------*--------------)
 B          3     0.567     0.981          (--------*-------)
 C          1     0.000     0.000   (--------------*--------------)
 D          4     6.350     8.165                 (------*-------)
 E         25     0.576     1.540                (--*--)
F1         11     0.018     0.040             (----*----)
F2         13     0.638     1.853              (----*---)
 G          1     0.000     0.000   (--------------*--------------)
 H          2     0.000     0.000       (----------*----------)
I1*         5    13.040    17.886                        (------*------)
I2         17     6.200    12.575                     (--*---)
                                   ------+---------+---------+---------+
Pooled StDev =    7.555                -10         0        10        20
```

Figure 97 The significant correlation between group of water quality with *Luticola goeppertiana* (Bleisch) D.G. Mann in Round, Crawford & Mann

One-way ANOVA: Eolmin versus code

```
Analysis of Variance for Eolmin
Source     DF        SS        MS        F        P
code       10      6723       672     3.20    0.002
Error      72     15149       210
Total      82     21872
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
 A          1     24.60      0.00           (---------*---------)
 B          3      0.00      0.00      (-----*-----)
 C          1      0.00      0.00  (---------*---------)
 D          4      7.88     15.75          (----*---)
 E         25      2.97     11.94           (-*-)
F1         11     13.94     19.32              (--*--)
F2         13      8.01     12.61             (--*-)
 G          1      0.00      0.00  (---------*---------)
 H*         2     58.55     33.02                             (------*-----)
I1          5      8.86      8.74           (---*---)
I2         17      8.51     15.71            (--*-)
                                   ----------+---------+---------+------
Pooled StDev =    14.51                      0        30        60
```

Figure 98 The significant correlation between group of water quality with *Eolimna minima* (Grunow) Lange-Bertalot

One-way ANOVA: Mayato versus code

```
Analysis of Variance for Mayato
Source     DF        SS        MS        F        P
code       10      5358       536     2.04    0.042
Error      72     18944       263
Total      82     24302
                                   Individual 95% CIs For Mean
                                   Based on Pooled StdEv
Level       N      Mean     StDev  ---------+---------+---------+-------
 A          1      8.40      0.00     (-------*-------)
 B          3     15.50     17.24          (----*----)
 C*         1     66.00      0.00                      (-------*-------)
 D          4     11.85     15.69          (---*---)
 E         25      7.17     13.66           (-*)
F1         11     15.73     26.03            (--*-)
F2         13      5.77     11.92          (-*--)
 G          1      0.00      0.00   (-------*-------)
 H          2      2.65      3.75      (-----*----)
I1          5      1.74      2.41        (--*---)
I2         17     16.98     16.98             (-*-)
                                   ---------+---------+---------+-------
Pooled StDev =    16.22                     0        40        80
```

Figure 99 The significant correlation between group of water quality with *Mayamaea atomus* (Kützing) H. Lange-Bertalot

One-way ANOVA: Ulnuln versus code

```
Analysis of Variance for Synuln
Source     DF        SS        MS        F        P
code       10     87.04      8.70     2.22    0.026
Error      72    282.80      3.93
Total      82    369.84
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
 A          1     0.000     0.000  (-------*-------)
 B          3     0.000     0.000     (----*----)
 C*         1     8.600     0.000                    (-------*-------)
 D          4     0.000     0.000      (---*---)
 E         25     0.424     1.037         (-*)
F1         11     0.473     1.079         (-*-)
F2         13     0.069     0.250        (-*-)
 G          1     0.000     0.000  (-------*-------)
 H          2     1.100     1.556       (-----*-----)
I1          5     0.100     0.224       (--*---)
I2         17     1.494     3.889           (-*-)
                                   --------+---------+---------+--------
Pooled StDev =    1.982                  0.0       5.0      10.0
```

Figure 100 The significant correlation between group of water quality with *Ulnaria ulna* (Nitzsch) P. Compère

4.4 Diatom Indices

4.4.1 The developing of Mekong River and its tributaries Index

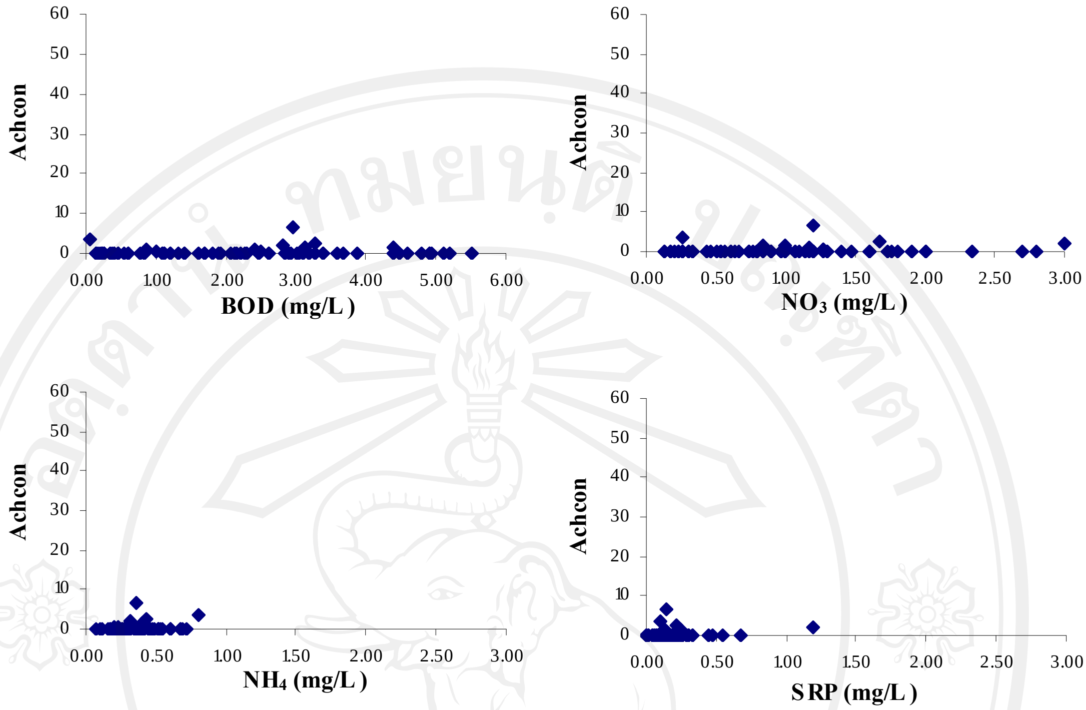
Twenty nine selected benthic diatoms were used to establish the Mekong Index. The concentrations of nitrate nitrogen, ammonium nitrogen, soluble reactive phosphorus and BOD_5 were divided into six classes as shown in Table 17. The methods used to calculate the trophic index value were modified from Lorraine and Vollenweider (1981), Wetzel (1983), Kelly (2000), Pektong (2002), AARL PC Score (Peerapornpisal *et al*., 2002) and Kunpradid (2005).

Twenty nine species of selected diatoms against with some physico-chemical parameters for Mekong Index and index values were showed in Figures 101-134 and Table 18.

It was found that most of had a fourth score that indicated water quality in mesotrophic status excepted *Melosira varians* that had 3 score that indicated water quality in oligo-mesotrophic status, and *Eolimna subminuscula*, *Fragilaria bidens*, *Mayamaea atomus*, *Navicula symmetrica*, *Nitzschia dissipata*, *Nitzschia palea*, *Nitzschia supralitorea* and *Planothidium frequentissimum* that had fifth score that indicated water quality in meso-eutrophic status. Water quality estimation in Mekong River and its tributaries based on the Mekong River and its tributaries index were shown in Figure 135.

Table 17 The seven classes include nitrate nitrogen, ammonia nitrogen, soluble reactive phosphorus and BOD_5,and scores for calculating the Mekong Index

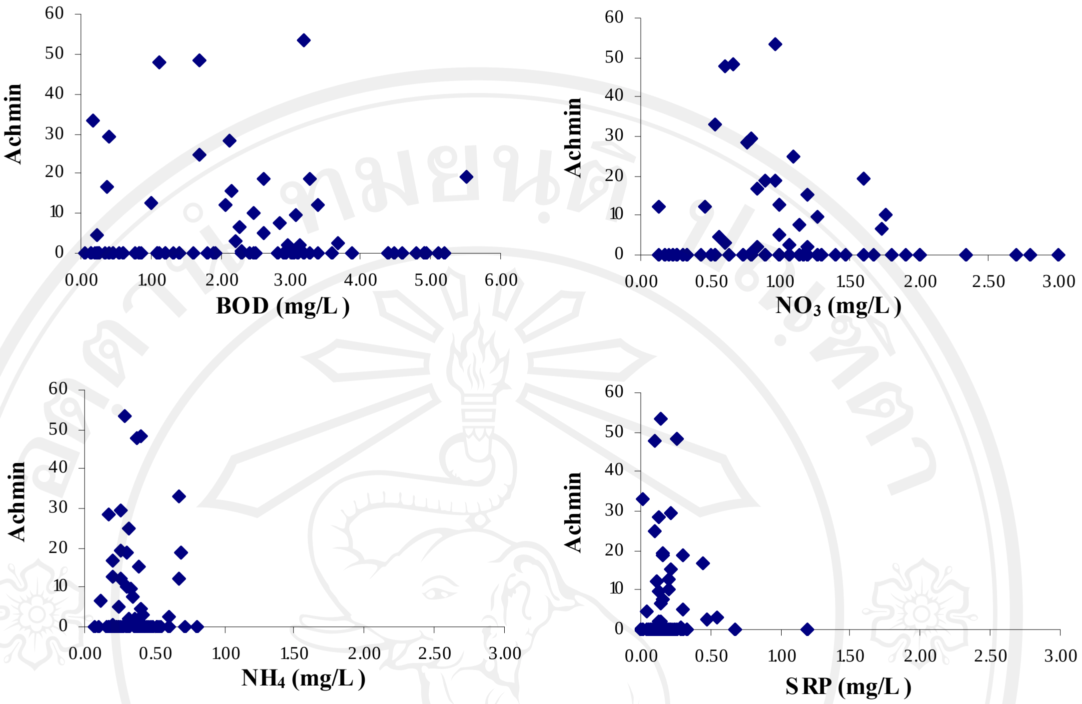
Scores	1	2	3	4	5	6	7
BOD ($mg.l^{-1}$)	<0.5	0.5-1.0	1.0-2.0	2.0-4.0	4.0-10.0	10.0-20.0	>20.0
Nitrate-N ($mg.l^{-1}$)	<0.01	0.01-0.05	0.05-0.2	0.2-2.0	2.0-5.0	5.0-10.0	>10.0
Ammonium-N ($mg.l^{-1}$)	<0.01	0.01-0.05	0.05-0.2	0.2-0.5	0.5-1.0	1.0-5.0	>5.0
SRP ($mg.l^{-1}$)	<0.01	0.01-0.03	0.03-0.1	0.1-0.30	0.30-1.0	1.0-3.0	>3.0
Trophic Status	Hyper-oligotrophic status	Oligotrophic status	Oligo-mesotrophic status	Mesotrophic status	Meso-eutrophic status	Eutrophic status	Hyper-eutrophic status



Achnanthidium convergens (H. Kobayasi) H. Kobayasi

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value (4)				Mesotrophic status		

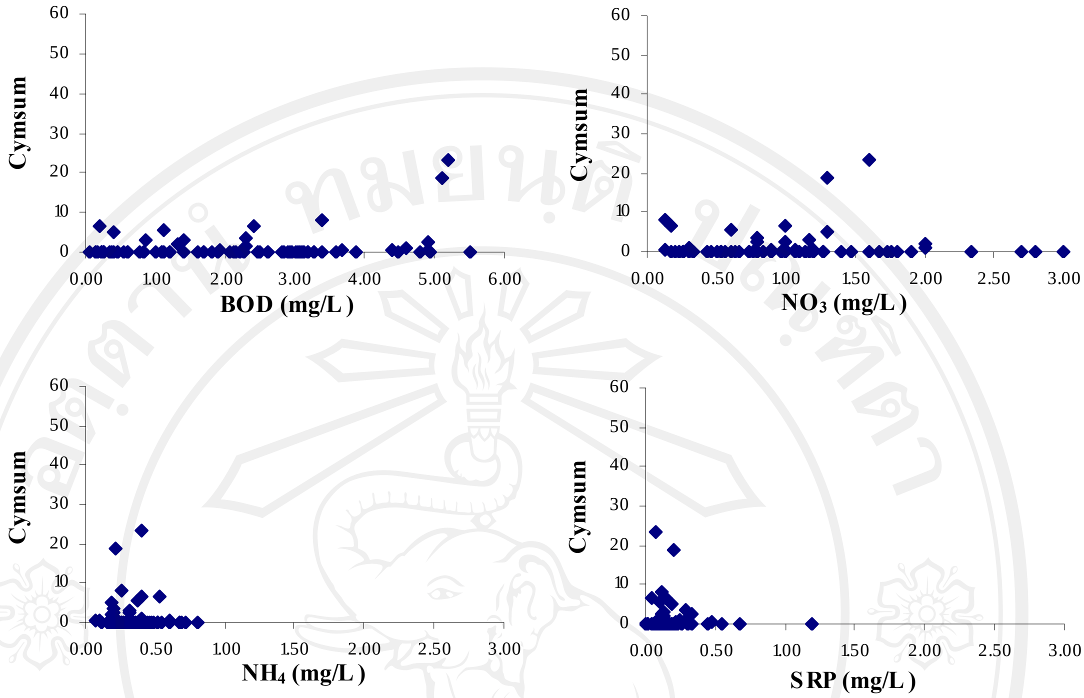
Figure 101 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Achnanthidium minutissimum (Kützing) Czarnecki

parameter	1	2	3	4	5	6
BOD			*			
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value (4)			Mesotrophic status			

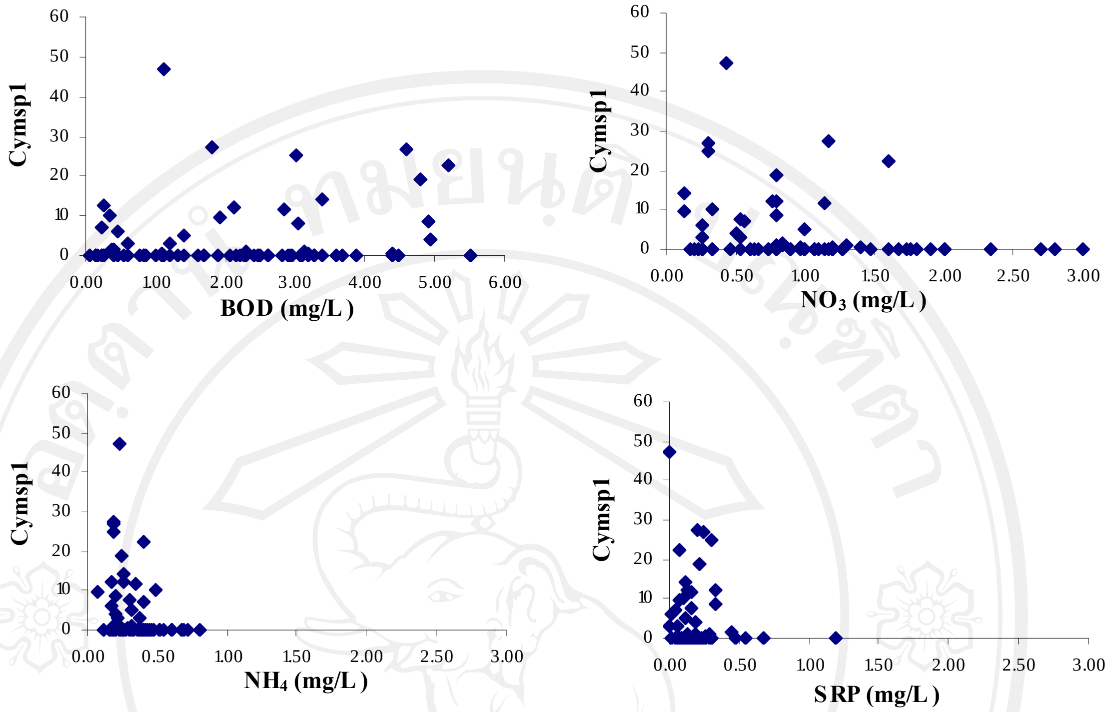
Figure 102 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Cymbella sumatrensis Hustedt

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)				Mesotrophic status		

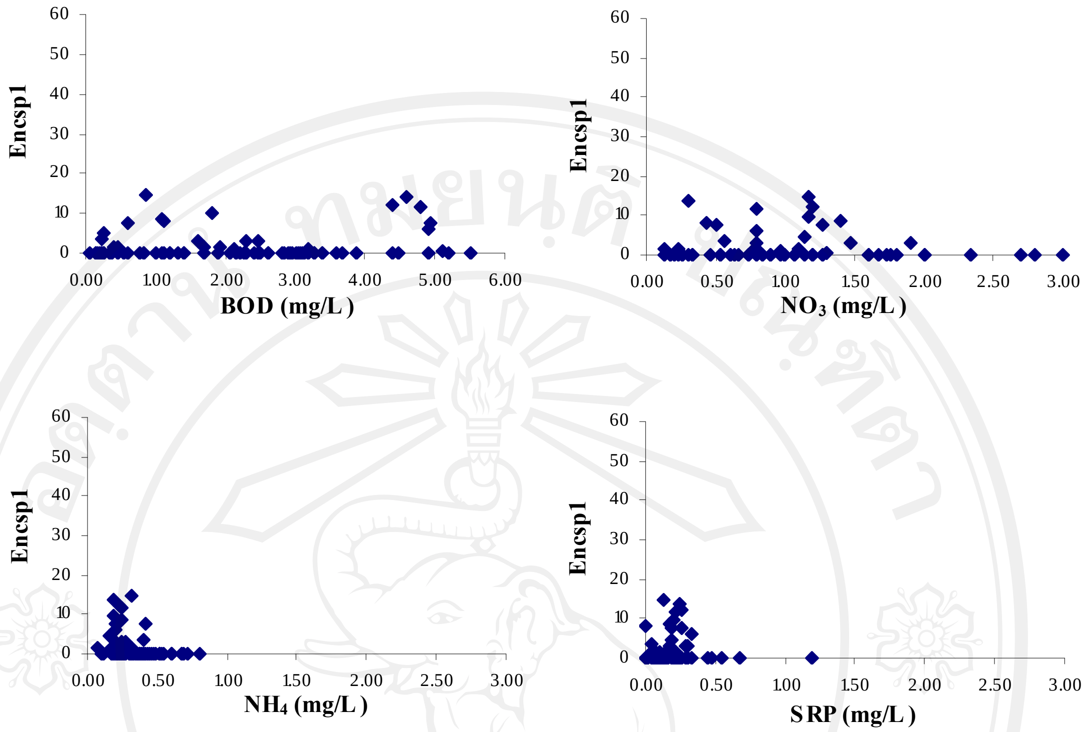
Figure 103 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Cymbella sp.1

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP			*			
Index value(4)				Mesotrophic status		

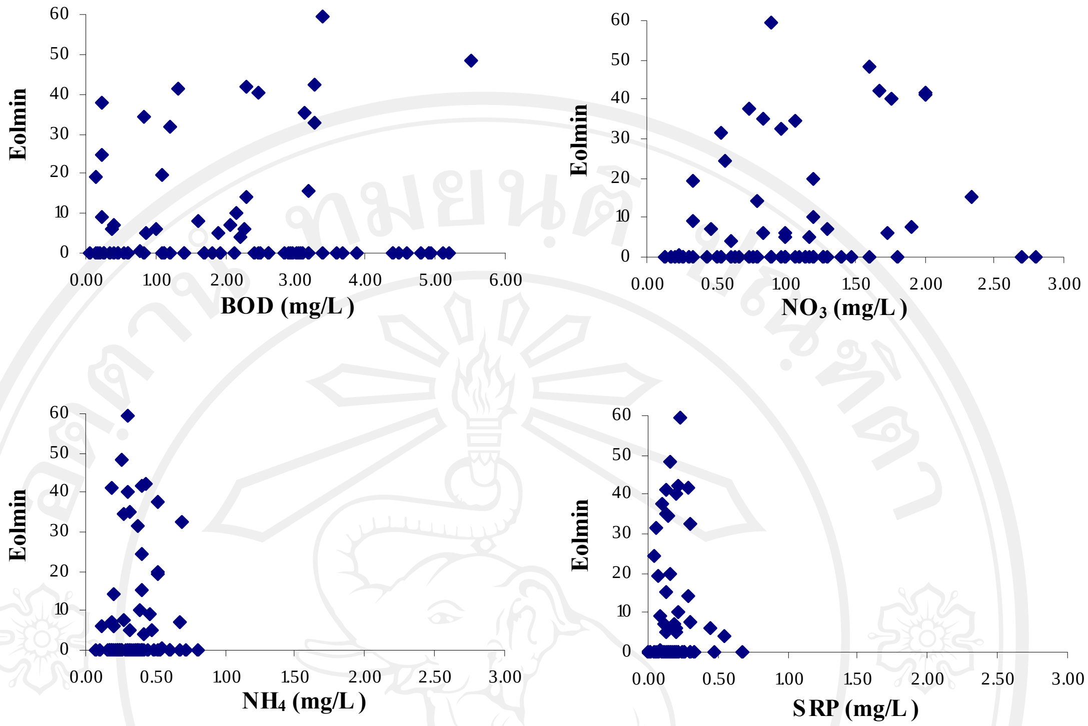
Figure 104 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Encyonema sp.1

parameter	1	2	3	4	5	6
BOD			*			
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)			Mesotrophic status			

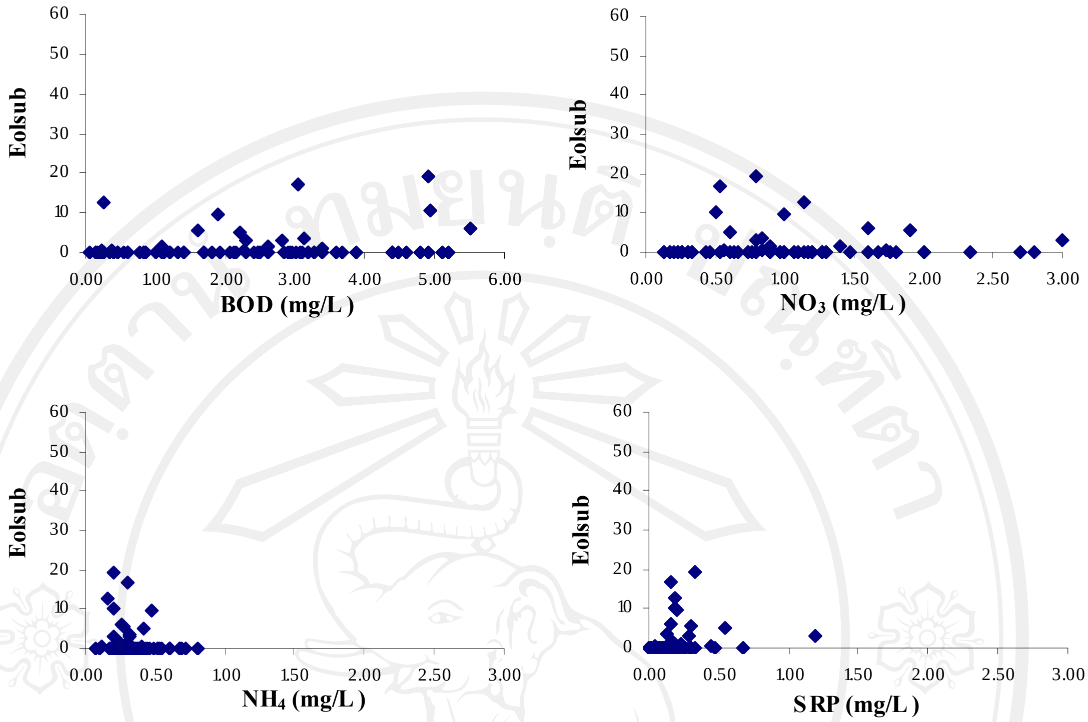
Figure 105 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Eolimna minima (Grunow) Lange-Bertalot

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)			Mesotrophic status			

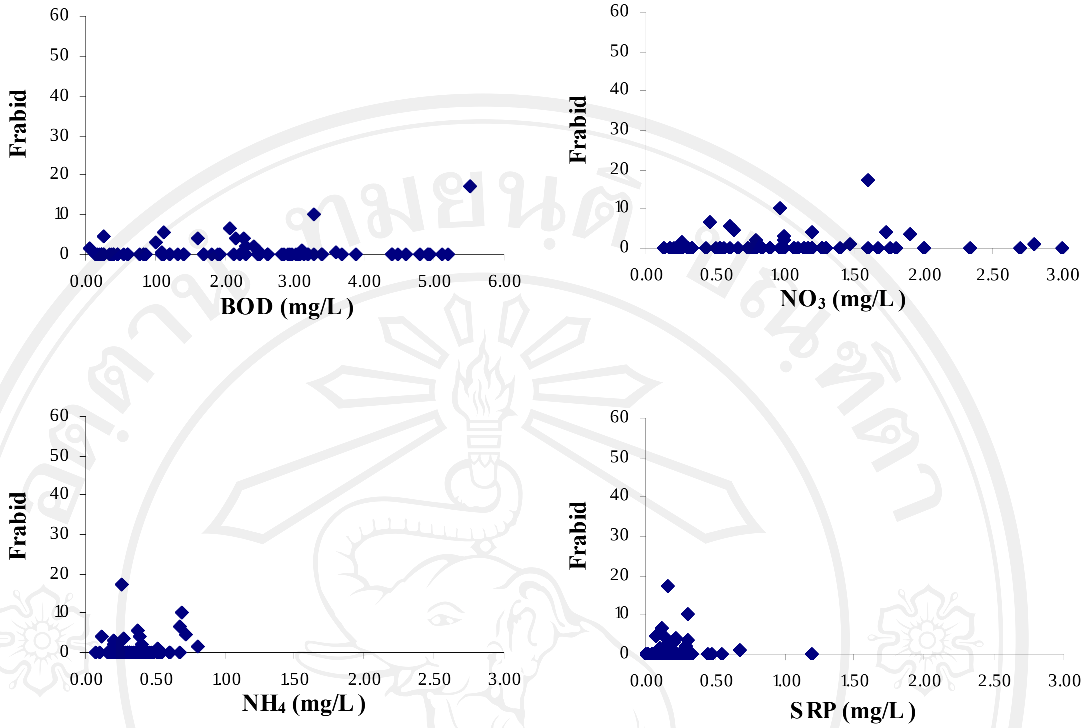
Figure 106 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Eolimna subminuscula (Manguin) Gerd Moser

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N				*		
SRP					*	
Index value(5)			Meso-Eutrophic status			

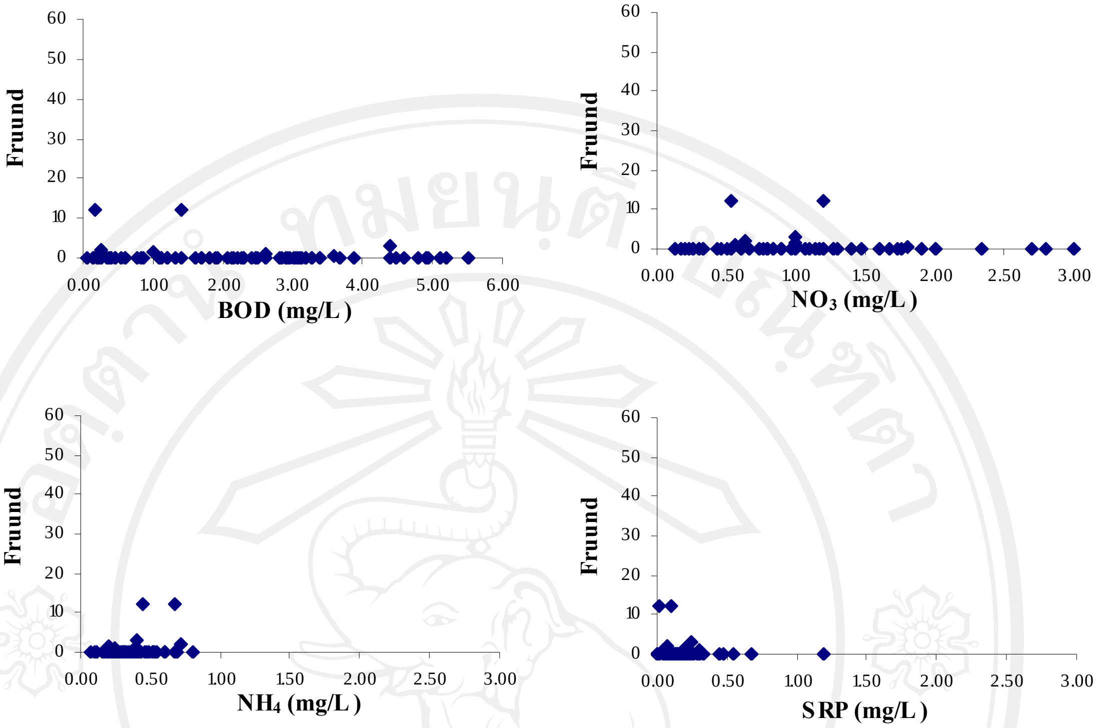
Figure 107 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Fragilaria bidens Heiberg

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(5)	Meso-Eutrophic status					

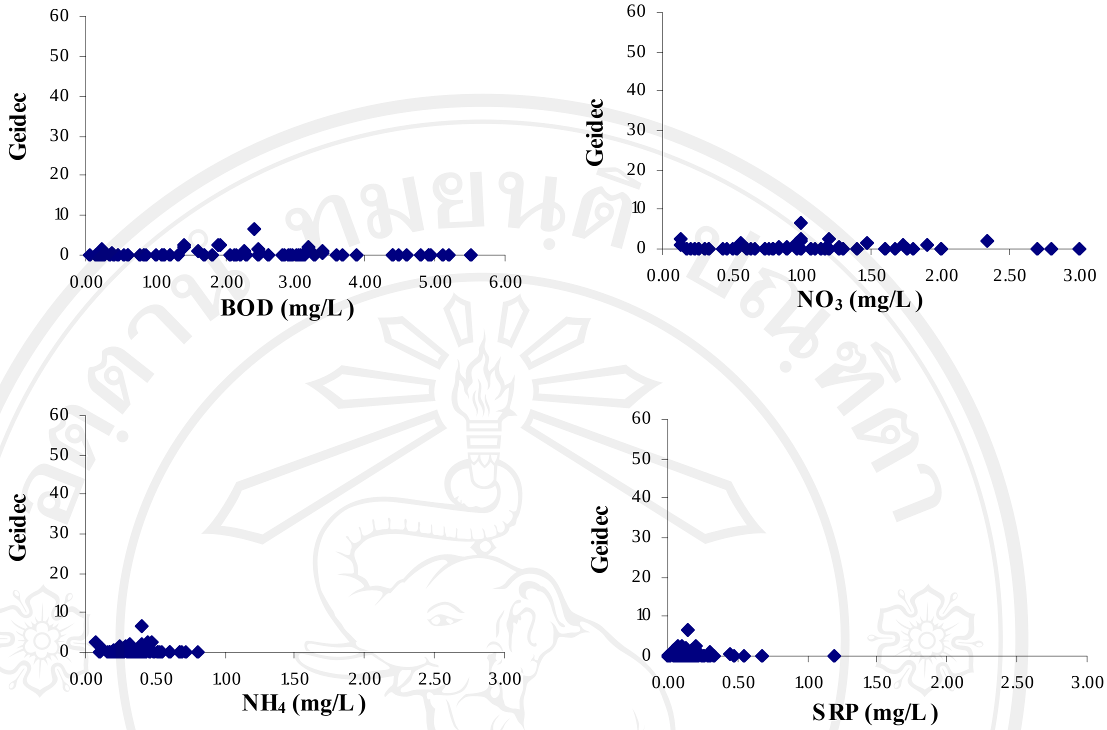
Figure 108 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Frustulia undosa D. Metzeltin & H. Lange-Bertalot

parameter	1	2	3	4	5	6
BOD			*			
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value			Mesotrophic status			

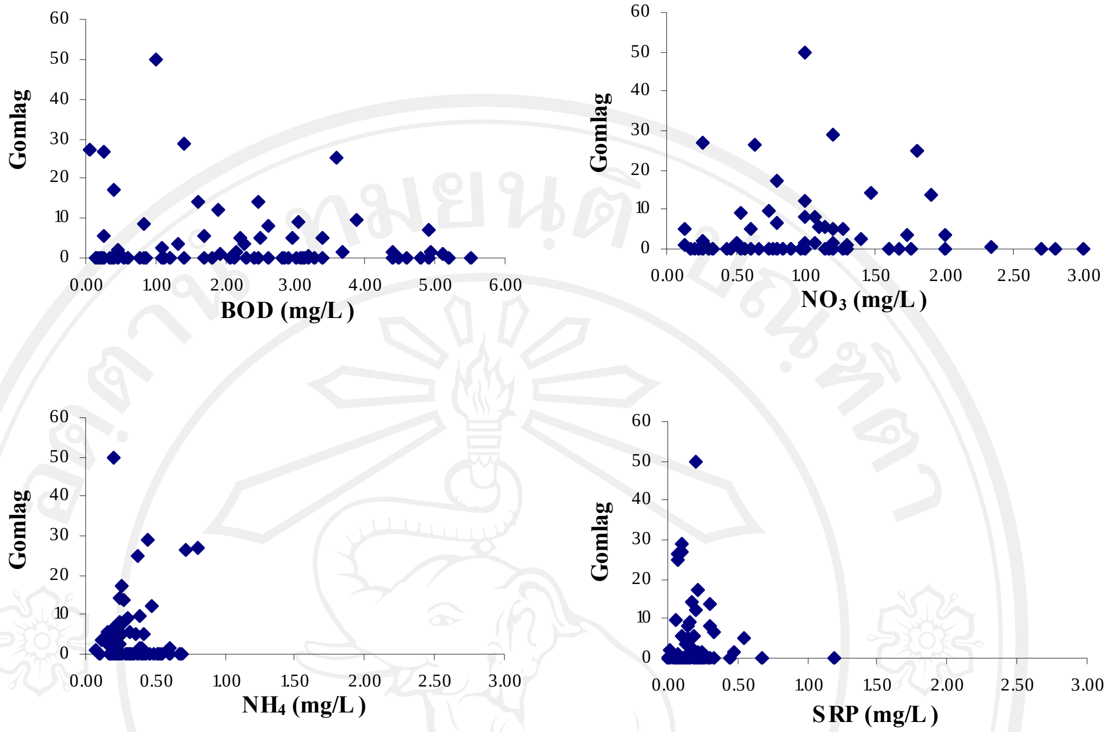
Figure 109 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Geissleria decussis (Østrup) Lange-Bertalot&Metzeltin

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)				Mesotrophic status		

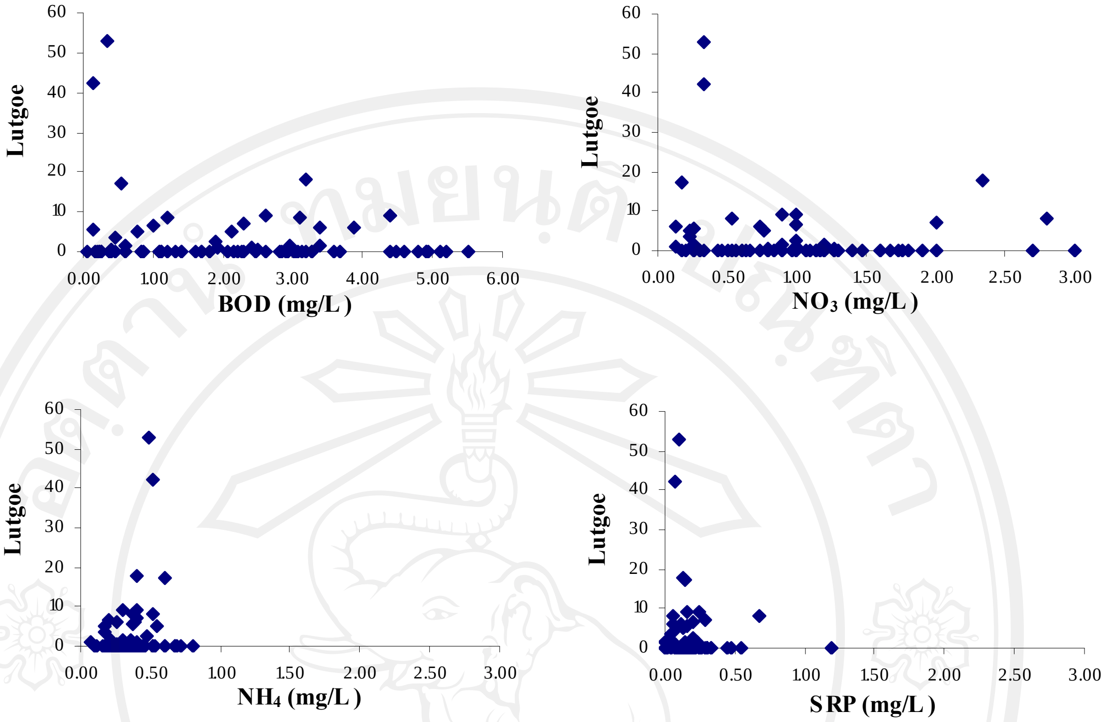
Figure 110 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Gomphonema lagenula Kützing

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

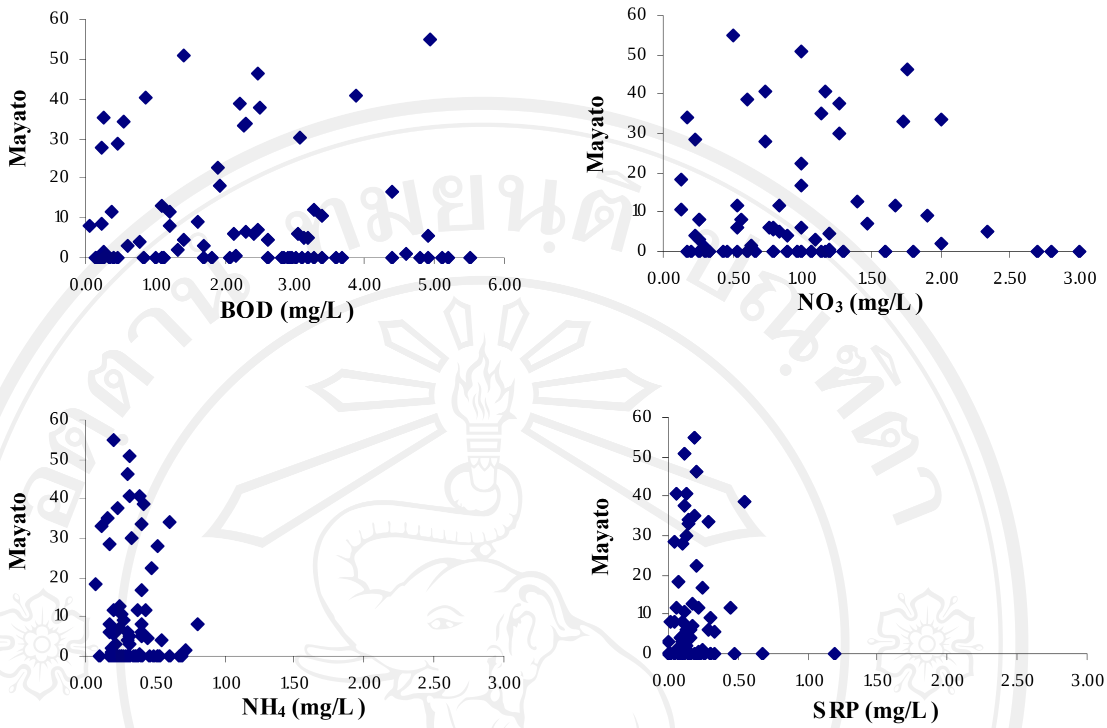
Figure 111 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Luticola goeppertiana (Bleisch) D.G.Mann in Round,Crawford&Mann

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

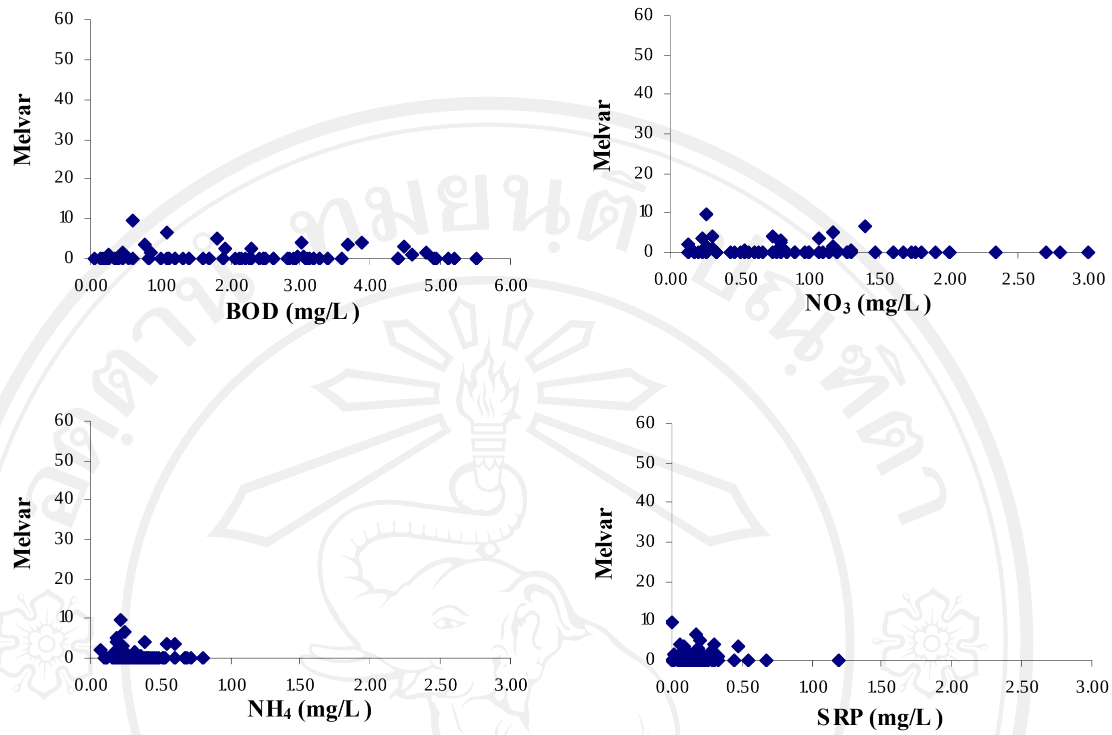
Figure 112 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Mayamaea atomus (Kützing) H. Lange-Bertalot

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N					*	
SRP					*	
Index value(5)	Meso-Eutrophic status					

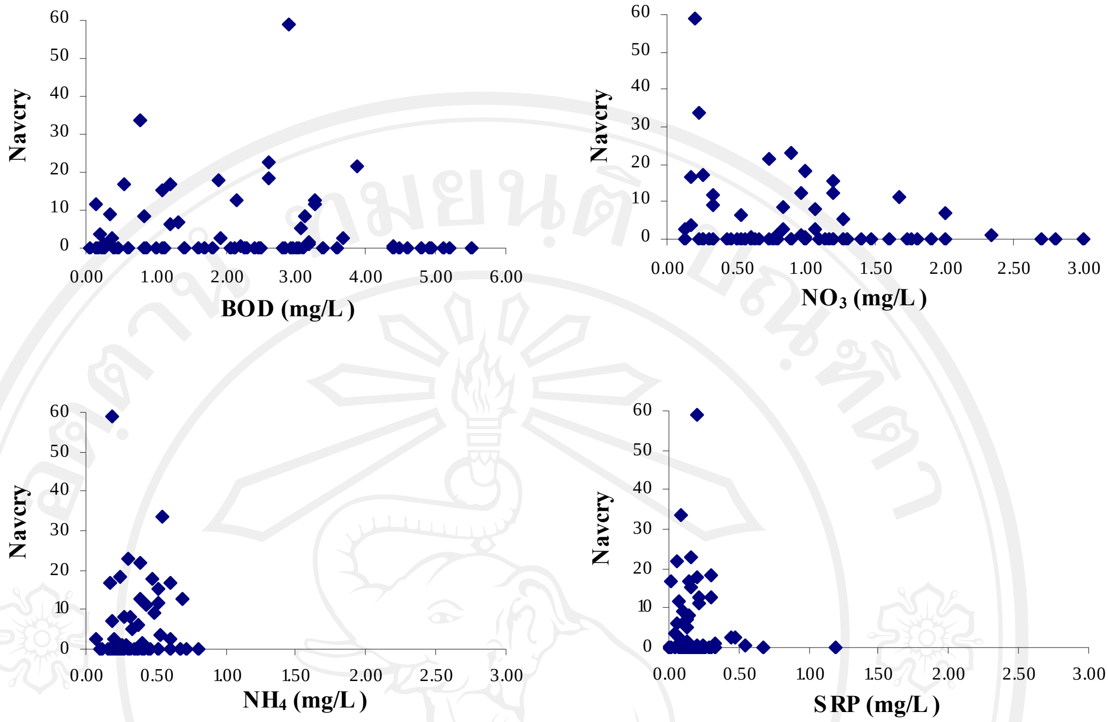
Figure 113 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Melosira varians C. Agardh

parameter	1	2	3	4	5	6
BOD			*			
NO_3 -N				*		
NH_4^+-N			*			
SRP			*			
Index value(3)			Oligo-mesotrophic status			

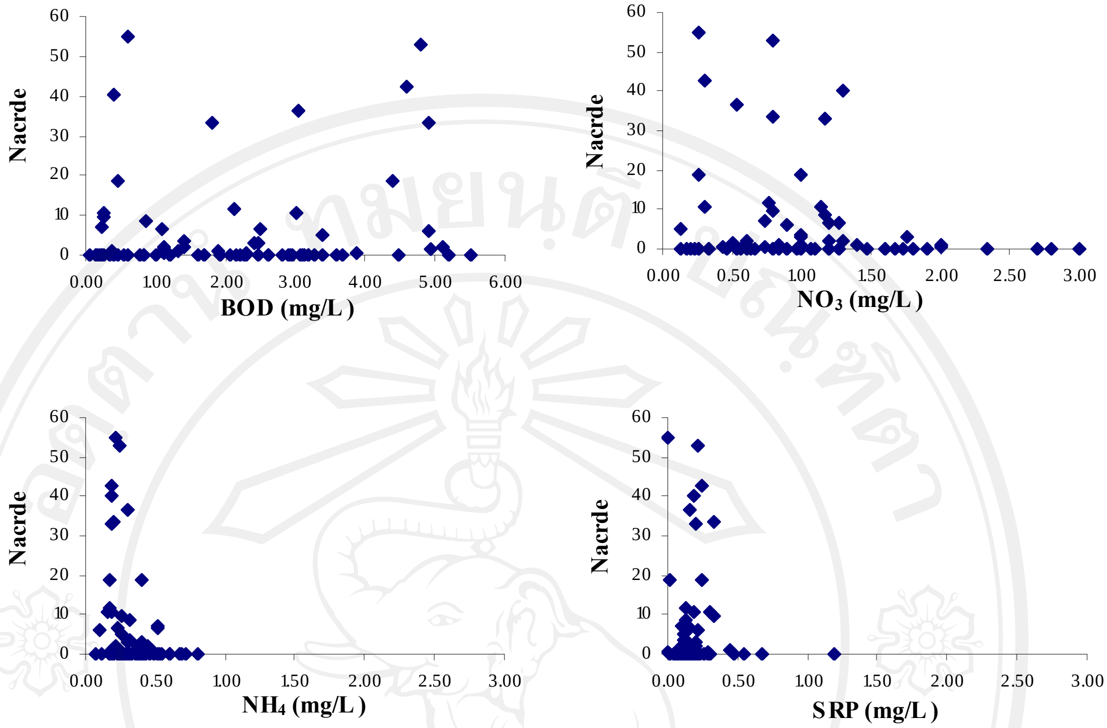
Figure 114 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula cryptotenella Lange-Bertalot

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

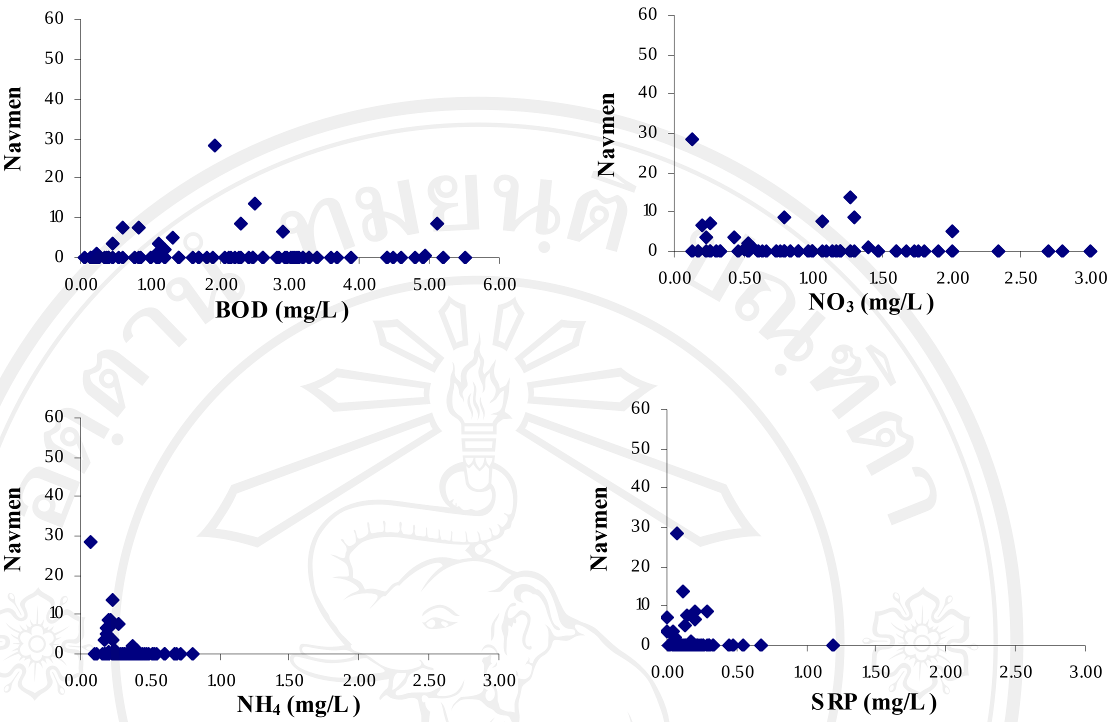
Figure 115 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula cryptotenelloides Lange-Bertalot

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N			*			
NH_4^+-N				*		
SRP				*		
Index value(4)			Mesotrophic status			

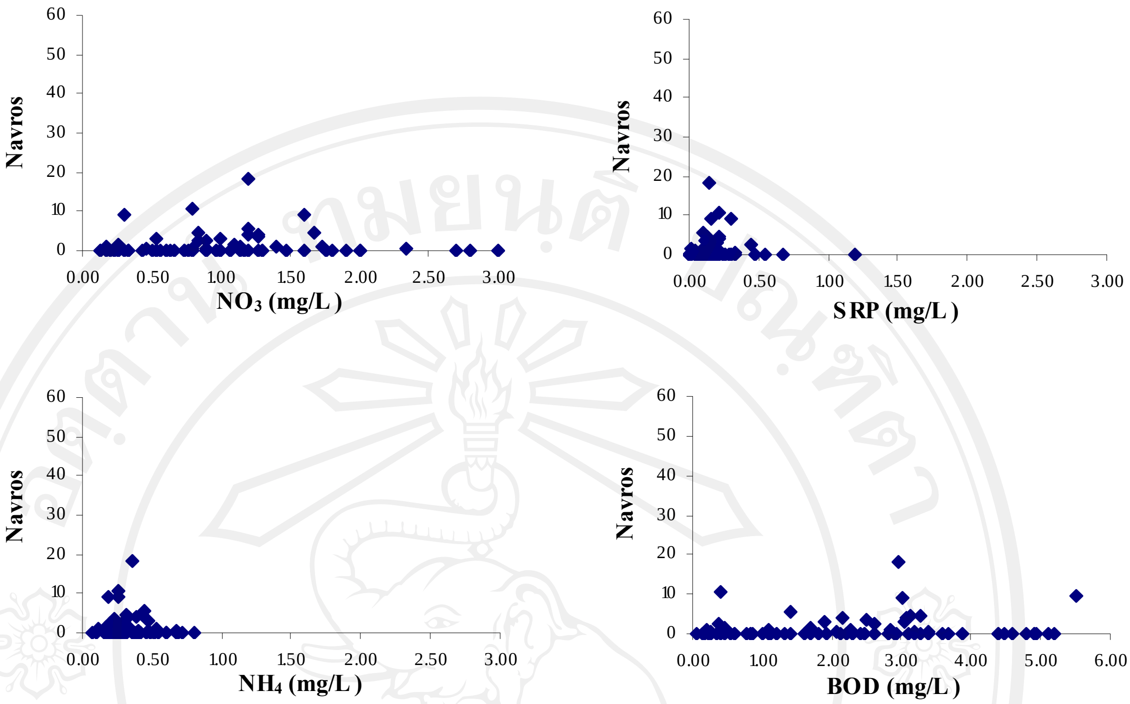
Figure 116 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula meniscula Schumann

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)			Mesotrophic status			

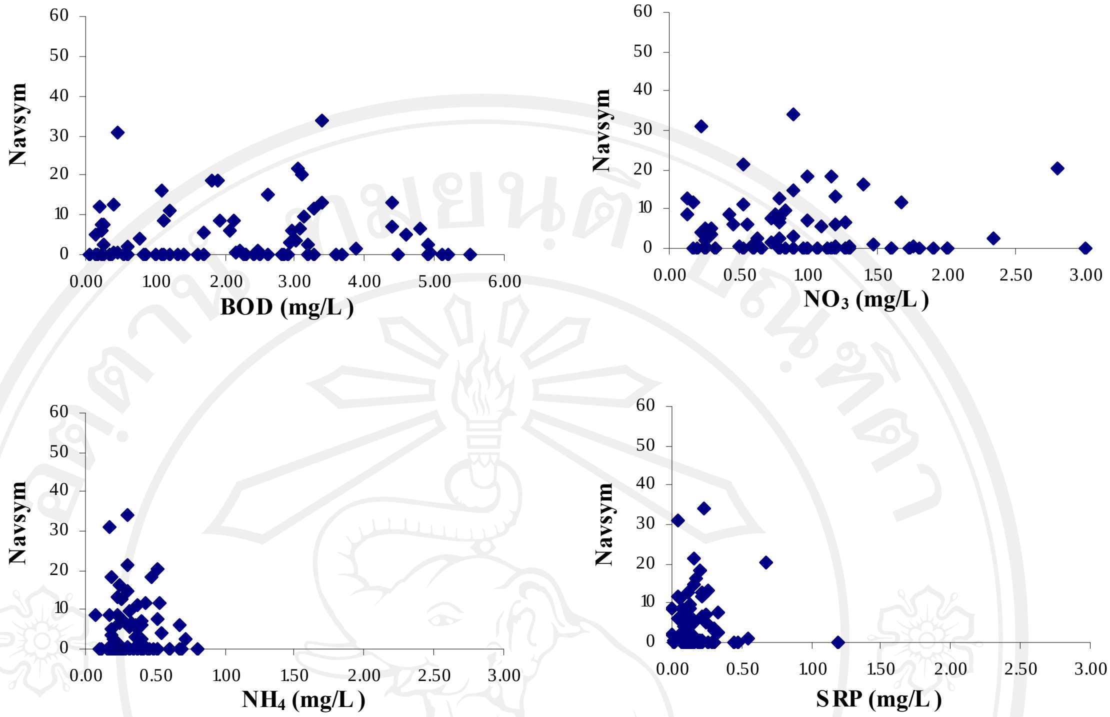
Figure 117 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula rostellata Kützing

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)				Mesotrophic status		

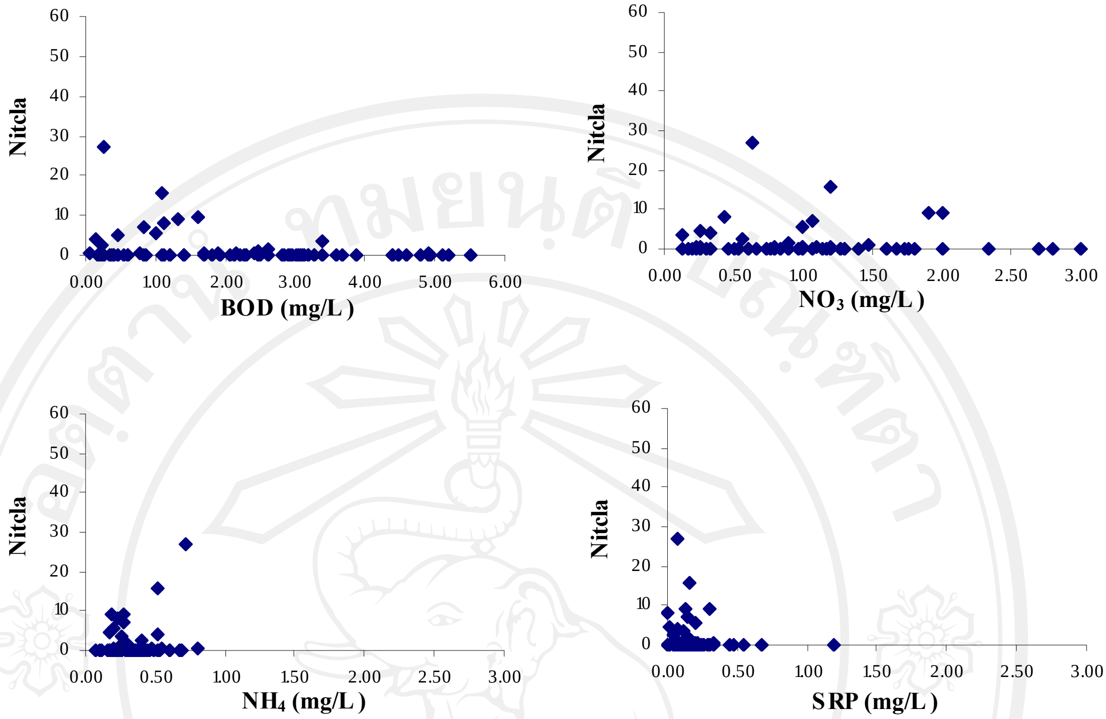
Figure 118 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula symmetrica R.M. Patrick

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP					*	
Index value(5)				Meso-Eutrophic status		

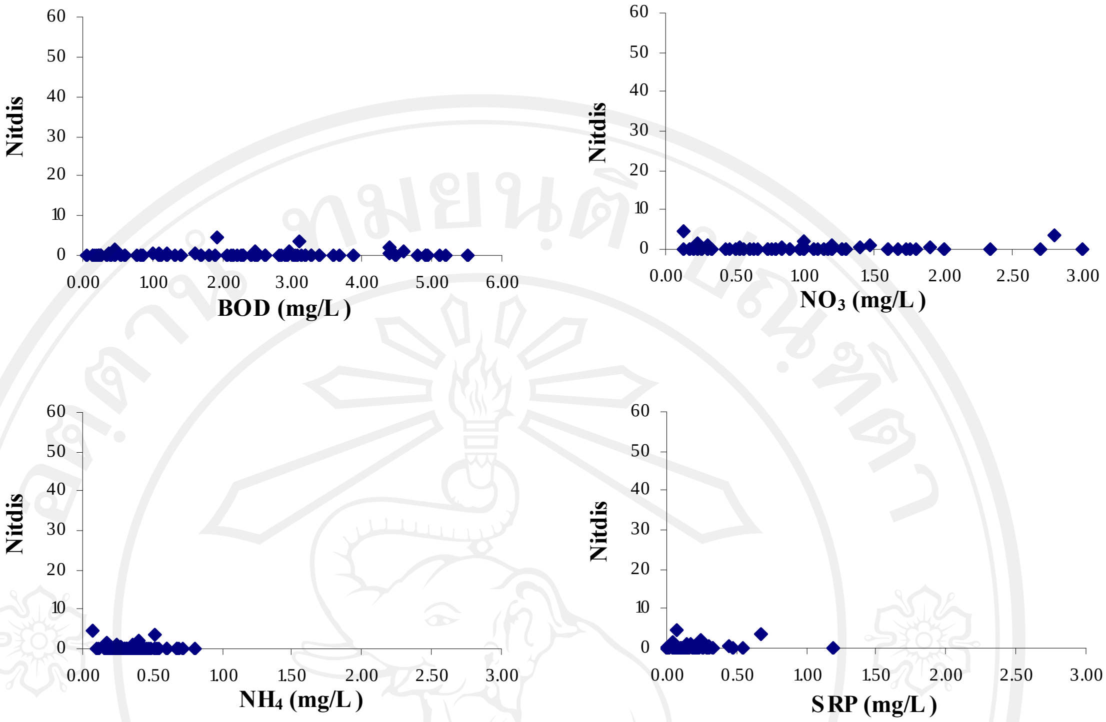
Figure 119 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia clausii Hantzsch

parameter	1	2	3	4	5	6
BOD			*			
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

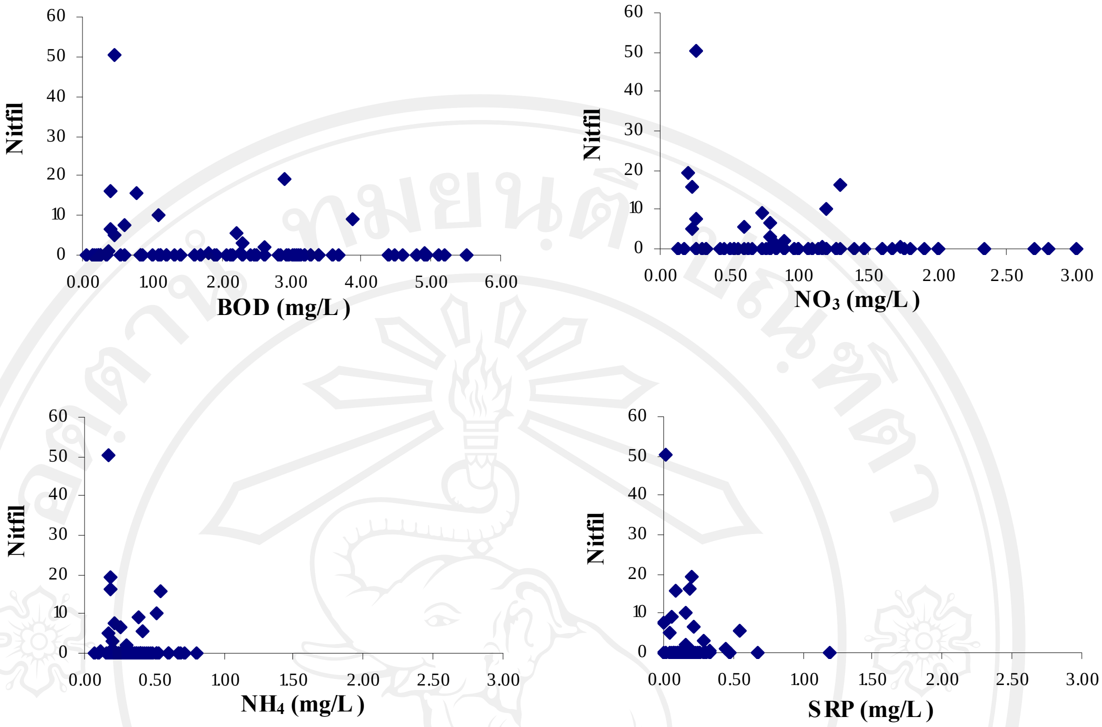
Figure 120 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia dissipata (Kützing) Grunow

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N					*	
NH_4^+-N				*		
SRP					*	
Index value(5)				Meso-Eutrophic status		

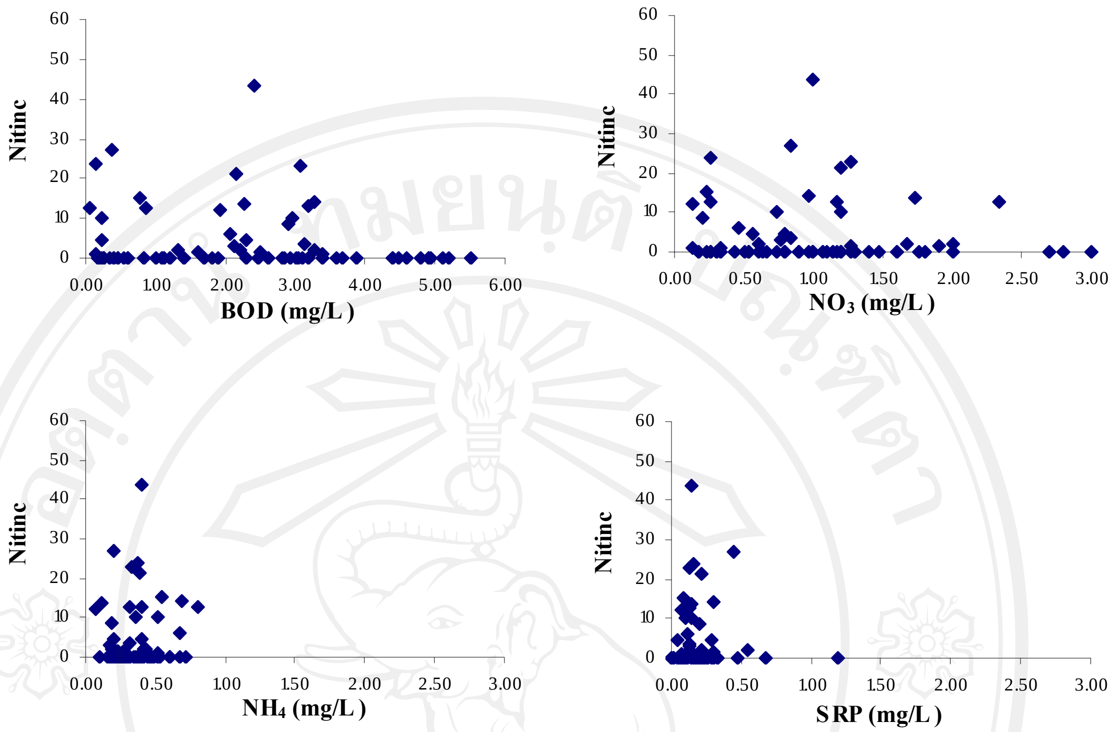
Figure 121 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia filiformis (W. Smith) Hustedt

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)				Mesotrophic status		

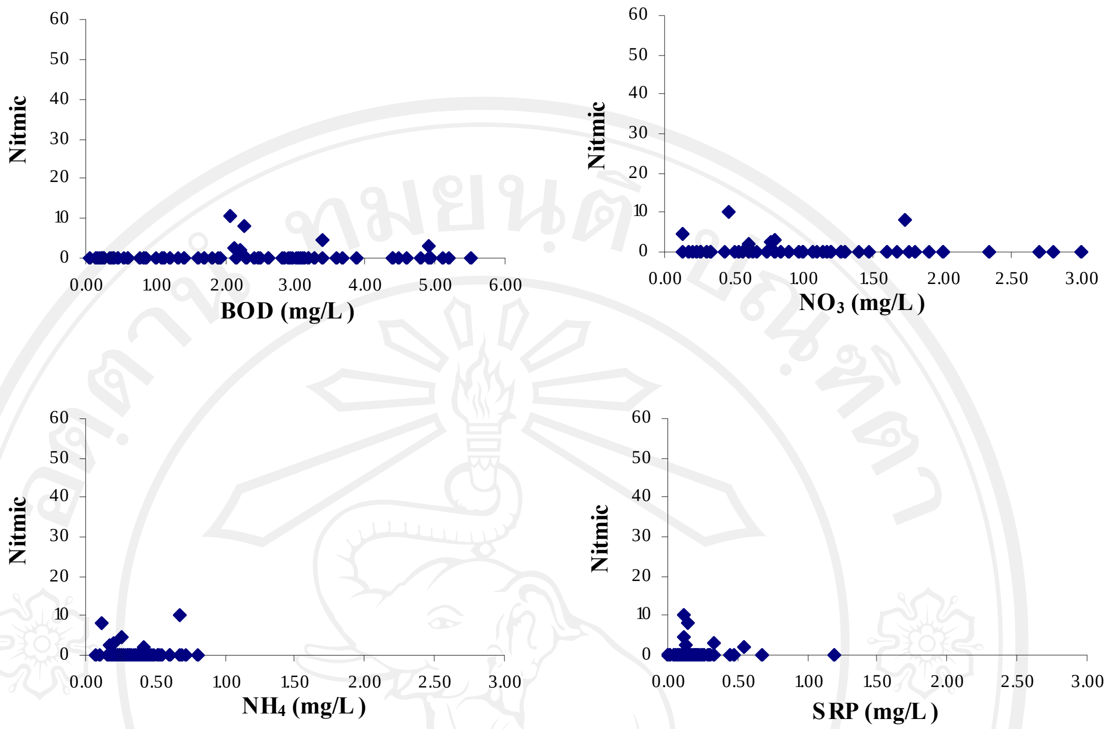
Figure 122 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia inconspicua Grunow

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

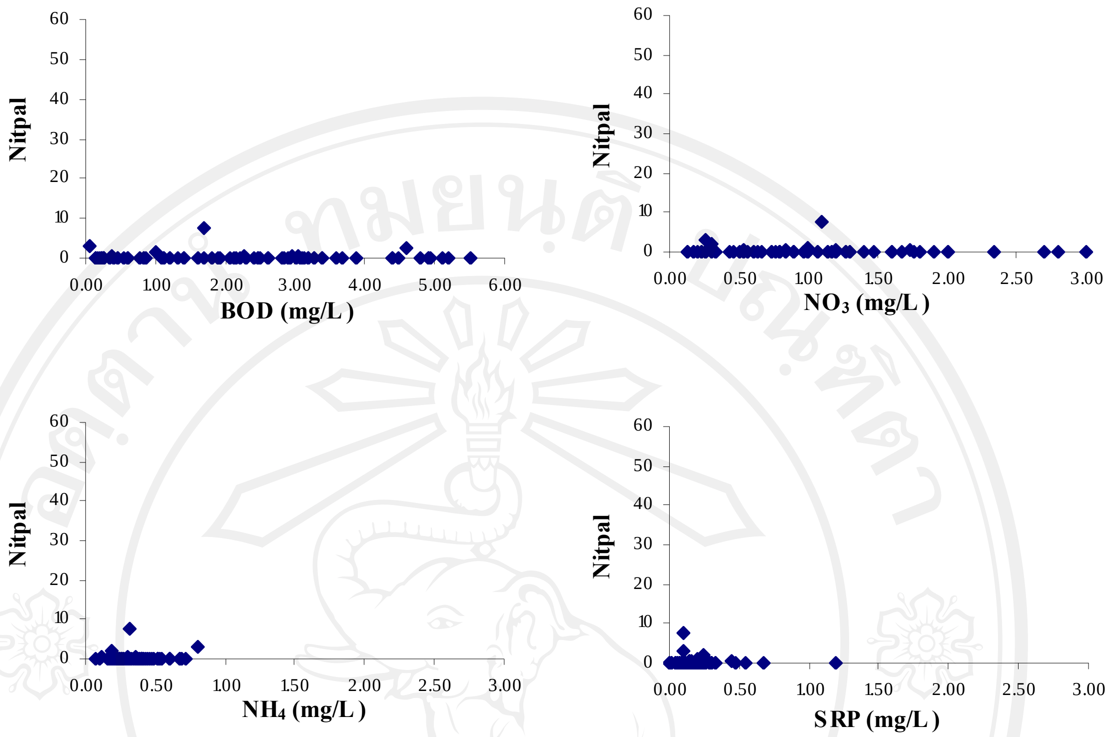
Figure 123 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia microcephala Grunow

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

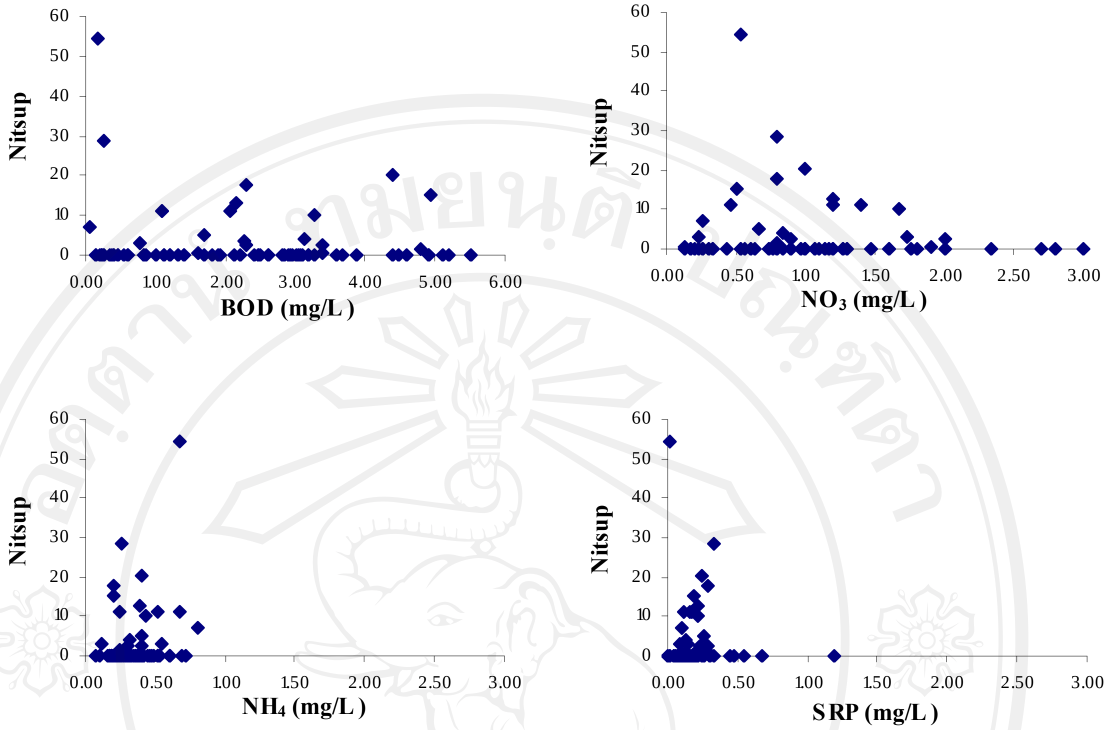
Figure 124 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia palea (Kützing) W. Smith

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(5)				Meso-Eutrophic status		

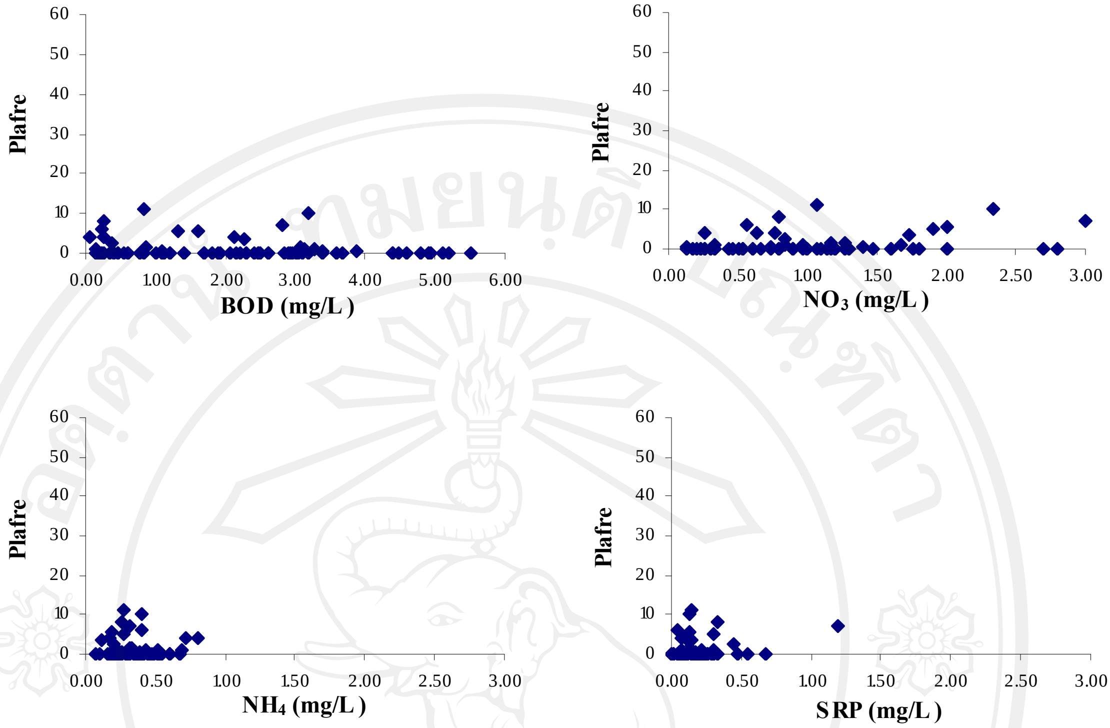
Figure 125 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia supralitorea Lange-Bertalot

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(5)			Meso-Eutrophic status			

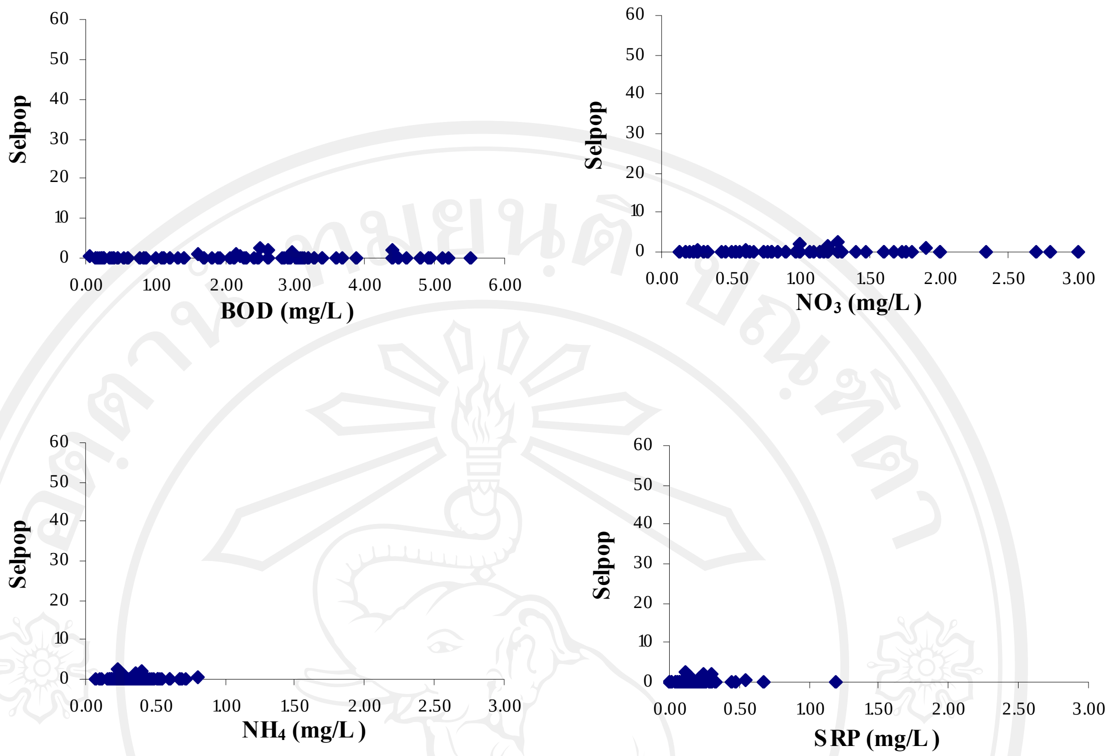
Figure 126 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Planothidium frequentissimum (Lange-Bertalot) Round&L.Bukhtiyarova

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N					*	
NH_4^+-N				*		
SRP					*	
Index value(5)			Meso-Eutrophic status			

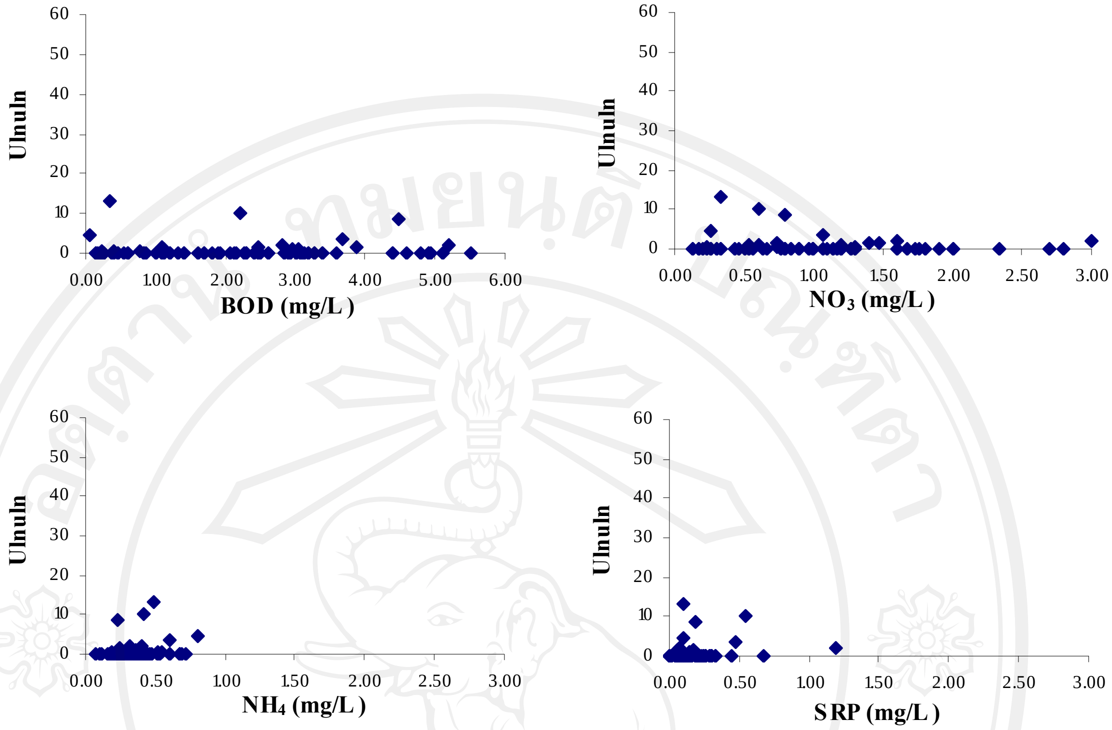
Figure 127 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Sellaphora pupula (Kützing) Mereschkovsky

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)			Mesotrophic status			

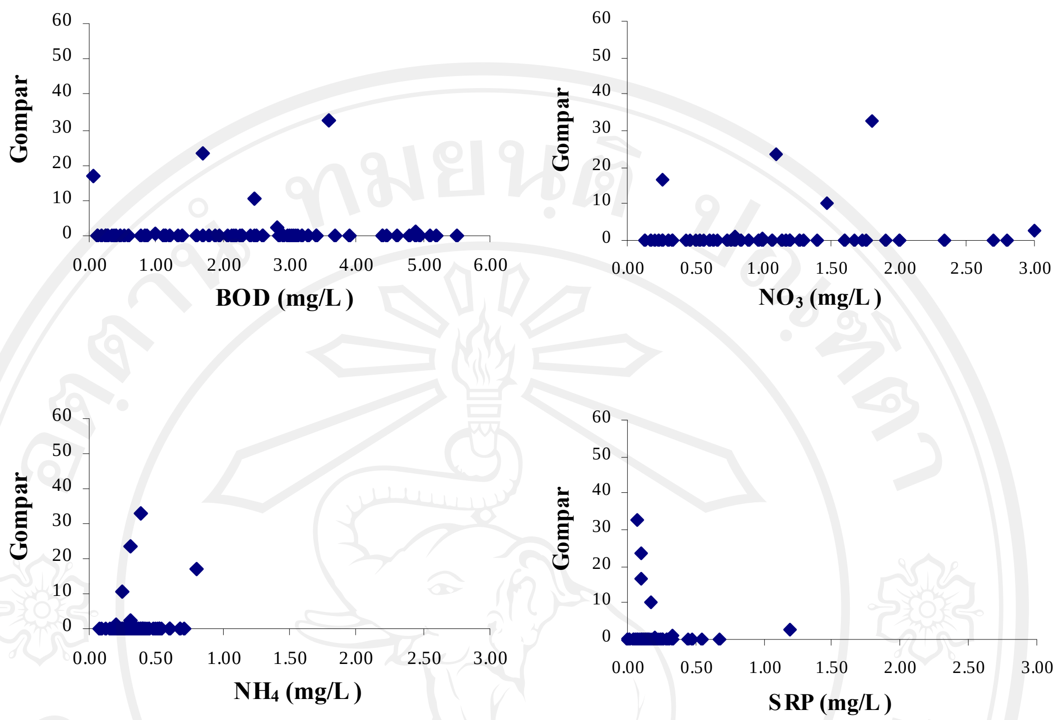
Figure 128 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Ulnaria ulna (Nitzsch) P. Compère

parameter	1	2	3	4	5	6
BOD					*	
NO_3 -N				*		
NH_4^+-N					*	
SRP				*		
Index value(4)			Mesotrophic status			

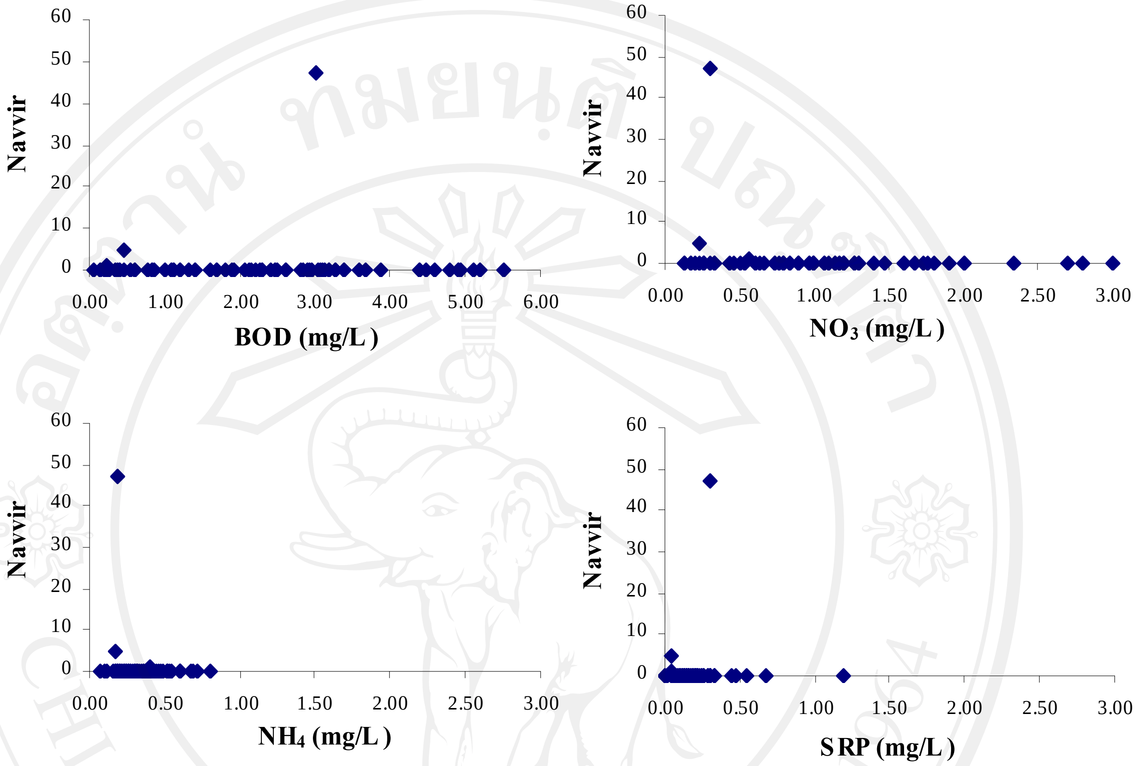
Figure 129 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Gomphonema parvulum (Kützing) Kützing var. *parvulum*

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N			*			
NH_4^+-N				*		
SRP			*			
Index value(4)			Mesotrophic status			

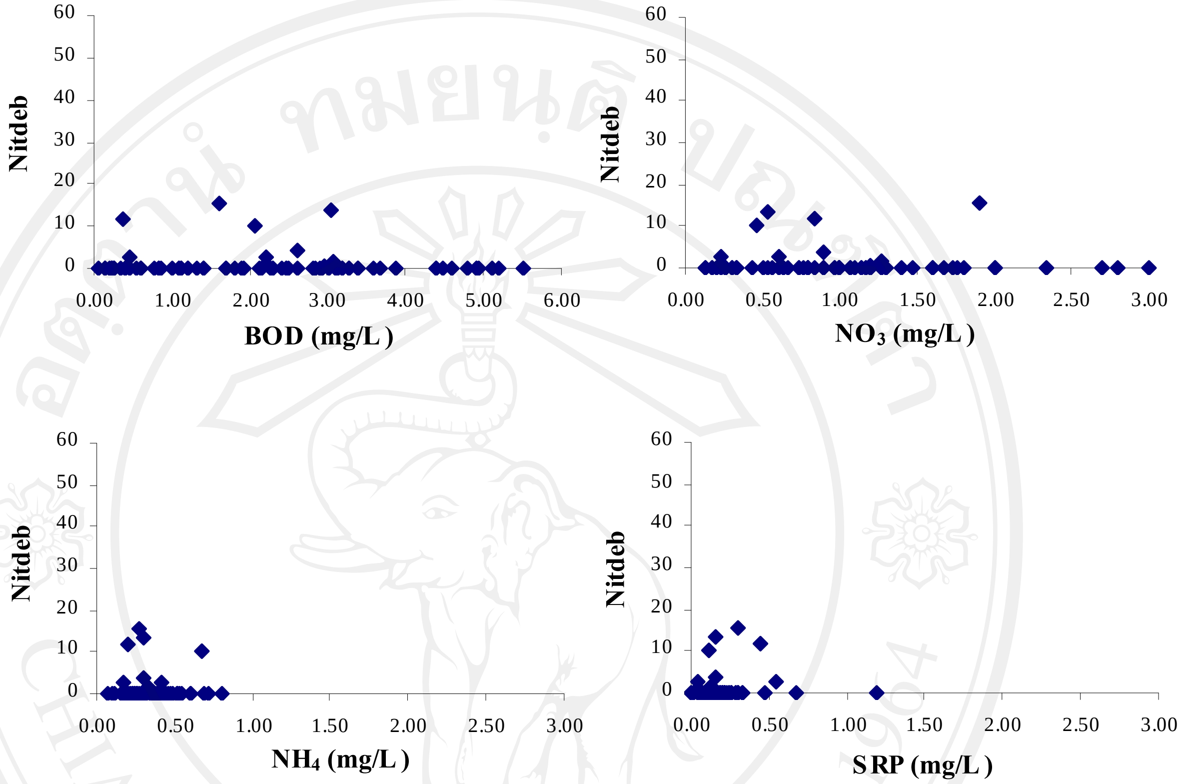
Figure 130 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Navicula viridula var. *viridula* (Kützing) Ehrenberg

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N			*			
NH_4^+-N			*			
SRP					*	
Index value(4)			Mesotrophic status			

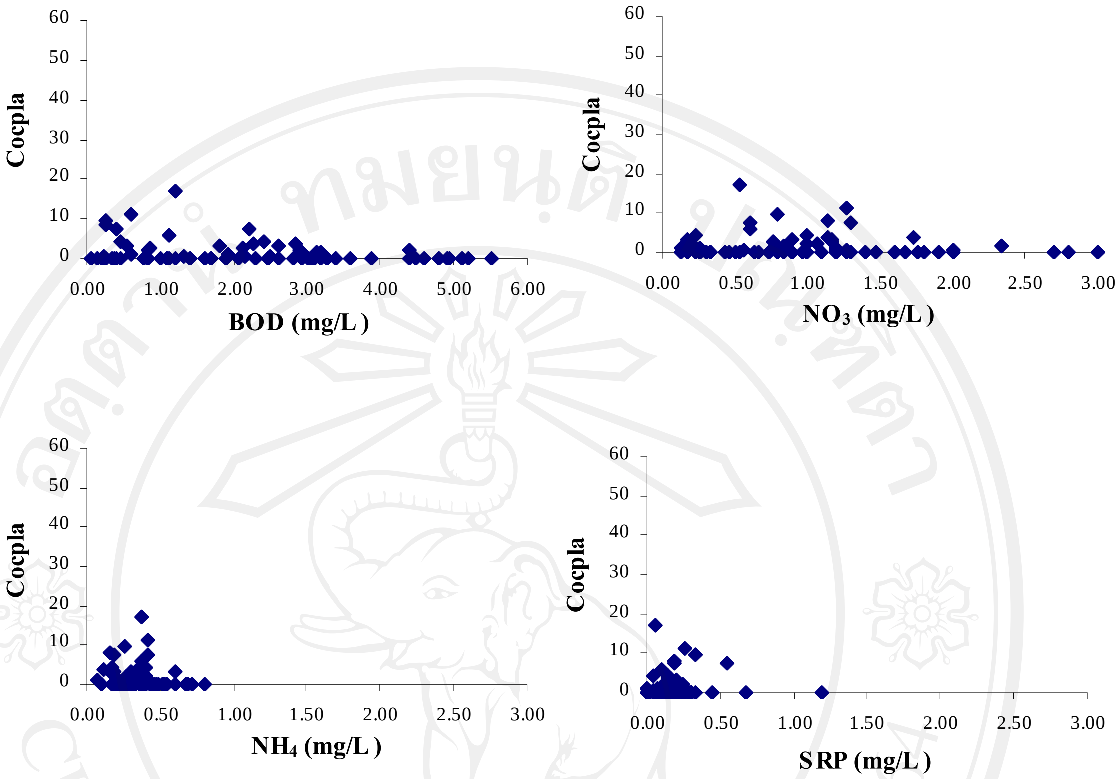
Figure 131 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Nitzschia palea var. *debilis* (Kützing) Grunow

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N			*			
NH_4^+-N				*		
SRP					*	
Index value(4)			Mesotrophic status			

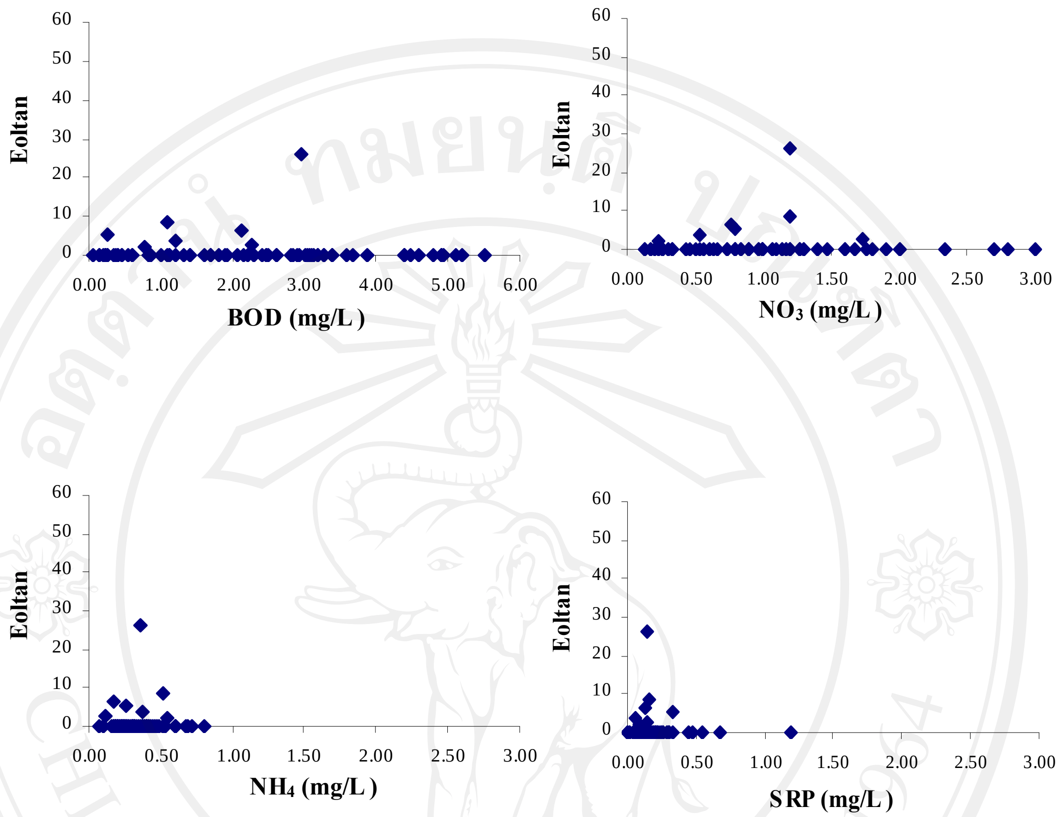
Figure 132 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Cocconeis placentula Ehrenberg

parameter	1	2	3	4	5	6
BOD		*				
NO_3 -N				*		
NH_4^+-N				*		
SRP			*			
Index value(3)			Oligo-Mesotrophic status			

Figure 133 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index



Eolimna tantula (Hustedt) Lange-Bertalot

parameter	1	2	3	4	5	6
BOD				*		
NO_3 -N				*		
NH_4^+-N				*		
SRP				*		
Index value(4)				Mesotrophic status		

Figure 134 Scatter plots of selected species (numbers of cells) against with some physico-chemical parameters for Mekong Index

Table 18 Index values of all species list for Mekong Index

Taxa	Index value
Achnanthidium convergens (H. Kobayasi) H. Kobayasi	4
Achnanthidium minutissimum (Kützing) Czarnecki	4
Cocconeis placentula Ehrenberg	3
Cymbella sp.1	4
Cymbella sumatrensis Hustedt	4
Encyonema sp.1	4
Eolimna minima (Grunow) Lange-Bertalot	4
Eolimna subminuscula (Manguin) Gerd Moser	5
Eolimna tantula (Hustedt) Lange-Bertalot	4
Fragilaria bidens Heiberg	5
Frustulia undosa D. Metzeltin & H. Lange-Bertalot	4
Geissleria decussis (Østrup) Lange-Bertalot&Metzeltin	4
Gomphonema parvulum (Kützing) Kützing var. *Parvulum*	4
Luticola goeppertiana (Bleisch) D.G.Mann in Round,Crawford&Mann	4
Gomphonema lagenula Kützing	4
Mayamaea atomus (Kützing) H. Lange-Bertalot	5
Melosira varians C. Agardh	3
Navicula cryptotenella Lange-Bertalot	4
Navicula rostellata Kützing	4
Navicula symmetrica R.M. Patrick	5
Navicula menisculus Schumann	4
Navicula cryptotenelloides Lange-Bertalot	4
Nitzschia clausii Hantzsch	4
Navicula viridula var. *viridula* (Kützing) Ehrenberg	4
Nitzschia palea var. *debilis* (Kützing) Grunow	4
Nitzschia dissipata (Kützing) Grunow	5
Nitzschia filiformis (W. Smith) Hustedt	4
Nitzschia inconspicua Grunow	4
Nitzschia microcephala Grunow	4
Nitzschia palea (Kützing) W. Smith	5
Nitzschia supralitorea Lange-Bertalot	5
Planothidium frequentissimum (Lange-Bertalot)Round&L.Bukhtiyarova	5
Sellaphora pupula (Kützing) Mereschkovsky	4
Ulnaria ulna (Nitzsch) P. Compère	4

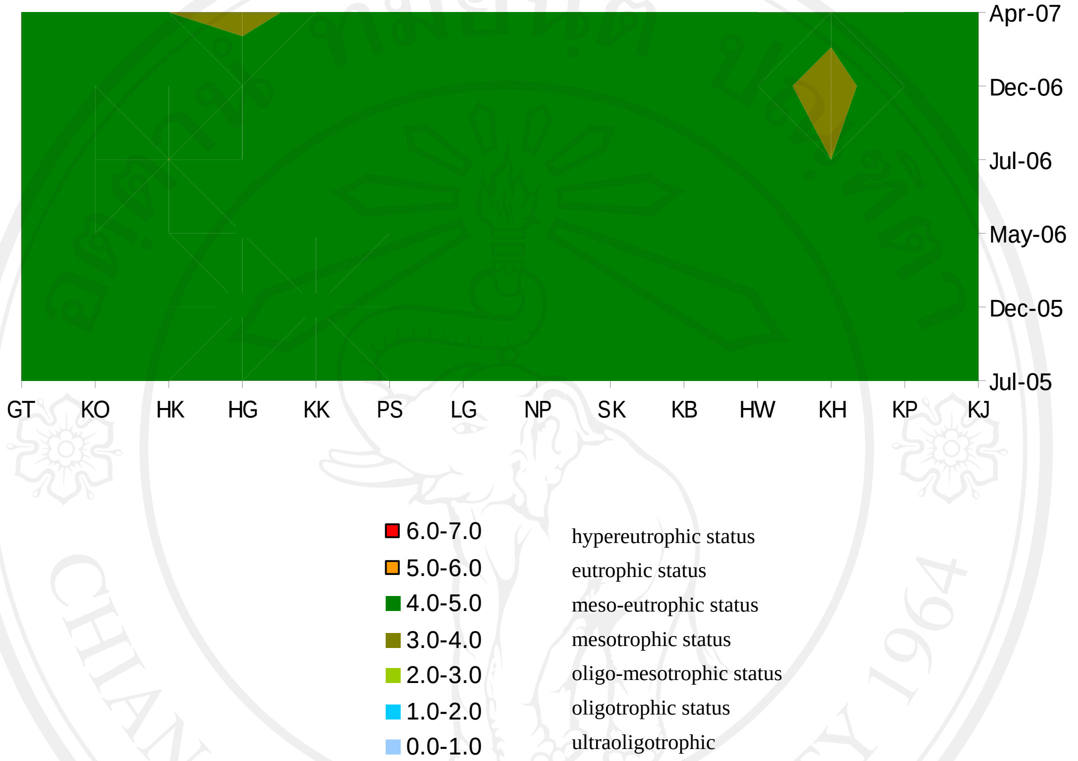


Figure 135 Water quality estimation in Mekong River and its tributaries based on the Mekong River and its tributaries Index

4.4.2 The comparison of the Saprobic Index of Rott (Rott *et al*. 1997), Mae Sa Index (Pekthong, 2002), Ping and Nan Index (Kunpradid, 2005) to assess water quality in Mekong River and its tributaries

The comparison between the Saprobic Index of Rott (Rott *et al*. 1997), Mae Sa index (Pekthong, 2002), Ping and Nan index (Kunpradid, 2005) to assess water quality in Mekong River and its tributaries were shown in Figure 136.

The Saprobic Index of Rott in 1977 were very variable, water quality were classified into 7 catagories with scores ranging from 1.7 – 8.8. Whereas the Mae Sa index was classified at different level, 6 catagories with scores ranging from 4.0 -5.0. For Ping and Nan indices that had 7 catagories with scores ranging from 3.0 -4.0. The Mekong River and its tributaries index in this research, the index was calculated for the diatom data to evaluate water quality categories. The classifications of water quality were divided into 7 categories with scores ranging from 3.7 -5.0.

It was found that the Mekong River and its tributaries index was appropriated more than the others. The Mae Sa index was similar evaluation to the Mekong River and its tributaries index. Whereas there were very variables in the Saprobic index of Rott and were lower scores of water quality classification when compared with the Ping and Nan index.

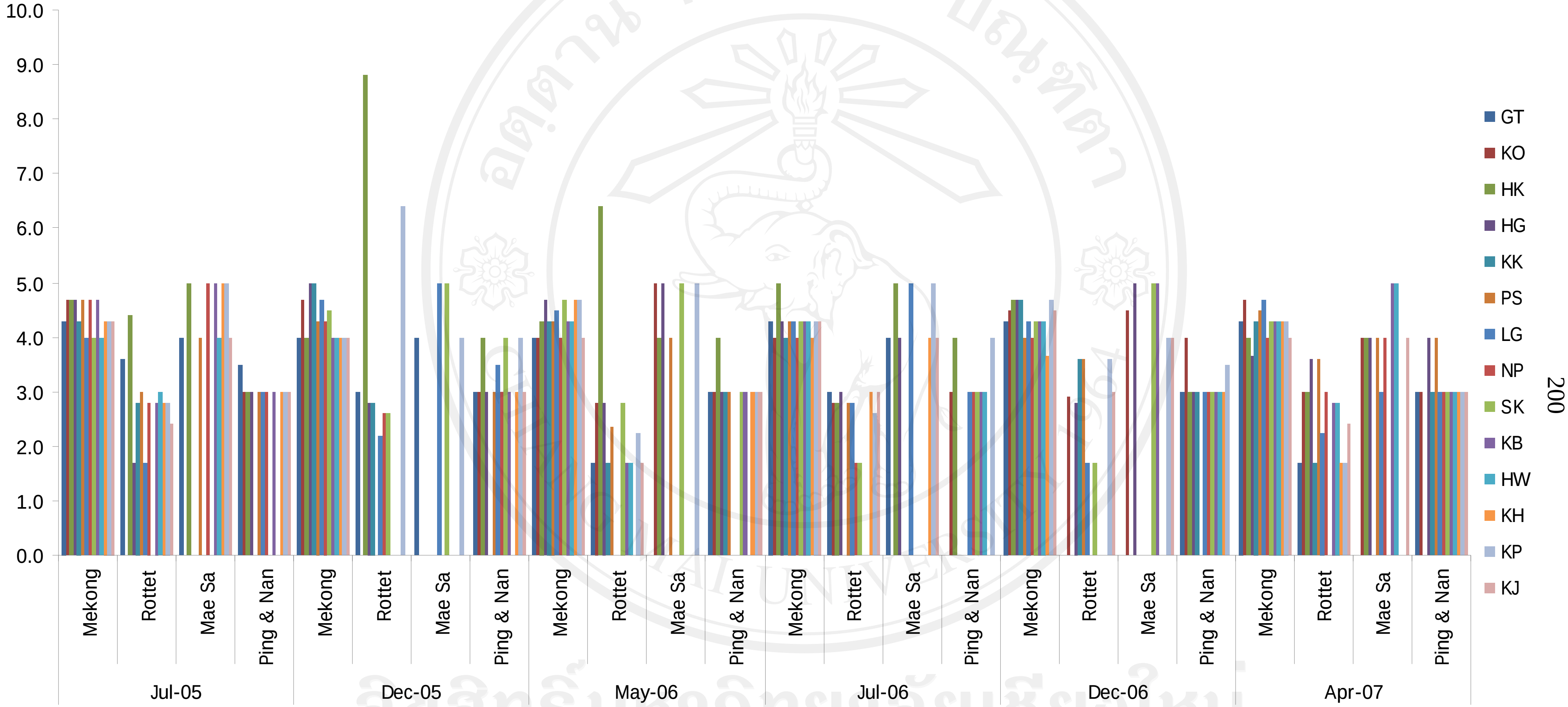


Figure 136 Water estimation in Mekong River and its tributaries by Mekong River and it tributaries Index, Saprobic Index of Rott *et al.*(1997), Mae Sa Index (2002) and Ping and Nan Index (2005)