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Research Article

Diversity of Benthic Diatoms and Water Quality of the Mekong River Passing Through Ubon Ratchathani Province, Thailand

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Abstract: The study on the diversity of benthic diatoms and water quality in the Mekong River as it passes through Ubon Ratchathani, Thailand was carried out from February 2007 to January 2008. Samples were collected from 10 stations, which were situated in areas involving different geographical features and human activities. Three hundred and seven species of benthic diatoms were found. The majority of them were *Gomphonema lagenula* Kützing, *Navicula rostellata* Kützing, *Nitzschia palea* (Kützing) W. Smith, *Luticola goeppertiana* (Bleisch) D. G. Mann, *Nitzschia liebetruthii* Rabenhorst, *Sellaphora pupula* (Kützing) Mereschkowsky, *Navicula erifuga* Lange-Bertalot and *Cymbella tumida* (Brébisson) Van Heurck, respectively. The water quality was slightly different at each sampling site which was classified as moderate water quality (mesotrophic status). Ban Na Muang, Pak Seang Temple, Ban Ta Mui, Ban Na Sanarm, the location behind the Municipal Market and Wigittra Beach were all found to possess moderate water quality (mesotrophic status). Chang Mop Cataract, Ban Koom, Ban Dan and Ban Huay Phai were found to have moderate to polluted water quality (mesotrophic to eutrophic status). The Multivariate Statistical Package (MVSP) particularly Principal Correspondence Analysis (PCA), and the cluster analysis were used to determine the relationship between the water quality and the present of benthic diatoms, in terms of biomonitoring. It was found that *Cymbella tumida* (Brébisson) Van Heurck and *Navicula erifuga* Lange-Bertalot could be indicators of mesotrophic status, whereas *Cymbella turgidula* Grunow, *Gomphonema clevei* var. *javanica* Hustedt, *Luticola goeppertiana* (Bleisch) D. C. Mann, *Nitzschia liebetruthii* Rabenhorst and *Nitzschia palea* (Kützing) W. Smith could be indicator of the meso-eutrophic status.

Keywords: Benthic diatom, Mekong river, Thailand, trophic status, Ubon ratchathani

INTRODUCTION

The Mekong River is the 12th longest river in the world and flows from China through Myanmar, Thailand, Laos and Cambodia and into Vietnam. In Thailand, the Mekong River flows from the northern and north-eastern borders to Myanmar and Laos. Ubon Ratchathani is the eastern most provinces that this river passes through Thailand, and a high diversity of organisms, including benthic diatoms and macroalgae, were found to be present there. Generally, in lotic ecosystems, benthic diatoms are groups of organisms which could be used as bioindicators of water quality. The composition of benthic diatoms is dependent upon the river's characteristics and other specific environmental variables such as hydrology, substratum, light, temperature and water chemistry (Pfister, 1992). These factors could affect the species composition and the organisms were found to be species-specific according to the environmental factors. Spatial patterns of diatom species assemblages and environmental factors effecting diatom species communities have been targeted in several studies (Biggs, 1990; Pipp and Rott, 1994; Reavie and Smol, 1998; Rott *et al*., 1998; Pan *et al*., 1999; Potapova and Charles, 2003; Soininen, 2002).

Diatoms have been used routinely, worldwide to monitor water quality in rivers and streams (Schoeman, 1979; Coste *et al*., 1991; Whitton and Kelly, 1995; Jüttner *et al*., 2003), for example, in Europe (Kelly, 1998; Prygiel and Coste, 1993), North America (Lowe and Pan, 1996; Stevenson and Pan, 1999), Africa (Archibald, 1972), Australia (Chessman, 1986; John, 1998; Chessman *et al*., 1999) and Asia (Wu, 1986; Hirano, 1967; Atazadeh *et al*., 2007; Shibazaki *et al*., 2011). In Thailand, there have been few research studies involving the use of benthic diatoms as biomonitors in streams and rivers such as the Mae Sa Stream (Pekthong, 2002), the Ping and Nan Rivers (Kunpradid, 2005), the Mekong River (Suphan, 2009), as well as the Tha Chin, Chi, Chanthaburi, Kwai and Tapee Rivers in Thailand (Leelahakriengkrai and

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Fig. 1: (1) Map of the Mekong river and Ubon ratchathani province; (2) the 10 sampling sites of the Mekong river as it passed through Ubon ratchathani province

Table 1: Latitude-longitude and elevation of the Mekong river in each sampling site

Sites	Name of site	Latitude-longitude	Elevation
1	Chang mop cataract	N16° 09′333″ E105° 06′833″	120 m
2	Ban na sanarm	N16° 03′630″ E105° 10′392″	127 m
3	Behind municipality market	N16° 02′622″ E105° 13′447″	118 m
4	Ban na muang	N16° 02′436″ E105° 15′531″	114 m
5	Pak seang temple	N15° 55′953″ E105° 20′700″	113 m
6	Ban ta mui	N15° 23′778″ E105° 32′778″	94 m
7	Wigittra beach	N15° 23′709″ E105° 31′750″	93 m
8	Ban koom	N15° 23′377″ E105° 29′759″	93 m
9	Ban huay pai	N15° 21′022″ E105° 27′807″	91 m
10	Ban dan	N15° 19′205″ E105° 29′792″	91 m

Peerapornpisal, 2011). The objective of this study was to investigate the diversity of the benthic diatoms found to be present in the Mekong River as it leaves Thailand in Ubon Ratchathani Province and to study the relationship between the change of species composition and species-specific quantity found in this river, in relation to the physical and chemical properties used for monitoring the Mekong River.

METHODOLOGY

Water sampling sites: Water samples were collected from 10 stations in Khemmarat District (site 1-4), Natal Subdistrict (site 5) and Khonggium District (site 6-10):- 1) Chang Mop Cataract, 2) Ban Na Sanarm, 3) the location behind the Municipal Market, 4) Ban Na Muang, 5) Pak Seang Temple, 6) Ban Ta Mui, 7) Wigittra Beach, 8) Ban Koom, 9) Ban Huay Pai and 10) Ban Dan. Site 3 and 10 were found to reflect a high level of human activities, Site 1, 5, 7 and 10 were located at tourist points, Site 5, 6 and 9 included agricultural and littoral zones. The samples were collected every month from February 2007 to January 2008 (Fig. 1 and Table 1).

Water quality analysis: Certain physico-chemical factors were measured at the sites by portable meters, i.e., temperature, pH, conductivity and velocity. The water samples were collected and preserved in a cool box (5-7°C) for chemical analysis in laboratories, i.e., DO BOD, soluble reactive phosphorus, nitrate-nitrogen and alkalinity by following Greenberg *et al*. (2005). The water quality was classified according to the trophic status using the methods of Lorraine and Vollenweider (1981), Wetzel (2001) and AARL-PC Score (Peerapornpisal *et al*., 2004).

Benthic diatoms diversity: To sample the diatoms, a plastic sheet with a 3×3 cm^2 cutout was placed on the upper surface of the selected stone or other substratum. The benthic diatoms were then brushed and washed off, into a plastic bowl, until the cutout area was completely clear. Each sample was transferred to a plastic container (5-7°C) (Suphan, 2009). In the laboratory, the samples were cleaned and digested by concentrated nitric acid and hydrogen peroxide (Rott *et al*., 1997). A mounting agent, Naphrax, was added to make a permanent slide for diatom identification and counting under a compound light microscope and a Scanning Electron Microscope (SEM, JEOL model JSM-5410LV), respectively.

Identification of benthic diatoms: The diatom samples were collected, identified and photographed under a 100X light microscope. Some species were observed with a scanning electron microscope. Identification was done according to Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Lange-Bertalot (2001), Kelly and Haworth (2002) and Lange-Bertalot (2007).

Table 2: Maximum and minimum levels of water quality in the Mekong river as it passed through Ubon Ratchathani province from February 2007 to January 2008

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Air temp. (°C)	24-37	27-39	27-35	26-37	25-39	24-36	25-34	25-35	23-38	22-35
Water temp. (°C)	22-33	22-35	23-33	23-35	22-34	21-34	22-32	22-33	21-33	21-31
Conduct. (µs/cm)	79-263	82-274	83-280	90-251	92-275	76-305	77-257	72-285	74-224	78-246
DO (mg/L)	6.4-11.6	3.4-10.1	4.3-9.5	5.9-9.5	6.1-9.5	6.3-9.3	6.4-11.7	6.2-9.2	5.3-9.2	4.7-9.1
% O_2 saturation	79-132	42-141	53-131	71-133	78-110	81-115	78-153	72-117	60-118	52-113
BOD (mg/L)	0.1-7.0	0.1-5.4	0.1-5.6	0.1-6.6	0.1-8.4	0.2-3.4	0.2-4.3	0.1-5.8	0.2-3.5	0.1-3.2
Alkalinity (mg/L)	21-100	23-96	18-96	18-100	20-97	21-96	20-121	22-91	19-89	22-101
pH	6.0-9.4	5.9-9.2	5.8-9.0	5.8-8.8	5.8-9.5	6.1-11.5	6.1-10.2	6.1-10.6	5.1-11.1	6.1-10.9
SRP (mg/L)	0.01-0.22	0.01-0.30	0.01-0.22	0.01-0.31	0.01-0.34	0.01-0.28	0.01-0.58	0.01-0.40	0.01-0.20	0.01-0.18
Nitrate-N (mg/L)	0.01-12.71	0.01-12.05	0.01-14.05	0.01-15.65	0.01-19.17	0.01-13.38	0.01-9.71	0.01-11.72	0.02-11.58	0.04-7.45
Trophic status	Meso-eutro	Meso	Meso	Meso	Meso	Meso	Meso-eutro	Meso-eutro	Meso-eutro	Meso-eutro
Water quality	Moderate-polluted	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate-polluted	Moderate-polluted	Moderate-polluted	Moderate-polluted

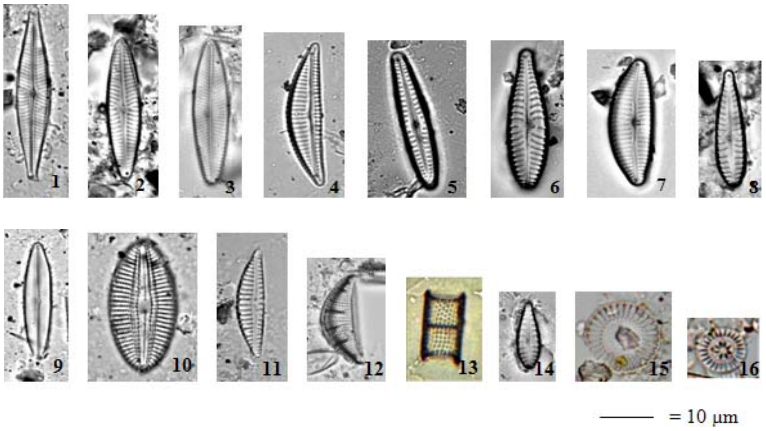

Fig. 2: Benthic diatoms found to be present in the Mekong river as it passed through Ubon Ratchathani; province from February 2007 to January 2008; 1) *Navicula notha* Wallace 2) *Navicula cryptotenelloides* Lange-Bertalot 3) *Navicula escambia* (Patrick) Metzeltin and Lange-Bertalot 4) *Encyonema silesiacum* (Bleisch) D. G. Mann; 5) *Gomphonema pumilum* (Grunow) Reichardt and Lange-Bertalot 6) *Gomphonema* sp., 4; 7) *Cymbella sumatrensis* Hustedt 8) and 14) *Gomphonema* sp., 1 9) *Navicula simulata* Manguin; 10) *Diploneis parma* Cleve 11) *Encyonema ventricosum* (Agardh) Grunow; 12) *Rhopalodia brebissonii* Krammer 13) *Aulocoseira granulata* (Ehrenberg) Simonsen; *Cyclotella meneghiniana* Kützing 16) *Cyclotella stelligera* Cleve and Grunow

RESULTS AND DISCUSSION

Water quality of the Mekong river: The study of some physico-chemical parameters of water quality of the Mekong River as it passed through Ubon Ratchathani Province, the results showed that the water quality varied at each sampling site (Table 2).

The trophic level and water quality were classified by Saprobic Index (Rott *et al*., 1997) and AARL-PC Score (Peerapornpisal *et al*., 2007) and were classified in two groups. In the first group, Sites 2, 3, 4, 5 and 6, were classified as having moderate water quality or mesotrophic status. In the second group, Sites 1, 7, 8, 9 and 10, were classified as having moderate to polluted water quality or mesotrophic to eutrophic status. The conductivity was found to be the highest in Site 1, 2, 3 and 4 during the summer season, followed by the cool dry and rainy seasons. In addition, it was found that the conductivity had a positively correlated with an abundance of benthic diatoms, such as *Nitzschia palea* (Kützing) W. Smith, *Cymbella turgidula* Grunow and *Navicula erifuga* Lange-Bertalot (Fig. 2). In the latter part of the rainy season, soluble reactive phosphorus and nitrate-nitrogen were recorded at high levels in Site 4, 5, 6, 7, 8 and 9, because the manure that is used in agriculture, leached into the river. In the late rainy season up to the early cool dry season, benthic diatoms were in gradually high abundance because of the present of suitable nutrients. (Table 2, 3 and Fig. 2) The similar result was reported by Patrick (1939). The results showed that *Melosira varians* Agardh, *Synedra ulna* (Nitzsch) Ehrenberg and *Navicula viridula* (Kützing) Ehrenberg were in high abundance in high nitrate-nitrogen (2.00-3.00 mg/L) water.

Diatom diversity: The study of the diversity of benthic diatoms in the Mekong River as it passed through Ubon Ratchathani, Thailand, from February 2007 to

Table 3: Dominant species, frequency, diversity index and evenness of benthic diatoms in the Mekong river as it passed through Ubon Ratchathani province from February 2007 to January 2008

Dominant species	Frequency	Richness	Diversity index	Evenness
Navicula rostellata Kützing	170	174	0.827	0.847
Gomphonema lagenula Kützing	180	156	0.974	0.980
Nitzschia palea (Kützing) W. smith	261	259	0.981	0.985
Luticola goeppertiana (Bleisch) D. G. mann	201	209	0.986	0.991
Nitzschia liebetruthii Rabenhorst	82	80	0.953	0.965
Sellaphora pupula (Kützing) Mereschkowsky	134	128	0.948	0.955
Navicula erifuga Lange-Bertalot	172	167	0.762	0.858
Cymbella tumida (Brébisson) Van heurck	202	197	0.961	0.966
Gomphonema clevei var. *javanica* Hustedt	194	34	0.881	0.908
Cymbella turgidula Grunow	273	267	0.990	0.993
Gomphonema pseudosphaerophorum Kobayasi	18	207	0.977	0.981
Pinnularia subcapitata Gregory	35	29	0.774	0.802
Amphora montana Krasske	6	5	0.323	0.404
Rhopalodia gibberula (Ehrenberg) O. F. müller	157	143	0.947	0.954
Nitzschia filiformis (W. smith) Hustedt	143	142	0.957	0.964
Bacillaria paxillifer (O. F. Müller) T. marsson	156	150	0.967	0.974
Navicula cryptotenella Lange-Bertalot	135	134	0.972	0.979
Gomphonema sp. 2	213	32	0.931	0.961
Cocconeis placentula Ehrenberg	250	237	0.983	0.987
Nitzschia fonticola Grunow	3	3	0.039	0.058
Luticola sp. 2	14	2	0.337	0.673
Melosira varians C. agardh	219	214	0.981	0.986
Synedra ungeriana var. *pseudogaillonii* (H. kobayasi et Idei)	170	159	0.970	0.976
Encyonema sp. 3	47	44	0.934	0.957
Amphora pediculus (Kützing) Grunow	51	13	0.865	0.937
Hantzschia amphioxys (Ehrenberg) Grunow	171	150	0.967	0.973
Achnanthes lanceolata spp *dubia* (Grunow) Lange-Bertalot	87	15	0.846	0.907
Navicula heimansoides Lange-Bertalot	85	83	0.923	0.934

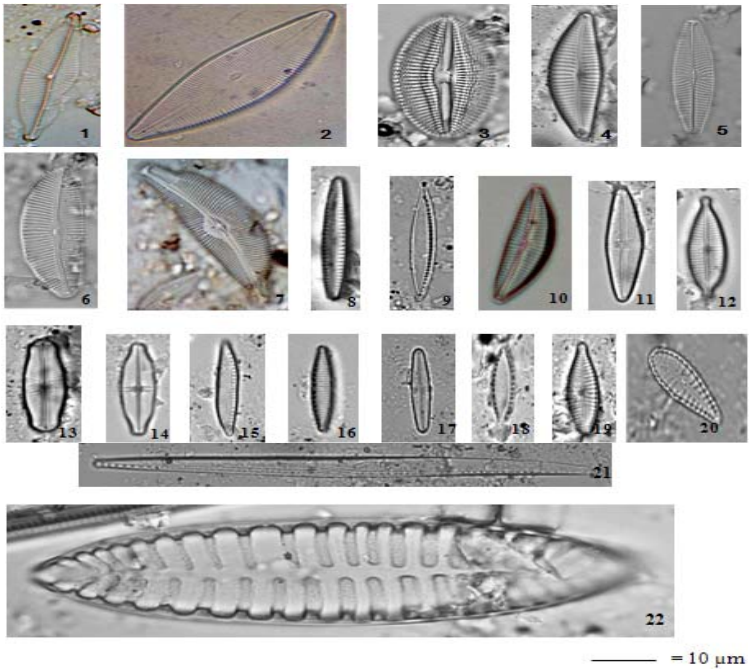

Fig. 3: Benthic diatoms found to be present in the Mekong river as it passed through Ubon Ratchathani; province from February 2007 to January 2008; 1) *Navicula rostellata* Kützing 2) *Cymbella bengalensis* (Grunow) Schmidt 3) *Diploneis subovalis* Cleve D.G. Mann 4) *Cymbella tropica* Krammer 5) *Navicula erifuga* Lange-Bertalot 6) *Cymbella* sp., 7) *Cymbella tumida* (Brébisson) Van Heurck 8) *Gomphonema clevei* var. *javanica* Hustedt 9) *Nitzschia palea* (Kützing) W. Smith 10) *Cymbella turgidula* Grunow 11) *Luticola goeppertiana* (Bleisch) D.G. Mann 12) *Gomphonema lagenula* Kützing 13) *Sellaphora pupula* (Kützing) Mereschkowsky 14) *Geissleria* sp., 15) *Nitzschia clausii* Hantzsch 16) *Nitzschia amphibia* Grunow; 17) *Achnanthidium minutissimum* var. *minutissimum* (Kützing) Czarnecky 18) *Nitzschia dealpina* Lange-Bertalot and Hofmann 19) *Gomphonema minutiforme* Lange-Bertalot 20) *Gomphonema minutum* (C. Agardh) C. Agardh 21) *Nitzschia scalpelliformis* Grunow 22) *Surirella splendida* (Ehrenberg) Kützing

January 2008, indicated 40 genera, 307 species. *Gomphonema lagenula* Kützing were the most abundant followed by *Navicula rostellata* Kützing, *Nitzschia palea* (Kützing) W. Smith, *Luticola goeppertiana* (Bleisch) D.G. Mann, *Nitzschia liebetruthii* Rabenhorst, *Sellaphora pupula* (Kützing) Mereschkowsky, *Navicula erifuga* Lange-Bertalot, *Cymbella tumida* (Brébisson) Van Heurck, *Gomphonema clevei* var. *javanica* Hustedt, *Cymbella turgidula* Grunow, *Gomphonema pseudosphaerophorum* Kobayasi, *Pinnularia subcapitata* Gregory, *Amphora montana* Krasske, *Rhopalodia gibberula* (Ehrenberg) O. F. Müller, *Nitzschia filiformis* (W. Smith) Hustedt, *Bacillaria paxillifer* (O. F. Müller) T. Marsson, *Navicula cryptotenella* Lange-Bertalot and *Gomphonema* sp., 2, respectively (Table 3 and Fig. 3).

The highest diversity index figures were *Cymbella turgidula* Grunow, *Luticola goeppertiana* (Bleisch) D.G. Mann, *Cocconeis placentula* Ehrenberg, *Nitzschia*

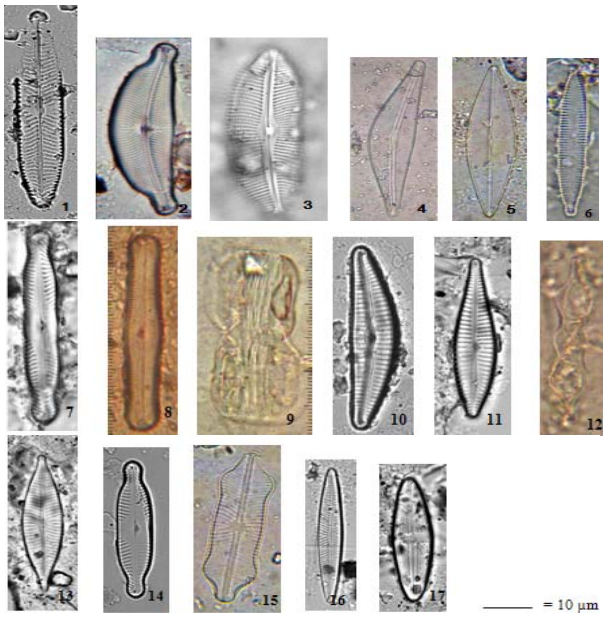

Fig. 4: Benthic diatoms found to be present in the Mekong river as it passed through Ubon Ratchathani; province from February 2007 to January 2008; 1) *Navicula* sp., 5 2) *Cymbella tumida* (Brébisson) Van Heurck 3) *Cymbella cucumis* Schmidt 4) *Cymbella neogena* (Grunow) Krammer 5) *Craticula halophila* (Grunow) 6) *Fragilaria fasciculata* (Agardh.) Lange-Bertalot 7) *Pinnularia grunowii* Krammer 8) *Pinnularia acrosphaeria* W. Smith var. *acrosphaeria* 9) and 12) *Entomoneis alata* (Ehrenberg) Ehrenberg 10) *Cymbella cymbiformis* Agardh 11) *Gomphonema gracile* f. *turris* Hustedt 13) *Navicula trivialis* Lange-Bertalot 14) *Pinnularia latarea* var. *thermophila* Krammer 15) *Placoneis* sp., 1 16) *Navicula cryptotenella* Lange-Bertalot 17) *Luticola peguana* (Grunow) D.G. Mann

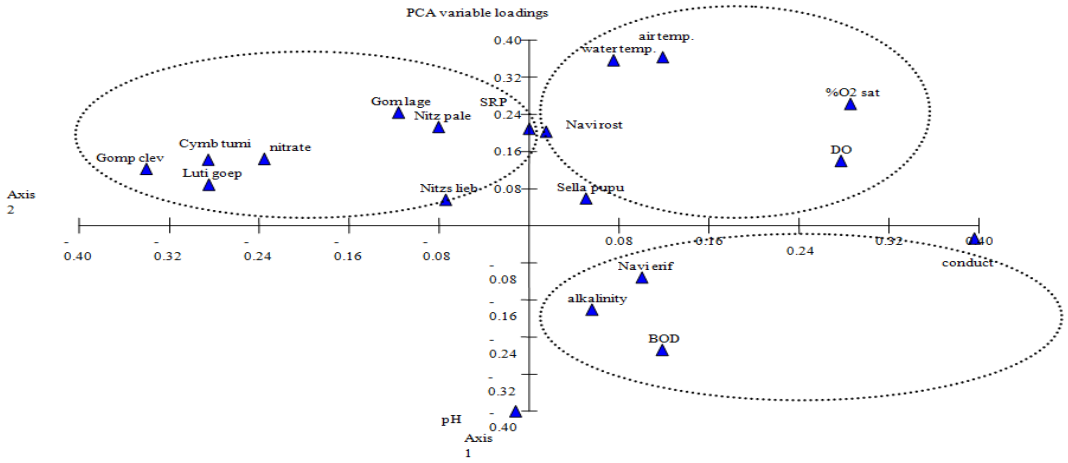

Fig. 5: Dominant benthic diatoms correlated with water quality in the Mekong river as it passed through Ubon Ratchathani province from February 2007 to January 2008

palea (Kützing) W. Smith and *Melosira varians* C. Agardh respectively. The highest evenness figures were *Cymbella turgidula* Grunow, *Luticola goeppertiana* (Bleisch) D.G. Mann, *Diploneis placentula* Ehrenberg, *Melosira varians* C. Agardh, *Nitzschia palea* (Kützing) W. Smith, *Gomphonema pseudosphaerophorum* Kobayasi and *Gomphonema lagenula* Kützing respectively. The highest richness figure were *Cymbella turgidula* Grunow, *Nitzschia palea* (Kützing) W. Smith, *Cocconeis placentula* Ehrenberg, *Melosira varians* C. Agardh, *Luticola goeppertiana* (Bleisch) D.G. Mann and *Gomphonema pseudosphaerophorum* Kobayasi, respectively.

The relationship between benthic diatoms and water quality: Benthic diatoms were highly abundant in late rainy season to early cool dry season. In rainy season, much of manure from agriculture was leached into the river. Soluble reactive phosphorus, nitrate-nitrogen, conductivity and clearness of water were majority factors that activated the high abundance of benthic diatoms in early cool dry season Fig. 4.

The correlation between dominant benthic diatoms and water quality could be used to classify benthic diatoms into two groups. Group 1, *Cymbella tumida* (Brébisson) Van Heurck and *Navicula erifuga* Lange-Bertalot, could be used to indicate moderate water quality or mesotrophic status. Group 2, *Cymbella turgidula* Grunow, *Gomphonema clevei* var. *javanica* Hustedt, *Luticola goeppertiana* (Bleisch) D. C. Mann, *Nitzschia liebetruthii* Rabenhorst and *Nitzschia palea* (Kützing) W. Smith could be used to indicate moderate to polluted water quality or mesotrophic to eutrophic status (Fig. 5).

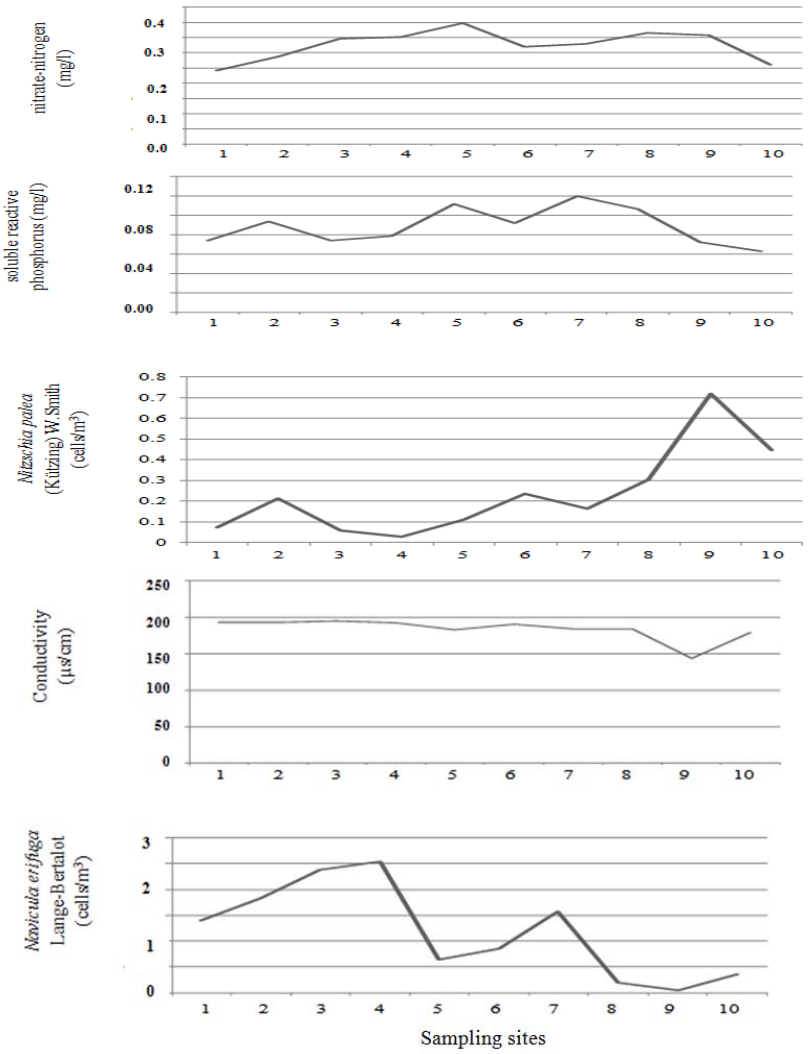

Fig. 6: Relationship between dominant species of benthic diatoms and nitrate-nitrogen, soluble reactive phosphorus and conductivity in the Mekong river as it passed through Ubon Ratchathani province from February 2007 to January 2008; 1)-3) relationship between nitrate-nitrogen, soluble reactive phosphorus and *Nitzschia palea* (Kützing) W. Smith; 4)-5) relationship between conductivity and *Navicula erifuga* Lange-Bertalot

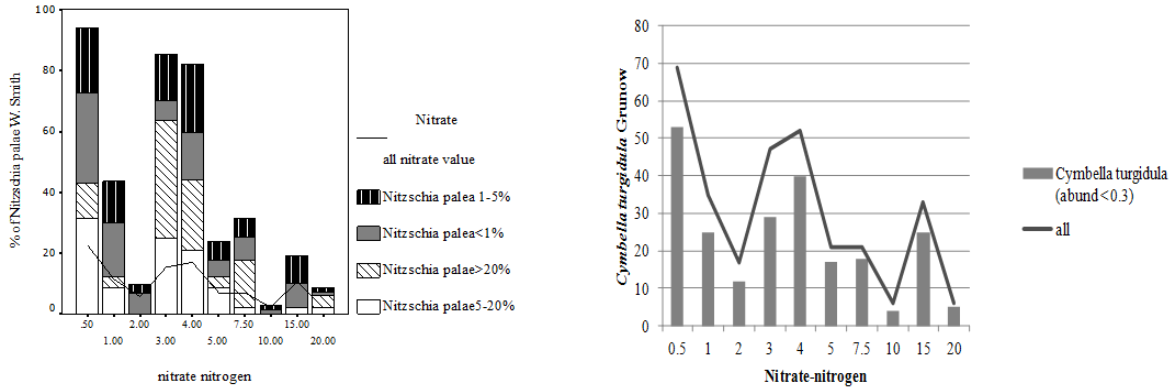

Fig. 7: Correlation of dominant and nitrate-nitrogen in each sampling site in the Mekong river as it passed through Ubon Ratchathani province from February 2007 to January 2008; 1) *Nitzschia palea* (Kützing) W. Smith 2) *Cymbella turgidula* Grunow

The results of this study of the dominant species of benthic diatoms and the water quality were found that *Cymbella tumida* (Brébisson) Van Heurck, *Gomphonema clevei* var. *javanica* Hustedt, *Luticola goeppertiana* (Bleisch) D.G. Mann, *Gomphonema lagenula* Kützing, *Nitzschia palea* (Kützing) W. Smith and *Nitzschia liebetruthii* Rabenhorst had positively correlated with nitrate-nitrogen and soluble reactive phosphorus. Furthermore, it was found that *Navicula erifuga* Lange-Bertalot had positively correlated with BOD, alkalinity and conductivity. *Navicula rostellata* Kützing and *Sellaphora pupula* (Kützing) Mereschkowsky had positively correlated with DO, percentage of oxygen saturation, and the air and water temperature (Fig. 6). *Nitzschia palea* (Kützing) W. Smith and *Cymbella turgidula* Grunow were abundant at the sites depending on the amounts of nitrate-nitrogen and soluble reactive phosphorus found in the river and the community zone location. *Navicula erifuga* Lange-Bertalot was abundant at the sites, depending on the conductivity (Fig. 6 and 7). The abundance of *Nitzschia palea* (Kützing) W. Smith in each site was associated with nitrate-nitrogen and soluble reactive phosphorus, while *Navicula erifuga* Lange-Bertalot was associated with conductivity of the river (Fig. 6). Additionally, *Nitzschia* and *Navicula* are usually associated with polluted ecosystem (Rumeau and Coste, 1988).

The number of benthic diatoms species found in the Mekong River, as it passed through Ubon Ratchathani Province was found to be similar to other big rivers, both within the country and upcountry such as, 310 species in the Sundays and Great Fish Rivers, South Africa (Archibald, 1972), 186 species in the Mekong River (2004-2005) (Peerapornpisal *et al.*, 2005), 168 species in the Mekong River in 5 provinces of Thailand (Pruetiworanan, 2008), 79 species in the Mekong river passing Chiang Rai Province, Thailand (Leelahakriengkrai and Pruetiworanan, 2009) and 252 species in the Mekong River passing from Myanmar to Thailand and Laos (Suphan, 2009). Since previously mentioned studies had collected data during specific seasons, not every month, the benthic diatoms were found to be less abundant than those recorded in this research, in which data was collected once a month over a single year from 10 sampling sites.

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