# Diversity of Macroalgae and Benthic Diatoms in the Area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province, Thailand

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**Abstract:** A study on the diversity of macroalgae and benthic diatoms in the area of Thong Pha Phum Project, Kanchanaburi Province was carried out from November 2001 – January 2003. Samples were collected from 7 sites. Sixty-one species of macroalgae were found and classified into 4 divisions. The majority of them were *Spirogyra* spp. and *Stigeoclonium* spp. in Division Chlorophyta; *Batrachospermum* spp. and *Audouinella* spp. in Division Rhodophyta; and *Nostochopsis* sp. and *Phormidium* spp. in Division Cyanophyta. One hundred and sixty two species of benthic diatoms were found and classified in Division Bacillariophyta. Most of them were *Achnanthes* spp., *Navicula* spp. and *Gomphonema* spp. Fifty-six species were new records for Thailand. For the water quality, it was found that the water quality based on trophic level in the undisturbed area could be classified into oligotrophic-mesotrophic status. In the disturbed area, the water quality was in mesotrophic - eutrophic status.

**Key words:** macroalgae, benthic diatoms, water quality, bioindicator, biomonitoring

## Introduction

In this research, macroalgae and benthic diatoms could be used to monitor water quality. These organisms are sensitive to changes of water quality. The study areas are located in the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province, Thailand. This research was conducted during a 1 year period from November 2001 – January 2003. The samples were collected from 7 sites. Water quality, such as physical, chemical and biological factors, including the collecting of samples of macroalgae and benthic diatoms should be investigated twice in each season. The results of this research could be applied to monitoring changing water quality in the future.

## Methodology

### *Study Area*

The study areas are located in the area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province, in the western part of Thailand. This area covers 1,200 square kilometers. Seven sites were selected which cover this area.

In this research, the sites were studied over one year. The details and map of each site are given in Table 1 and Fig. 1.

### *Physical and Chemical Properties of Water at the Sampling Sites*

Some physical and chemical properties were determined at the sampling sites. Temperature and conductivity were measured with a conductivity meter. pH levels were taken with a pH-meter and dissolved oxygen (DO) was measured by the azide modification method (APHA, AWWA and WEF, 1998).

### *Laboratory Investigation of Water Samples*

Alkalinity was measured by the methyl orange indicator method (APHA, AWWA and WEF, 1998). BOD was measured using the azide modification method. Coliform bacteria were analyzed by the method of Harrigan and Cance (1976). The turbidity and amounts of nutrients, i.e. nitrate-nitrogen, ammonium-nitrogen and soluble reactive phosphorus, were determined by spectrophotometer DR2010 (Hach Company).

### *Sampling of Macroalgae and Benthic Diatoms Samples and Identification*

Macroalgae were collected by scraping from their substrates such as cobbles, sand, plant roots and tree branches etc. The amount of macroalgae in each genus was estimated and recorded in the field data sheet.

Table 1. The details of each site in the area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province, November 2001 – January 2003.

| Site name | Altitude (m) | Description |
|---|---|---|
| 1. Huay Jok Kra Din | 630 | undisturbed area |
| 2. Huay Ae Tong | 645 | undisturbed area |
| 3. Jok Tong | 425 | undisturbed area |
| 4. Huay Kha Yang 1 | 270 | disturbed area |
| 5. Huay Kha Yang 2 | 215 | disturbed area |
| 6. Huay Kha Yang 3 | 235 | disturbed area |
| 7. Huay Kha Yang 4 | 195 | disturbed area |

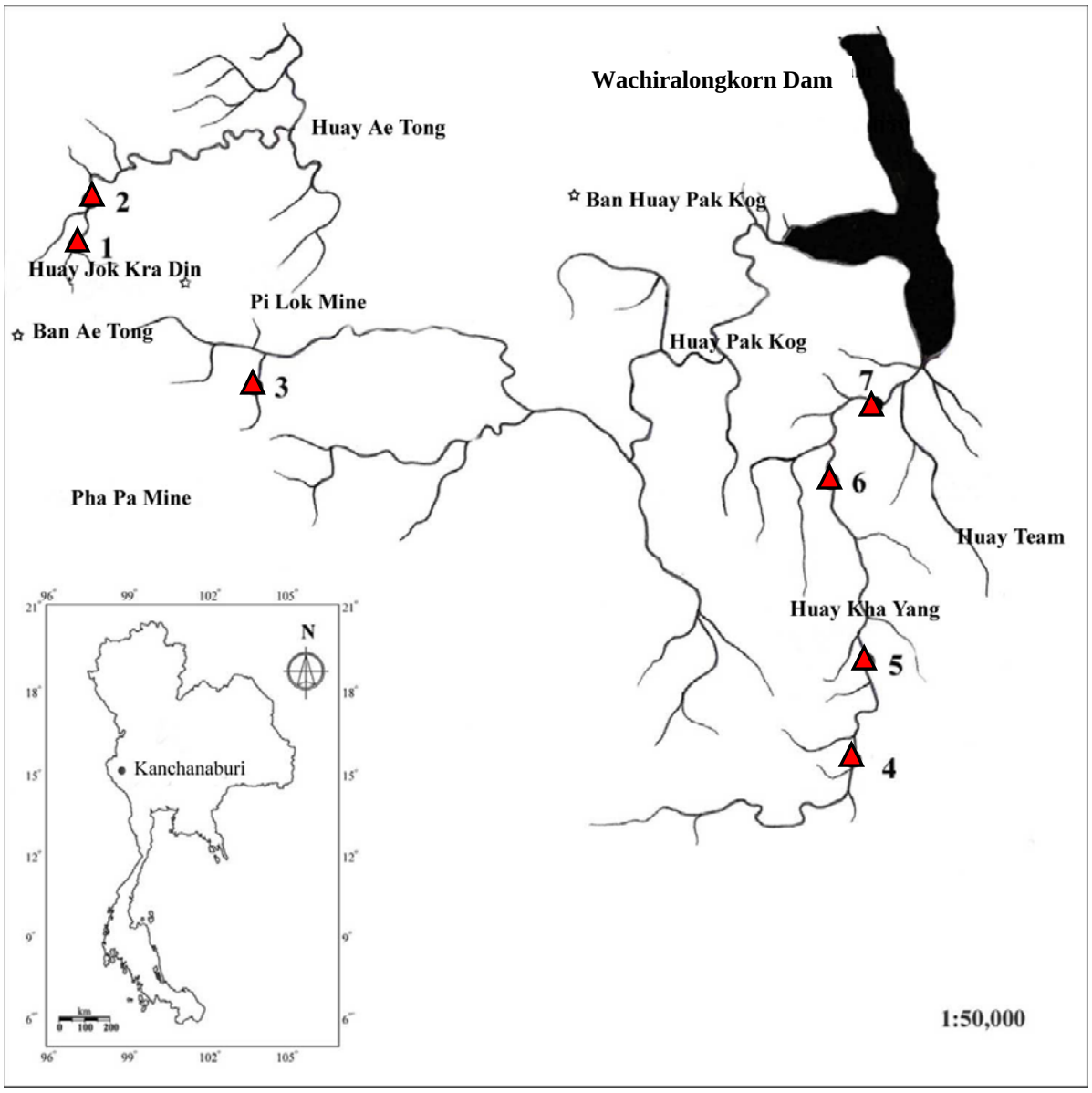



Figure 1. Map showing study sites in the area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province, November 2001-January 2003

Fresh samples were preserved in 2% glutaladehyde solution and put into an ice box at low temperature (5-10 ˚C). The details of substrates, colony patterns and clump forming characteristics were recorded for ecological study and identification. Identification and classification were done under a compound microscope and stereo microscope by relevant books such as Desikachary (1959), Whitford and Schumacher (1969), Necchi et al. (1997),

Komarek and Anagnostidis (1999), John et al. (2002) and Kumano (2002) etc.

Epilithic diatoms samples were scraped from 3-5 stones at each site. A plastic sheet with a square hole of area 4x4 = 16 $cm^2$ was placed on the upper surface of the selected stone, and benthic diatoms were brushed from the square hole. In the laboratory, the samples were cleaned by boiling for 15-30 minutes in concentrated HCI and $HNO_3$ and $H_2O_2$. Naphrax was used for mounting (Pfister, 1992; Rott et al., 1997). Light micrographs were made with an Olympus BX-40 microscope. Species that were unable to be identified by light microscope were reexamined by SEM. The taxonomic classification systems of the Süßwasserflora Mitteleuropas by Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Krammer (1992, 1997a, 1997b), Mettzeltin and Lange-Bertalot (1998), Rumrich et al. (2000), Lange-Bertalot (2001) were followed. The counting process was conducted using relative counts that concentrate on the relative portions of the species, until a total count of 300 specimens was reached. (modified from Rott et al., 1997).

## Results

### *Macroalgae Investigation*

Sixty-one species of macroalgae were found. They belonged to 4 Divisions: 43% in Division Chlorophyta (green algae), 39% in Division Cyanophyta (blue-green algae), 15% in Division Rhodophyta (red algae) and 3% in Division Charophyta (stoneworts). The most abundant genera were *Spirogyra* spp. and *Stigeoclonium* spp. in Division Chlorophyta; *Nostochopsis lobatus* Wood and *Phormidium* spp. of the blue green algae; and *Batrachospermum* spp. and *Audouinella* spp. in the Division Rhodophyta, etc. (Table 2 and Fig. 2).

### *Benthic Diatoms Investigation*

In this research, one hundred and sixty-two species of benthic diatoms were found and classified in Division Bacillariophyta; 98% in Order Pennales and 2% in Order Centrales. Most of them were pennate diatoms e.g. *Achnanthes* spp., *Frustulia* spp., *Navicula* spp. and *Gomphonema* spp. (Table 2 and Fig. 3).

### *New records for Thailand*

Fifty six species of the algae were

Table 2. Species list of macroalgae and benthic diatoms in the area of Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province from a survey carried out from November 2001-January 2003.

| Taxa | Taxa |
|---|---|
| **Division Cyanophyta** | **Family Rivulariaceae** |
| **Order Chamaesiphonales** | *Calotrix* sp. 1 |
| **Family Chamaesiphonaceae** | |
| *Chamaesiphon incrustan* Grunow | **Division Chlorophyta** |
| *Chamaesiphon* sp. 1 | **Order Siphonocladales** |
| *Chamaesiphon* sp. 2 | **Family Chladophoraceae** |
| **Order Nostocales** | *Cladophora glomerata* Küetzing |
| **Family Nostocaceae** | **Family Zygnemataceae** |
| *Nostoc* sp. | *Mougeotia* sp. |
| *Nostochopsis lobatus* Wood | *Spirogyra communis* (Hassall) Kützing |
| **Family Oscillatoriaceae** | *Spirogyra reflexa* Transeau |
| *Oscillatoria splendida* (Greville) Gomont | *Spirogyra* sp. 1 |
| *Oscillatoria* sp. 1 | *Spirogyra* sp. 2 |
| *Oscillatoria* sp. 2 | *Mougeotia* sp |
| *Lyngbya* sp. | *Zygnema* sp. 1 |
| *Microculeus* sp. | *Zygnema* sp. 2 |
| *Phormidium retzii* Gomont | *Zygnema* sp. 3 |
| *Phormidium uninatum* (Agardh) Gomont | **Order Oedogoniales** |
| *Phormidium* sp. 1 | **Family Oedogoniaceae** |
| *Phormidium* sp. 2 | *Bulbochaete* sp. 1 |
| *Phormidium* sp. 3 | *Bulbochaete* sp. 2 |
| *Phormidium* sp. 4 | *Oedogonium* sp. 1 |
| *Phormidium* sp. 5 | *Oedogonium* sp. 2 |
| *Phormidium* sp. 6 | *Oedogonium* sp. 3 |
| *Phormidium* sp. 7 | *Oedogonium* sp. 4 |
| *Phormidium* sp. 8 | *Oedogonium* sp. 5 |
| *Phormidium* sp. 9 | *Oedogonium* sp. 6 |
| **Family Scytonemataceae** | **Order Chaetophorles** |
| *Scytonema cincinnatum* Thuret | **Family Chaetophoraceae** |
| *Scytonema* sp. | *Chaetophora elegans* (Roth) C. Agardh |

Table 2. (continued)

| Taxa | Taxa |
|---|---|
| **Family Chaetophoraceae** | **Family Eunotiaceae** |
| *Stigeoclonium lubricum* (Dillwyn) Kützing | *Eunotia* sp. 11 |
| *Stigeoclonium flagelliforum* Kützing | *Eunotia* sp. 12 |
| *Stigeoclonium nanum* Kützing | *Achnanthes biasolettiana* Grunow |
| *Ulothrix* sp. 1 | *Achnanthes crenulata* Grunow |
| *Ulothrix* sp. 2 | *Achnanthes exigua* var. *constricta* (Torka) Hustedt |
| *Ulothrix* sp. 3 | *Achnanthes exigua* Grunow var. *exigua* |
| **Order Ulotrichales** | *Achnanthes inflata* (Kützing) Grunow |
| **Family Microsporaceae** | *Achnanthes minutissima* Kützing |
| *Microspora pachyderma* (Wille) Lagerheim | *Achnanthes minutissima* Kützing var. *minutissima* |
| | *Achnanthes oblongella* Østrup |
| **Division Charophyta** | *Achnanthes undata* Meister |
| **Order Charales** | *Achnanthes* sp. |
| **Family Characeae** | *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow |
| *Chara* sp. | *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurk |
| *Nitella* sp. | *Planothidium frequentissimum* (Lange-Bertalot) Lange- Bertalot |
| **Division Rhodophyta** | *Planothidium lanceolatum* (Brébisson) Lange-Bertalot |
| **Order Nemalionales** | *Planothidium minutissimum* (Krasske) Lange-Bertalot |
| **Family Erythotrichaceae** | *Planothidium rostratum* (Østrup) Round & Bukhtiyarova |
| *Compsopogon coeruleus* (Balbis) Montagne | **Family Naviculaceae** |
| **Family Batrachospermaceae** | *Amphora* sp. |
| *Batrachoapermum boryanum* Sirodot | *Brachysira* cf. *brebissonii* Ross in Hartley |
| *Batrachoapermum gelatinosum* (Linnaeus) de Candolle | *Brachysira* cf. *neoexilis* Lange-Bertalot |
| *Batrachoapermum macrosporum* Montagne | *Brachysira* cf. spec. cf. *neoacutas* Lange-Bertalot |
| *Batrachoapermum vugum* Agardh | *Caloneis silicula* (Ehrenberg) Cleve |
| **Family Chantransiaceae** | *Caloneis* sp. |
| *Audouinella cylindrica* Agardh | *Craticula* cf. *buderi* (Husledt) Lange-Bertalot |
| *Audouinella hermannii* (Roth) Duby | *Craticula* cf. *riparia* (Husledt) Lange-Bertalot var. *riparia* |
| *Audouinella pygmaea* (Kützing) Weber-van Bosse | *Diploneis oblonglla* (Naegeli) Cleve-Euler |
| *Audouinella* sp. | *Diploneis* cf. *subovalis* Cleve |
| | *Diploneis* sp. |
| **Division Bacillariophyta** | *Frustulia* cf. *amphipleuroides* (Grunow) Cleve-Euler |
| **Order Centrales** | *Frustulia crassinervia* (Brébisson in W. Smith) Lange-Bertalot & Krammer |
| **Family Melosiraceae** | *Frustulia saxonica* Rabenhorst |
| *Aulocoseira granulata* Ehrenberg | *Frustulia disjuncta* Lange-Bertalot |
| *Meloseira varians* Agardh | *Frustulia undosa* Lange-Bertalot |
| **Family Thalassiosiraceae** | *Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin |
| *Cyclotella* sp. | *Gomphonema affine* Kützing var. *affine* |
| **Order Pennales** | *Gomphonema affine* var. *rhombicum* Reichardt |
| **Family Fragilariaceae** | *Gomphonema entolejum* Østrup |
| *Fragilaria capucina* Desmazières | *Gomphonema gracile* Ehrenberg |
| *Fragilaria* cf. *capucina* var. *vaucheriae* (Kützing) Lange-Bertalot | *Gomphonema lagenula* Kützing |
| *Fragilaria tenera* (W. Smith) Lange-Bertalot | *Gomphonema parvulum* var. *exilissimum* Grunow |
| *Synedra* cf. *inaequalis* Kobayasi | *Gomphonema parvulum* var. *parvulius* Lange-Bertalot & Reichardt |
| *Synedra* cf. *inaequalis* var. *Jumlensis* Jüttener & Cox | *Gomphonema pumilum* (Grunow) Reichardt |
| *Synedra lanceolata* Kützing | *Gomphonema vibrio* Ehrenberg |
| *Synedra ulna* (Nitzsch) Ehrenberg | *Gomphonema* cf. *stonei* Reichardt |
| *Synedra ulna* var. *aequalis* (Kützing) Hustedt | *Gomphonema* sp. 1 |
| **Family Eunotiaceae** | *Gomphonema* sp. 2 |
| *Eunotia monodon* var. *tropica* Hust | *Gyrosigma scalproides* (Rabenhorst) Cleve |
| *Eunotia zygodon* Ehrenberg | *Gyrosigma spencerii* (Quekett) Griffith & Herfrey |
| *Eunotia* cf. *soleirolii* (Kützing) Rabenhorst | *Luticola* cf. *argutula* (Hustedt) D.G. Mann |
| *Eunotia* sp. 1 | *Luticola goeppertiana* (Bleisch) D.G. Mann |
| *Eunotia* sp. 2 | *Luticola* cf. *monita* (Hustedt) D.G. Mann |
| *Eunotia* sp. 3 | |
| *Eunotia* sp. 4 | |
| *Eunotia* sp. 5 | |
| *Eunotia* sp. 6 | |
| *Eunotia* sp. 7 | |
| *Eunotia* sp. 8 | |
| *Eunotia* sp. 9 | |
| *Eunotia* sp. 10 | |

Table 2. (continued)

| Taxa | Taxa |
|---|---|
| **Family Naviculaceae** | **Family Naviculaceae** |
| *Luticola* cf. *mutica* (Kützing) D.G. Mann | *Sellaphora pupula* (Kützing) Mereschkowsky |
| *Luticola* sp. | *Sellaphora* sp. |
| *Navicula capitatoradiata* Germain | *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg |
| *Navicula* cf. *lepostrita* Jørgensen | *Stauroneis anceps* Ehrenberg |
| *Navicula radiosa* Kützing | *Stauroneis smithii* Grunow |
| *Navicula rostellata* Kützing | *Stauroneis* sp. |
| *Navicula viridula* Kützing | **Family Bacillariaaceae** |
| *Navicula symmetrica* Patrick | *Hantzschia amphioxys* (Ehrenberg) Grunow |
| *Navicula* sp. 1 | *Nitzschia dissipata* (Kützing) Grunow var. *dissipata* |
| *Navicula* sp. 2 | *Nitzschia palea* (Kützing) W. Smith |
| *Navicula* sp. 3 | **Family Cymbellaceae** |
| *Navicula* sp. 4 | *Cymbella japonica* Reichelt |
| *Navicula* sp. 5 | *Cymbella perjaponica* Krammer & Lange-Bertalot |
| *Navicula* sp. 6 | *Cymbella tumida* (Brébisson) Van Heurck |
| *Navicula* sp. 7 | *Cymbella turgidula* Grunow |
| *Navicula* sp. 8 | *Cymbella* sp. 1 |
| *Navicula* sp. 9 | *Cymbella* sp. 2 |
| *Navicula* sp. 10 | *Cymbella* sp. 3 |
| *Navicula* sp. 11 | *Cymbella* sp. 4 |
| *Navicula* sp. 12 | *Cymbella* sp. 5 |
| *Navicula* sp. 13 | *Cymbella* sp. 6 |
| *Navicula* sp. 14 | *Cymbella* sp. 7 |
| *Navicula* sp. 15 | *Cymbella* sp. 8 |
| *Navicula* sp. 16 | *Cymbella* sp. 9 |
| *Navicula* sp. 17 | *Encyonema* cf. *neomesianum* Krammer |
| *Navicula* sp. 18 | *Encyonema* sp. 1 |
| *Navicula* sp. 19 | *Encyonema* sp. 2 |
| *Navicula* sp. 20 | *Encyonema* sp. 3 |
| *Neidium iridis* (Ehrenberg) Cleve | *Encyonema* sp. 4 |
| *Neidium* cf. *affine* var. *humerus* Reimer | *Encyonema* sp. 5 |
| *Neidium* sp. | *Encyonema* sp. 6 |
| *Pinnularia brauniana* (Grunow) Mills | *Encyonema* sp. 7 |
| *Pinnularia divergens* var. *linearis* Østrup | *Encyoopsis leei* var. *leei* Lange-Bertalot |
| *Pinnularia graciloides* Hustedt | *Encyoopsis* cf. *leei* var. *sinensis* Metzeltin & Krammer |
| *Pinnularia mesolepta* (Ehrenberg) W. Smith | **Family Surirellaceae** |
| *Pinnularia* cf. *microstauron* (Ehrenberg) Cleve | *Surirella angusta* Kützing |
| *Pinnularia* cf. *pseudogibba* Krammer | *Surirella biseriata* Brébisson |
| *Pinnularia supcapitata* Gregory | *Surirella elegans* Ehrenberg |
| *Pinnularia supcapitata* var. *elongata* Krammer | *Surirella roba* Leclercq |
| *Pinnularia supinterrupta* Krammer & Schroeter | *Surirella linearis* W. Smith |
| *Pinnularia* sp. 1 | *Surirella splendida* Krammer |
| *Pinnularia* sp. 2 | *Surirella* cf. *subsalsa* W. Smith |
| *Reimeria sinuata* (Gregory) Kociolek & Stcermer | *Surirella* sp. |
| *Rhopalodia* sp. | |
| *Sellaphora amoena* Lange-Bertalot | |
| *Sellaphora* cf. *gibbula* Lange-Bertalot | |

new records for Thailand; eleven of them were macroalgae: 3 species in Division Cyanophyta, 3 species in Division Chlorophyta and 5 species in Division Rhodophyta. Forty five species were benthic diatoms in Division Bacillariophyta (Lewmanomont et al., 1995 and Peerapornpisal et al., 2000).

***Water Quality***

The water quality was classified by trophic level by using the methods of Wetzel (1983) and Lorraine and Vollenweider (1981). The methods have been modified for use in Thailand by Applied Algal Research Laboratory, Chiang Mai University by altering the amounts of DO, BOD, conductivity, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus. It was classified into oligotrophic-mesotrophic status to mesotrophic-eutrophic status depending on the sampling site and seasonal changes (Fig. 4). It was clear that the water quality in undisturbed areas was more clean than in disturbed areas.

## Discussion and Conclusion

In this investigation, sixty-one species of macroalgae were found and classified into 4

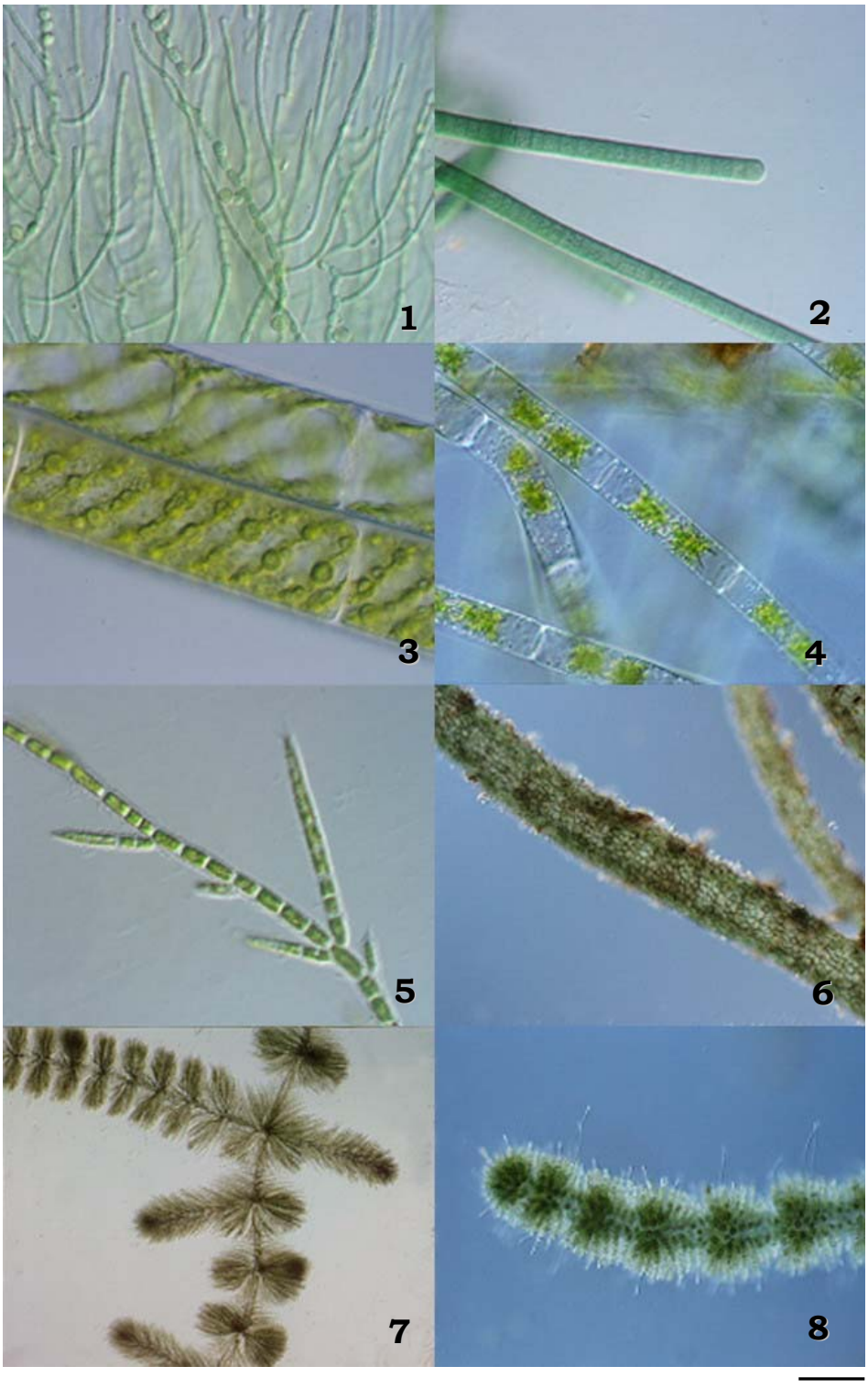



Figure 2. Light micrographs of macroalgae collected in the area of Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province from November 2001 - January 2003. (Scale bar = 20 µm)
**Division Cyanophyta:**1- *Nostochopsis lobatus* Wood, 2- *Phormidium retzii* Gomont, **Division Chlorophyta:** 3- *Spirogyra* sp., 4- *Zygnema* sp., 5 - *Stigeoclonium lubricum* (Dillwyn) Kützing, **Division Rhodophyta:** 6 - *Comsopogon coeruleus* (Balbis) Montagne, 7 - *Batrachospermum gelatinosum* (Linnaeus) de Candolle, 8 - *Batrachospermum vagum* (Roth) C.Agardh

Divisions as follows: Chlorophyta, Cyanophyta, Rhodophyta and Charophyta. One hundred and sixty-two species of benthic diatoms were found and classified in Division Bacillariophyta. Fifty-six species of the algae were new records for Thailand, eleven of them

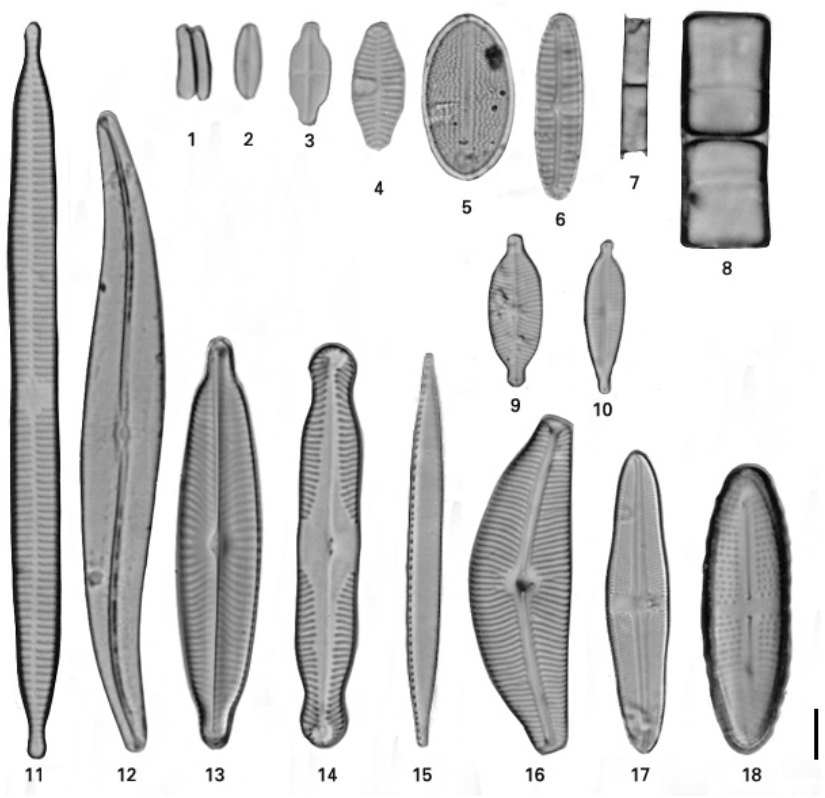
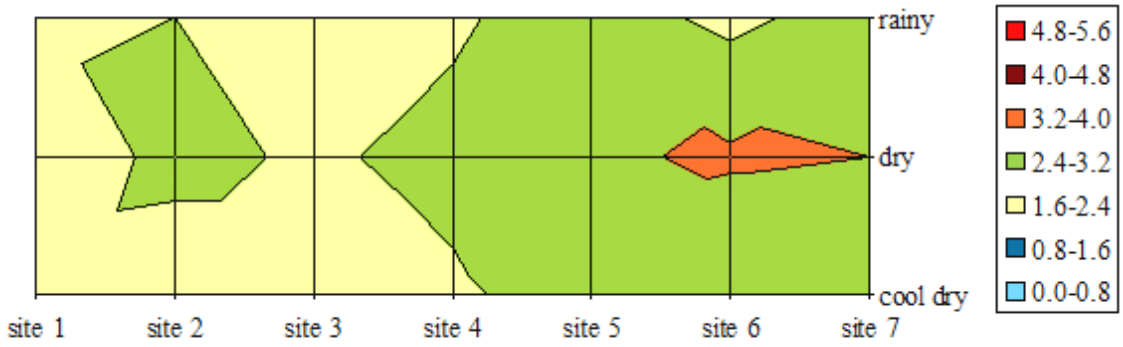



Figure 3. Light micrographs of benthic diatoms collected in the area of Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province from November 2001 – January 2003. (Scale bar = 10 µm)
**Division Bacillariophyta:** (1-2) *Achnanthes* spp., (3) *Achnanthes exigua* var. *constricta* (Torka) Hustedt, (4) *Planothidium frequentissimum* (Lange-Bertalot) Lange-Bertalot, (5) *Cocconeis placentula* Ehrenberg, (6) *Encyoopsis leei* var. *leei* Lange-Bertalot, (7) *Aulacoseira granulata* Ehrenberg, (8) *Melosira varians* Agardh, (9) *Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin, (10) *Gomphonema lagenula* Kützing, (11) *Synedra ulna* (Nitzsch) Ehrenberg, (12) *Gyrosigma spencerii* (Quekett) Griffith & Herfrey, (13) *Navicula viridula* Kützing, (14) *Pinnularia mesolepta* (Ehrenberg) W. Smith, (15) *Nitzschia palea* (Kützing) W. smith, (16) *Cymbella tumida* (Brébisson) Van Heurck, (17) *Luticula* sp., (18) *Achnanthes crenulata* Grunow.

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|---|---|---|---|
| 0-0.8 | ultraoligotrophic | site 1 | Huay Jok Kra Din |
| 0.8-1.6 | oligotrophic | site 2 | Huay Ae Tong |
| 1.6-2.4 | oligo-mesotrophic | site 3 | Jok Tong |
| 2.4-3.2 | mesotrophic | site 4 | Huay Kha Yang 1 |
| 3.2-4.0 | meso-eutrophic | site 5 | Huay Kha Yang 2 |
| 4.0-4.8 | eutrophic | site 6 | Huay Kha Yang 3 |
| 4.8-5.6 | hypereutrophic | site 7 | Huay Kha Yang 4 |

Figure 4. Area plots of water quality in the area of the Golden Jubilee Thong Pha Phum Project, Thong Pha Phum District, Kanchanaburi Province from November 2001-January 2003

were macroalgae and forty-five species were benthic diatoms.

The results showed that the water quality in this area could be classified into oligotrophic – mesotrophic status to mesotrophic - eutrophic status depending on the sampling site and seasonal changes. Most of them showed oligotrophic-mesotrophic status because these areas were upstream where the water quality would be expected to be clean (Wetzel, 1983).


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