

## DIVERSITY OF PHYTOPLANKTON AND BENTHIC ALGAE IN MAE SA STREAM, DOI SUTHEP–PUI NATIONAL PARK, CHIANG MAI

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### ABSTRACT

The diversity of phytoplankton and benthic algae in Mae Sa stream, Doi Suthep–Pui National Park, Chiang Mai Province, was assessed from April 1997 to February 1998. Eighty-seven species of phytoplankton were found which could be classified into 5 phyla, 8 orders, 19 families and 31 genera. The majority of the phytoplankton were diatoms in the Order Pennales and the most abundant species were *Melosira varians* Agardh, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Cymbella tumida* (Brébisson) Van Heurck, and *Nitzschia linearis* (Agardh) W. Smith.

A total of 172 species of benthic algae were found, of which 68 species had never been recorded in Thailand before. They represented 9 families and 25 genera. The most abundant species were also diatoms in the Order Pennales. The majority of the species belonged to the genera *Navicula* (38 species), *Nitzschia* (23 species), *Fragilaria* (16 species) and *Gomphonema* (15 species).

Key words: benthic algae, biodiversity, diatom, Doi Suthep–Pui, phytoplankton, stream algae

### INTRODUCTION

An investigation of the diversity of phytoplankton and benthic algae was carried out in Mae Sa stream, located in Mae Rim District, Chiang Mai, Thailand. The purposes of the study were to investigate the diversity of algae and the species composition of phytoplankton and benthic algae communities in relation to water quality.

Although study of phytoplankton diversity in Thailand commenced at the end of 19<sup>th</sup> century, the present state of knowledge is unsatisfactory. According to available literature, green algae (Chlorophyceae) have been thoroughly studied with regard to freshwater phytoplankton. Marine diatoms and dinoflagellates (Bacillariophyceae and Dinophyceae) are considered to be adequately known, in terms of systematic studies. The first publication of a phytoplankton study in Thailand was by SCHMIDT (1900–1916). He published “Flora of Koh Chang,” based on materials collected by the Danish Expedition to Siam 1899–1900, in which 161 genera, 1,001 species, 287 varieties and 63 forms of Cyanobacteria, Chlorophyta and Chromophyta were reported (WONGRAT, 1998).

Other forms of algae in streams include benthic algae, the attached form of algae, associated with different types of substrata (COX, 1996). The terms periphyton and aufwuchs are also applied to that community of organisms growing on submerged objects (aquatic plants, rocks, etc.) (BOLD & WYNNE, 1985). Most benthic algae in freshwater habitats are

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“bluegreen algae” (Cyanobacteria), green algae (Chlorophyta), diatoms (Bacillariophyta), or red algae (Rhodophyta) (HYNES, 1970; PHILIP, 1986; STEVENSON *ET AL.*, 1996).

Diatoms generally have the highest species richness among benthic algal communities. The total number of diatom species worldwide may be at least 20,000, comprising 200 genera; about 50% more than for bluegreen, green and red algae (ROUND, 1973; BOLD & WYNNE, 1985).

The diatom flora of Thailand has been investigated by foreign scientists for a hundred years, according to a checklist of algae in Thailand (LEWMANOMONT *ET AL.*, 1995). A total of 46 genera, 385 species, 144 varieties and 43 forms have been recorded. The diatom flora has been covered by the following papers, published by foreign scientists.

ÖSTRUP (1902) recorded 81 different diatoms from Thailand’s second largest island (after Phuket), Koh Chang in the Gulf of Thailand. PATRICK (1936) reported 185 diatom species in the intestinal contents of tadpoles from Thailand and the Federal Malay States. Material collected by the Joint Thai–Japanese Biological Expedition to Southeast Asia 1961–1962 was identified by Hirano. In 1967, he published an account of 143 diatom species, 114 of them from Thailand. Most of these samples were collected in the Chiang Mai area and the others from localities in central and southern Thailand (HIRANO, 1967).

In freshwater material collected by Foged in 1966 in central and northern Thailand, about 378 taxa were published. Among these, 8 new species, 5 new varieties and 2 new forms were additional records for Thailand (FOGED, 1971).

From 1971 to date, Thai scientists have also worked on diatoms but not very intensively. Most work has been done on plankton. Collections have been made from all parts of Thailand but mostly from the North and Northeast (WONGRAT, 1998).

## STUDY AREA

Established in 1981, Doi Suthep–Pui National Park is located in Chiang Mai Province, northern Thailand, and has an area of 261 km<sup>2</sup>. Doi Suthep (elevation 1,601 m a.s.l.) and Doi Pui (1,685 m a.s.l.) are part of a geologically ancient ridge forming the western boundary of the Ping River Valley. The forests on Doi Suthep–Pui can be divided into deciduous and evergreen forest types. Some 2,000 mm of rain fall on the park each year, mostly from May to October. The dry season comes between November and March. The average annual temperature, recorded near Phuphing Palace, is 20°C with maximum and minimum average temperatures of 24°C and 17°C respectively. The Mae Sa Watershed is situated in Mae Rim District, Chiang Mai Province. Part of the watershed lies within Doi Suthep–Pui National Park, which is one of the world’s greatest areas for biodiversity, where natural forests and other wildlife resources are protected. (GRAY *ET AL.*, 1991).

The Mae Sa watershed is becoming heavily impacted by increasing agro-industrialization and tourism development. The results of this survey of diversity of phytoplankton and benthic algae can be applied to monitoring changes in water quality in the future.

Twelve sites were studied once per season over one year from April 1997 to February 1998. The sites were selected along the Mae Sa stream (Fig. 1). The name and details of each site are given in Table 1.

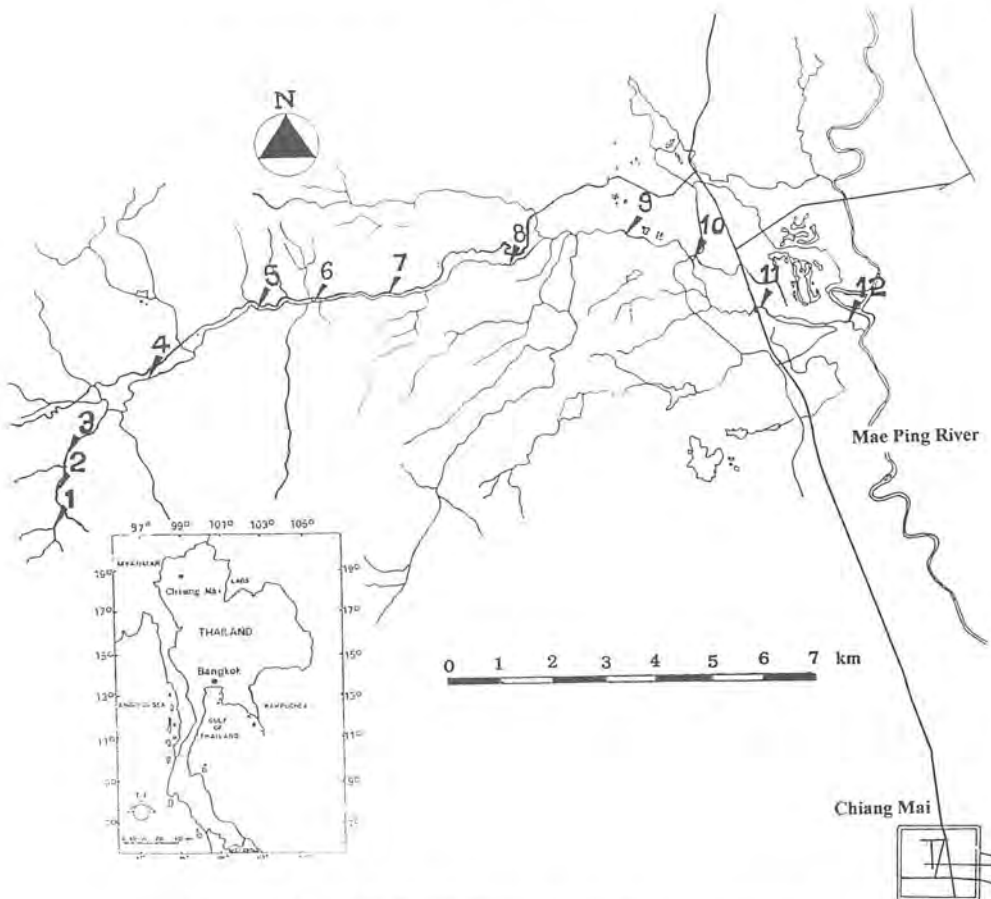


Figure 1. Map of the Mae Sa Stream showing the 12 sampling sites.

Figure 1. Map of the Mae Sa Stream showing the 12 sampling sites.

Table 1. Site names, altitude (m a.s.l.) and descriptions.

Site name	Altitude (m)	Description
1. Kong Hae Village	1,075	agriculture and residential
2. entrance to Kong Hae Village	1,000	agriculture and residential
3. Pong Yang elephant camp	960	tourist attraction
4. Sri Muang Kham Village	760	agriculture and residential
5. Huay Dee Mee	700	residential
6. Queen Sirikit Botanical Garden	650	tourist attraction
7. Mae Sa elephant camp	550	tourist attraction
8. Mae Sa waterfall	390	tourist attraction
9. Mae Rim bridge	340	residential
10. Cholaprathan bridge	330	residential
11. Pa Muang Village	330	residential
12. Mae Sa Luang Village	340	agriculture and residential

## METHODOLOGY

### Sampling and Preparation

Phytoplankton samples were collected for identification using a plankton net of mesh size 10  $\mu\text{m}$ . Samples were preserved with Lugol's solution and were kept cool and dark before observation under a light microscope.

Epilithic diatom samples were scraped from 3–5 stones at each site. In the laboratory, the samples were cleaned by boiling for 15–30 minutes in concentrated HCl or HNO<sub>3</sub> and H<sub>2</sub>O<sub>2</sub>. Naphrax was used for mounting (BARBER & HAWORT, 1981; ROUND ET AL., 1990). Light micrographs were made with an Olympus BX-40 microscope. Scanning electron micrographs were made with a JEOL JSM-840A microscope, operated at 8–20 KV. Black and white film was used.

### Identification

The taxonomic classification systems of the Süßwasserflora Mitteleuropas by KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, 1991b), KRAMMER (1992, 1997a, 1997b), LANGE-BERTALOT & KRAMMER (1989), LANGE-BERTALOT (1995) and REICHARDT (1984) were followed. In some cases, however, the relevant keys in books or theses of some tropical studies such as FOGED (1971, 1975, 1976), PODZORSKI & HAKANSSON (1987), VYVERMAN (1991) and BENAVIDES (1994) were used.

The features of the diatom frustule are very complex and fine details are hard to see under the light microscope. SEM was used to investigate valve shapes (diameter, length, width), striae patterns (striae frequency in 10  $\mu\text{m}$ ) and other features (raphe, puncta, areolae, fibulae, nodule, septa, costae, stigmata, rib, spine, wing and canals) for species that were difficult to identify (BARBER & HAWORT, 1981; ROUND ET AL., 1990).

## RESULTS

### Phytoplankton Investigation

Eighty-seven species of phytoplankton were found which could be classified into 5 phyla, 8 orders, 19 families and 31 genera. The majority of the phytoplankton species were diatoms in the Order Pennales and the most abundant species were *Melosira varians* Agardh, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Cymbella tumida* (Brébisson) Van Heurck, and *Nitzschia linearis* (Agardh) W. Smith. Some cyanobacteria, *Anabaena*, *Pseudanabaena*, *Lyngbya*, *Cylindrospermopsis*, were also found in planktonic form. Some green algae such as *Ankistrodesmus*, *Closterium*, *Cosmarium*, *Isthmochloron*, *Monoraphidium*, *Pediastrum*, *Staurastrum*, *Tetrastrum* and *Scenedesmus* were also present. The phytoplankton list is presented in Table 2.

Table 2. Species list of all phytoplankton and benthic algae in Mae Sa Stream, Suthep-Pui National Park, Chiang Mai. (P = Plankton, B = Benthic algae)

Phytoplankton and benthic algae	Form	Site distribution
<b>CYANOBACTERIA</b>		
Order Oscillatoriales, Family Oscillatoriaceae		
<i>Lyngbya circumcreta</i> West, G. S.	P	5,12
<i>Oscillatoria acuminata</i> Gomont	B	1,2,7,10
<i>Oscillatoria</i> spp.	P, B	2,3,6,7,8,9,10,11,12
<i>Planktolyngbya limnetica</i> Lemm.	P	10,11,12
<i>Spirulina major</i> (Gomont) Kützing	P	12
Order Nostocales, Family Nostocaceae		
<i>Anabaena</i> sp.	P	1,3,4,5,6,7,8,10,12
<i>Cylindrospermopsis raciborskii</i> (Wolosz.) Seenayya & Subba	P	10
<i>Nostoc</i> spp.	B	1,2,10,12
<i>Nostochopsis</i> sp.	B	1
<i>Pseudanabaena</i> sp.	P	1,2,4,6,8,10,12
Family Rivulariaceae		
<i>Gleotrichia</i> sp.	P	2
<b>CHLOROPHYTA</b>		
Order Volvocales, Family Volvocaceae		
<i>Gonium</i> sp.	P	2
Order Tetrasporales, Family Tetrasporaceae		
<i>Tetraspora</i> sp.	P	11
Order Chlorosphaerales, Family Oocystaceae		
<i>Ankistrodesmus</i> sp.	P	3,4,5,7,10
<i>Monoraphidium</i> sp.	P	11
Family Scenedesmaceae		
<i>Coelastrum</i> sp.	P	7,8
<i>Scenedesmus javanensis</i> Chod.	P	5,7
<i>Scenedesmus</i> spp.	P	1,4,7,9
<i>Tetrastrum</i> sp.	P	12
Family Hydrodictyceae		
<i>Hydrodictyon reticulatum</i> (Linn.) Lagerheim	B	2
<i>Pediastrum duplex</i> Meyen	P	1,8,9
<i>Pediastrum simplex</i> Meyen	P	1,9,12
<i>Pediastrum</i> sp.	P	10

Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
Order Chaetophorales, Family Chaetophoraceae <i>Stigeoclonium</i> spp.	B	2,10,12
Order Oedogoniales, Family Oedogoniaceae <i>Oedogonium</i> spp.	B	2
Order Siphonocladales, Family Cladophoraceae <i>Cladophora</i> spp.	B	1-12
<i>Rhizoclonium</i> spp.	B	1,2,7,8,10,12
Order Zygnematales, Family Zygnemataceae <i>Spirogyra</i> spp.	B	1,2,3,4,5,7,10,11,12
Family Desmidiaceae <i>Closterium</i> sp.	P	1,3,5,10
<i>Cosmarium reniforme</i> var. <i>compressum</i> Needst.	P	10,12
<i>Spondylosium panduriforme</i> (Heimerl) Teil. var. <i>panduriforme</i> f. <i>panduriforme</i>	P	11,12
<i>Staurastrum</i> sp.	P	2,3,7
EUGLENOPHYTA		
Order Euglenales, Family Euglenaceae <i>Euglena</i> spp.	P	1,2,3,4,7,10,11,12
<i>Phacus pisciformis</i> Klebs	P	1,3,6,11,12
<i>Trachelomonas volvocina</i> Ehr.	P	3,4,7,9,12
<i>Trachelomonas</i> spp.	P	1,5,11,12
DINOPHYTA		
Order Dinokontae, Family Gymnodiniaceae <i>Gymnodinium</i> sp.	P	1,2,3,11
Family Peridiniaceae <i>Peridinium cunningtonii</i> Lemm.	P	8
<i>Peridinium</i> sp.	P	1,3,4,5,11
<i>Peridiopsis cunningtonii</i> Lemm.	P	1
Family Ceratiaceae <i>Ceratium hirundinella</i> (O.F. Müller) Schrank	P	1,5
RHODOPHYTA		
Family Bratrachospermaceae <i>Batrachospermum macrosporum</i> Montague	B	1
<i>Ceramium</i> sp.	B	1,2,10,11,12

Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
<b>BACILLARIOPHYTA</b>		
Order Centrales, Family Thalassiosiraceae		
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen	P,B	1,2,3,5,6,7,8,10
<i>Cyclotella stelligera</i> Cleve & Grunow	B	2,5,6,7,8
<i>Cyclotella</i> spp.	P,B	1,3,6
<i>Melosira moniliformis</i> (O.F. Müller) Agardh	P	1,2,4,6,7
<i>Melosira varians</i> Agardh	P,B	1-12
Order Pennales, Family Fragilariaceae		
<i>Fragilaria biceps</i> (Kützing) Lange-Bertalot	B	12
<i>Fragilaria bidens</i> Heiberg	B	6,11
<i>Fragilaria capucina</i> Desmazières	P,B	10,12
<i>Fragilaria elliptica</i> Schumann	B	2
<i>Fragilaria pinnata</i> Ehrenberg var. <i>pinnata</i>	B	12
<i>Fragilaria ulna</i> (Nitzsch) Lange-Bertalot	P,B	1-12
<i>Fragilaria ulna</i> var. <i>acus</i> (Kützing) Lange-Bertalot	B	3
<i>Fragilaria</i> spp.	P,B	1-12
<i>Synedra ulna</i> var. <i>aequalis</i> (Kützing) Hustedt	B	12
Family Eunotiaceae		
<i>Eunotia bilunaris</i> (Ehrenberg) Mills var. <i>bilunaris</i>	B	1
<i>Eunotia minor</i> (Kützing) Grunow	B	7
<i>Eunotia</i> spp.	P	1,2,4,10,11,12
Family Achnantheaceae		
<i>Achnanthes chlidanos</i> Hohn & Hellermann	B	2,3
<i>Achnanthes crenulata</i> Grunow	B	3,4,5
<i>Achnanthes exigua</i> Grunow var. <i>exigua</i>	B	1,2,3,4,11,12
<i>Achnanthes helvetica</i> (Hustedt) Lange-Bertalot	B	7
<i>Achnanthes lanceolata</i> (Brébisson) Grunow	B	1,2,3,4,5,6,7,9,10,12
<i>Achnanthes minutissima</i> Kützing	B	1,2,3,4,5,6
<i>Achnanthes oblongella</i> Oestrup	B	7
<i>Achnanthes</i> spp.	P,B	1,2,3,4,5,6,8,9,10,11,12
<i>Cocconeis placentula</i> Ehrenberg	P,B	1-12
Family Naviculaceae		
<i>Caloneis bacillum</i> (Grunow) Cleve	B	2,4,5
<i>Caloneis lauta</i> Carter & Bailey-Watts	B	12
<i>Caloneis</i> sp.	B	12
<i>Diatoma ehrenbergii</i> Kützing	B	11
<i>Diatoma vulgare</i> Bory	B	12
<i>Diploneis litoralis</i> (Donk.) Cleve	B	4,5
<i>Diploneis subovalis</i> Cleve	B	2,3,5
<i>Diploneis</i> spp.	P,B	2,12
<i>Frustulia vulgare</i> (Thwaites) De Toni	B	1,2,3,4,5,6
<i>Frustulia</i> spp.	P,B	1,2,3,4,6,10,11

Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
<i>Gyrosigma kützingii</i> (Grunow) Cleve	B	2,3,6
<i>Gyrosigma nodiferum</i> (Grunow) Reimer	B	7
<i>Gyrosigma scalproides</i> (Rabenhorst) Cleve	B	1,2,3,4,5,6
<i>Gyrosigma spencerii</i> (Quekett) Griffith & Henfrey	B	2
<i>Gyrosigma</i> spp.	P	1,3,4,5,6,7,8,9,10,11,12
<i>Navicula amphibola</i> Cleve	B	7
<i>Navicula bacillum</i> Ehrenberg	B	11
<i>Navicula cohnii</i> (Hilse) Lange-Bertalot	B	1,2,3,4,5,6
<i>Navicula concentrica</i> Carter	B	1
<i>Navicula cryptocephala</i> Kützing	B	1,2,3,4,5,6,7
<i>Navicula cryptotenella</i> Lange-Bertalot	P,B	1-12
<i>Navicula disjuncta</i> Hustedt	B	1,2,3,4,5,6,11,12
<i>Navicula exigua</i> (Gregory) Grunow	B	1,2,3,11
<i>Navicula gastrum</i> (Ehrenberg) Kützing	B	11
<i>Navicula gregaria</i> Donkin	B	7
<i>Navicula jaagii</i> Meister	B	3
<i>Navicula laevisissima</i> Kützing var. <i>laevisissima</i>	B	1
<i>Navicula lanceolata</i> (Agardh) Ehrenberg	P,B	7,8,10,12
<i>Navicula microdigituradiata</i> Lange-Bertalot	B	7
<i>Navicula mobiliensis</i> var. <i>capitata</i>	B	12
<i>Navicula mutica</i> Kützing	B	12
<i>Navicula mutica</i> Kützing var. <i>mutica</i>	B	3
<i>Navicula placentula</i> (Ehrenberg) Grunow	B	7
<i>Navicula pupula</i> Kützing var. <i>pupula</i>	B	1,2,3,4,5,6,12
<i>Navicula schroeterii</i> Meister	B	11
<i>Navicula subplacentula</i> Hustedt	B	12
<i>Navicula tripunctata</i> (O. F. Müller) Bory	B	7
<i>Navicula viridula</i> var. <i>rostellata</i> (Kützing) Cleve	B	12
<i>Navicula viridula</i> (Kützing) Ehrenberg	B	1,2,3,4,5,6,10,11,12
<i>Navicula</i> spp.	P,B	1-12
<i>Neidium affine</i> var. <i>longiceps</i> (Gregory) Cleve	B	7
<i>Neidium ampliatum</i> (Ehrenberg) Krammer	B	7
<i>Neidium dubium</i> (Ehrenberg) Cleve	B	6
<i>Neidium productum</i> (W. Smith) Cleve	B	7
<i>Neidium</i> sp.	P	1,2,5,6,11
<i>Pinnularia acrosphaeria</i> Rabenhorst	B	7
<i>Pinnularia braunii</i> (Grunow) Cleve	B	12
<i>Pinnularia brevicostata</i> Cleve	B	7
<i>Pinnularia interrupta</i> W. Smith	B	1,2,3,4,5
<i>Pinnularia mesolepta</i> (Ehrenberg) W. Smith	B	2
<i>Pinnularia subgibba</i> Krammer	B	7
<i>Pinnularia viridiformis</i> Krammer	B	3
<i>Pinnularia viridis</i> (Nitzsch) Ehrenberg	B	1,2,3,6
<i>Pinnularia</i> spp.	P,B	1-12
<i>Stauroneis angustevittata</i>	B	12



Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
<i>Stauroneis smithii</i> Grunow	P,B	1,2,3
Family Nitzschiaceae		
<i>Hantzschia amphioxys</i> (Ehrenberg) Grunow	B	1,2,3,6
<i>Hantzschia distinctepunctata</i> (Hustedt) Hustedt	B	7
<i>Nitzschia bremensis</i> Hustedt	B	7
<i>Nitzschia brevissima</i> Grunow	B	2
<i>Nitzschia coarctata</i> Grunow	B	1
<i>Nitzschia dissipata</i> (Kützing) Grunow	B	1,2,4,5,6,12
<i>Nitzschia fonticola</i> Grunow	B	3,4,12
<i>Nitzschia granulata</i> Grunow	B	3
<i>Nitzschia levidensis</i> (W. Smith) Grunow	B	10
<i>Nitzschia linearis</i> (Agardh) W. Smith	P,B	1,2,3,4,5,6,7,8,9,11,12
<i>Nitzschia palea</i> (Kützing) W. Smith	B	1,2,4,7,12
<i>Nitzschia sigmoidae</i> (Nitzsch) W. Smith	B	1,7,8
<i>Nitzschia subacicularis</i> Hustedt	B	3
<i>Nitzschia</i> spp.	P,B	1-12
Family Cymbellaceae		
<i>Amphora coffeaeformis</i> (Agardh) Kützing	B	7
<i>Amphora dusenii</i> Brun	B	2
<i>Amphora libyca</i> Ehrenberg	P,B	1,2,3,4,9,11,12
<i>Amphora montana</i> Krasske	B	1,2,3,4,5,6,11
<i>Amphora ovalis</i> (Kützing) Kützing	B	1,2
<i>Amphora</i> spp.	B	12
<i>Cymbella affinis</i> Kützing	B	7
<i>Cymbella amphicephala</i> Naegeli	B	2
<i>Cymbella aspera</i> (Ehrenberg) Cleve	P,B	1
<i>Cymbella cistula</i> (Ehrenberg) Kirchner	B	5
<i>Cymbella hustedtii</i> Krasske	B	12
<i>Cymbella naviculiformis</i> Auerswald	B	1,2,3
<i>Cymbella silesiaca</i> Bleisch	B	1,3,4,6
<i>Cymbella tumida</i> (Brébisson) Van Heurck	P,B	1,3,4,5,6,7,8,9,10,11,12
<i>Cymbella turgidula</i> Grunow	B	1,3,4,5,6,7,12
<i>Cymbella</i> spp.	P,B	1-12
<i>Gomphonema affine</i> Kützing	B	1
<i>Gomphonema augur</i> Ehrenberg	P,B	1,2,3,4,5,6
<i>Gomphonema augur</i> var. <i>turris</i> (Ehrenberg) Lange-Bertalot	B	1
<i>Gomphonema carolinense</i> Hagelstein	B	2,3,4,6
<i>Gomphonema clevei</i> Fricke	B	1,2,4,5
<i>Gomphonema constrictum</i> Ehrenberg	P	2,6,10
<i>Gomphonema gracile</i> Ehrenberg	B	1,4,5,6
<i>Gomphonema lanceolatum</i> Ehrenberg	B	2,3,5
<i>Gomphonema micropus</i> Kützing	B	2
<i>Gomphonema minutum</i> (Agardh) Agardh	B	3,4,5,6,7
<i>Gomphonema parvulum</i> var. <i>lagenula</i> (Kützing) Frenguelli	B	3

Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
<i>Gomphonema parvulum</i> (Kützing) Kützing	B	1,2,3,4,5,6,12
<i>Gomphonema pumilum</i> var. <i>rigidum</i>	B	7,12
<i>Gomphonema subclavatum</i> Grunow	B	3,5
<i>Gomphonema</i> spp.	P,B	1-12
Family Bacillariaceae		
<i>Bacillaria paradoxa</i> Gmelin	P,B	6,8,10,11,12
Family Epithemiaceae		
<i>Epithemia</i> sp.	P	1,2,3,4,5
<i>Rhoicosphenia</i> sp.	P	1,3,5,6
<i>Rhopalodia gibba</i> (Ehrenberg) O. Müller var. <i>gibba</i>	B	2,10
<i>Rhopalodia</i> sp.	P,B	2,9,10,11,12
Family Surirellaceae		
<i>Cymatopleura salea</i> var. <i>epicolata</i> (W. Smith) Ralfs	P,B	9,10,12
<i>Surirella angusta</i> Kützing	B	11
<i>Surirella bifrons</i> Ehrenberg	B	11
<i>Surirella biseriata</i> Brébisson	B	2,11,12
<i>Surirella capronii</i> Brébisson	P,B	1,2,3,4,5,6,7,10,12
<i>Surirella elegans</i> Ehrenberg	B	12
<i>Surirella spiralis</i> Kützing	B	7,10
<i>Surirella tenera</i> Gregory	B	2
<i>Surirella</i> spp.	P,B	1-12

### Benthic Algae Investigation

A total of 172 species of benthic algae were found (shown in Table 1). The most abundant were also diatoms in the Order Pennales. The majority of the species belonged to the diatom genera *Navicula* (38 species), *Nitzschia* (23 species), *Fragilaria* (16 species) and *Gomphonema* (15 species).

The most abundant species were *Navicula viridula* (Kützing) Ehrenberg, *Nitzschia palea* (Kützing) W. Smith, *Fragilaria capucina* Desmazières, *Cymbella tumida* (Brébisson) Van Heurck, *Gomphonema parvulum* (Kützing) Grunow, *Fragilaria ulna* (Nitzsch) Lange-Bertalot. The common species were *Aulacoseira granulata* (Ehrenberg) Simonsen, *Cymbella tumida* (Brébisson) Van Heurck, *Cocconeis placentula* Ehrenberg, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* (Kützing) Grunow and *Melosira varians* Agardh.

Filamentous macroalgae such as *Oscillatoria* spp. (cyanobacteria) *Hydrodictyon* sp., *Spirogyra* spp., *Cladophora* spp., *Rhizoclonium* spp., *Stigeoclonium* spp. and *Oedogonium* spp. (green algae) and *Batrachospermum macrospermum* Montague and *Ceramium* spp. (red algae) were recorded.

## New Records

Sixty-eight diatom species were considered to be new records for Thailand, belonging to 9 families and 25 genera (Table 3). The species list of diatoms was compared with the checklist of freshwater algae in Thailand by LEWMANOMONT *ET AL.* (1995).

Table 3. New record species of diatoms in Mae Sa Stream, Suthep–Pui National Park, Chiang Mai.

ORDER CENTRALES	<i>Frustulia weinholdii</i> Hustedt
Family Thalassiosiraceae	<i>Gomphonema affine</i> Kützing
<i>Cyclotella stelligera</i> Cleve & Grunow	<i>Gomphonema augur</i> var. <i>turris</i> (Ehrenberg) Lange-Bertalot
<i>Stephanodiscus</i> sp.	<i>Gomphonema minutum</i> (Agardh) Agardh
<i>Thalassiosira weissflogii</i> (Grunow) Fryxell & Hasle	<i>Gomphonema pumilum</i> var. <i>rigidum</i>
Family Hemidiscaceae	<i>Navicula amphibola</i> Cleve
<i>Actinocyclus normanii</i> (Gregory) Hustedt	<i>Navicula cohnii</i> (Hilse) Lange-Bertalot
ORDER PENNALES	<i>Navicula concentrica</i> Carter
Family Fragilariaceae	<i>Navicula cryptotenella</i> Lange-Bertalot
<i>Diatoma ehrenbergii</i> Kützing	<i>Navicula elginensis</i> (Gregory) Ralfs var. <i>elginensis</i>
<i>Diatoma moniliformis</i> Kützing	<i>Navicula jaagii</i> Meister
<i>Diatoma vulgare</i> Bory	<i>Navicula laevis</i> Kützing var. <i>laevis</i>
<i>Fragilaria biceps</i> (Kützing) Lange-Bertalot	<i>Navicula mutica</i> Kützing var. <i>mutica</i>
<i>Fragilaria bidens</i> Heiberg	<i>Navicula subplacentula</i> Hustedt
<i>Fragilaria elliptica</i> Schumann	<i>Navicula tripunctata</i> (O. F. Müller) Bory
<i>Fragilaria ulna</i> (Nitzsch) Lange-Bertalot	<i>Navicula trivialis</i> Lange-Bertalot
Family Eunotiaceae	<i>Neidium ampliatum</i> (Ehrenberg) Krammer
<i>Eunotia bilunaris</i> (Ehrenberg) Mills var. <i>bilunaris</i>	<i>Pinnularia subgibba</i> Krammer
<i>Eunotia minor</i> (Kützing) Grunow	<i>Pinnularia viridiformis</i> Krammer
Family Achnantheaceae	<i>Sellaphora pupula</i> (Kützing) Mereschkowsky
<i>Achnanthes chlidanos</i> Hohn & Hellermann	<i>Stauroneis producta</i> Grunow
<i>Achnanthes exigua</i> Grunow var. <i>exigua</i>	Family Epithemiaceae
<i>Achnanthes helvetica</i> (Hustedt) Lange-Bertalot	<i>Rhopalodia gibba</i> (Ehrenberg) O. Müller var. <i>gibba</i>
<i>Achnanthes lanceolata</i> ssp. <i>lanceolata</i> (Brébisson)	Family Bacillariaceae
Grunow var. <i>haynaldii</i> (Schaarschmidt) Cleve	<i>Hantzschia distinctepunctata</i> (Hustedt) Hustedt
<i>Achnanthes undata</i> Meister	<i>Nitzschia acula</i> Hantzsch
<i>Cocconeis placentula</i> var. <i>pseudolineata</i> Geitler	<i>Nitzschia angustatula</i> Lange-Bertalot
Family Naviculaceae	<i>Nitzschia bremensis</i> Hustedt
<i>Amphora coffeaeformis</i> (Agardh) Kützing	<i>Nitzschia brevissima</i> Grunow
<i>Amphora dusenii</i> Brun	<i>Nitzschia coarctata</i> Grunow
<i>Amphora libyca</i> Ehrenberg	<i>Nitzschia dubia</i> W. Smith
	<i>Nitzschia granulata</i> Grunow

Table 3. (continued).

<i>Caloneis lauta</i> Carter & Bailey-Watts	<i>Nitzschia literalis</i> Grunow
<i>Caloneis silicula</i> (Ehrenberg) Cleve	<i>Nitzschia palustris</i> Hustedt
<i>Cymbella amphicephala</i> Naegeli	<i>Nitzschia subacicularis</i> Hustedt
<i>Cymbella hustedtii</i> Krasske	Family Surirellaceae
<i>Cymbella silesiaca</i> Bleisch	<i>Cymatopleura solea</i> var. <i>apiculata</i> (W. Smith) Ralfs
<i>Cymbella sinuata</i> Gregory	<i>Surirella bifrons</i> Ehrenberg
<i>Cymbella turgidula</i> Grunow	<i>Surirella spiraloidea</i> Hustedt
<i>Cymbellopsis</i> sp.	<i>Surirella splendida</i> (Ehrenberg) Kützing
<i>Nitzschia fonticola</i> Grunow	

## DISCUSSION

The survey reported here extends our knowledge of biodiversity in Thailand, with regard to phytoplankton and benthic algae as valuable natural resources. Studies of freshwater algae in Thailand started at the end of the 19<sup>th</sup> century and were carried out by foreign scientists. A checklist of the freshwater *Algae in Thailand* (LEWMANOMONT ET AL., 1995), compiled from 53 publications, lists 161 genera, 1001 species, 287 varieties and 63 forms, reported from the Divisions or Phyla Cyanophyta (Cyanobacteria), Chlorophyta, Chromophyta (divided into four classes: Bacillariophyceae, Chrysophyceae, Dinophyceae and Cryptophyceae) and Rhodophyta.

Additional studies on freshwater algae have been done by Thai scientists since 1977, but it is obvious that Thailand is making slow progress in freshwater algae biodiversity studies (LEWMANOMONT ET AL., 1995).

At present, the status of phytoplankton and benthic algae diversity in Thailand deserves serious attention. The comparison between the number of algae species known in the world and in Thailand implies that there are many more species waiting for discovery and study in detail (Table 4).

Table 4. The number of algae species known in the world compared with the number known in Thailand (BAIMAI, 1995).

Algae group	No. of species known in the world	No. of species known in Thailand	No. of species expected to be discovered in Thailand
Chlorophyta	7,000	1,500	1,000
Phaeophyta	1,500	300	600
Rhodophyta	4,000	400	400
Chrysophyta	12,500	700	500
Phyrrhophyta	1,100	300	600

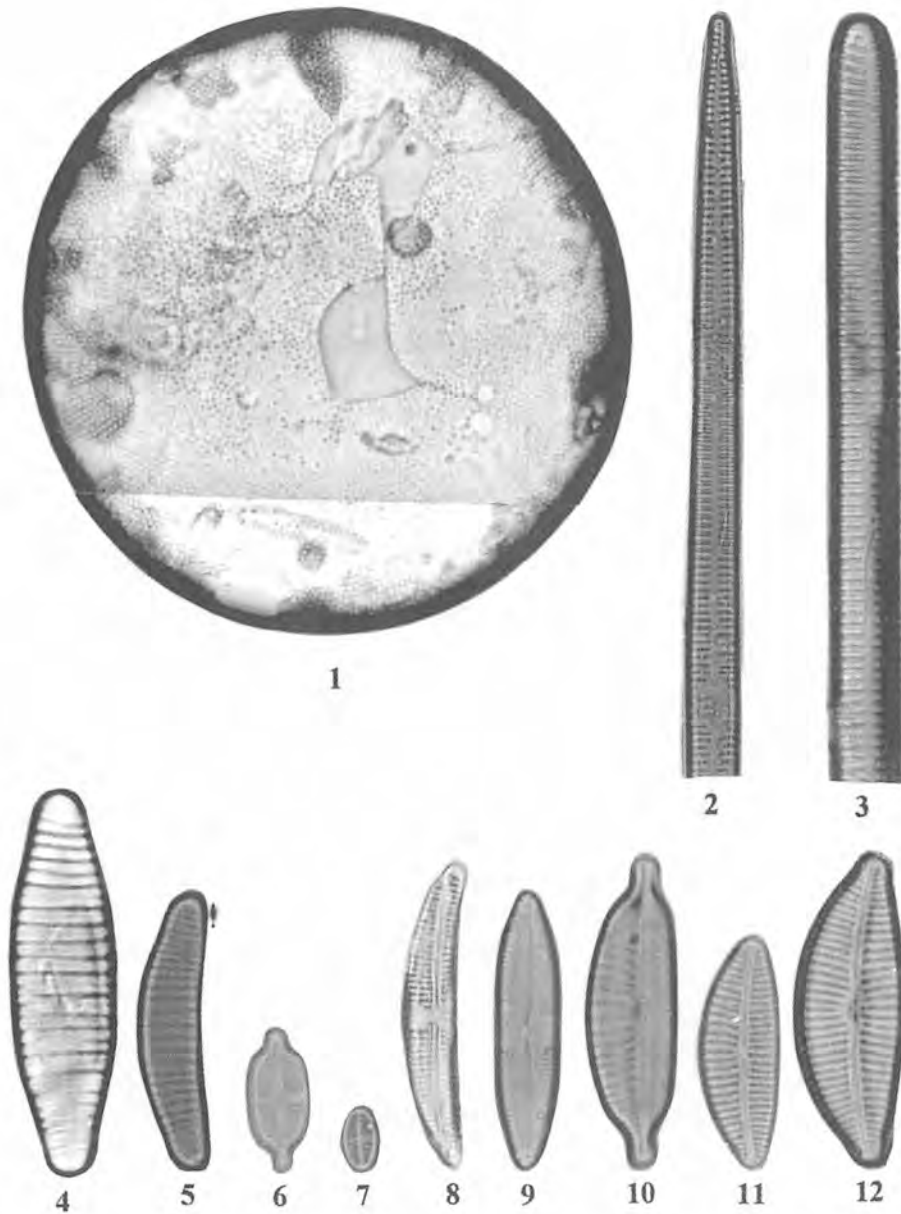


Figure 2. Light micrographs showing some newly recorded species of diatoms in Mae Sa Stream, Suthep-Pui National Park, Chiang Mai (scale bar = 10  $\mu$ ).

1, *Actinocyclus normanii* (Gregory) Hustedt; 2, *Fragilaria biceps* (Kützing) Lange-Bertalot; 3, *Fragilaria ulna* (Nitzsch) Lange-Bertalot; 4, *Diatoma vulgaris* Bory; 5, *Eunotia minor* (Kützing) Grunow; 6, *Achmanthes exigua* Grunow var. *exigua*; 7, *Achmanthes helvetica* (Hustedt) Lange-Bertalot; 8, *Amphora libyca* Ehrenberg; 9, *Caloneis lauta* Carter & Bailey-Watts; 10, *Cymbella amphicephala* Naegeli; 11, *Cymbella hustedtii* Krasske; 12, *Cymbella turgidula* Grunow

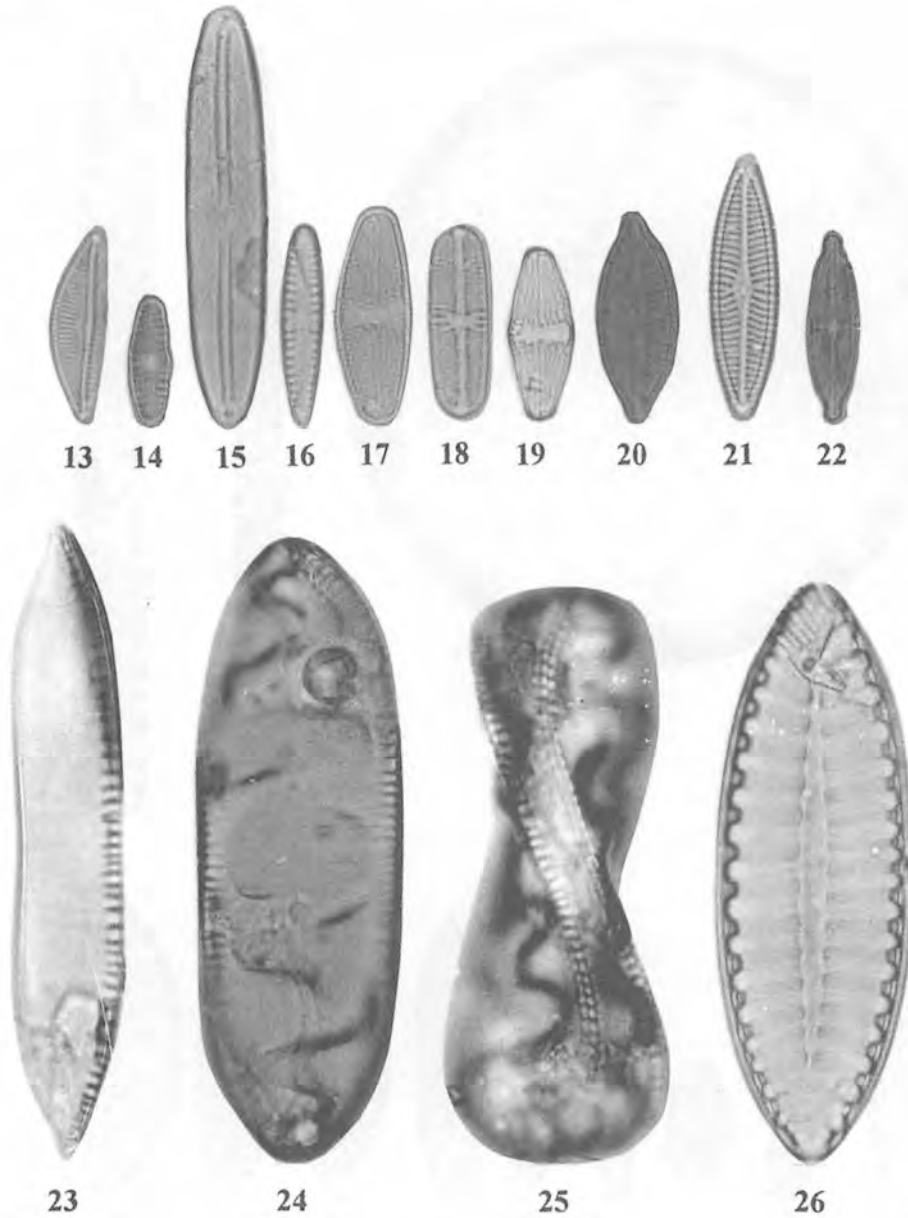


Figure 3. Light micrographs show some newly recorded species of diatom in Mae Sa Stream, Suthep–Pui National Park, Chiang Mai (scale bar = 10  $\mu$ ).

13, *Cymbella silesiaca* Bleisch; 14, *Cymbella sinuata* Gregory; 15, *Frustulia weinholdii* Hustedt; 16, *Gonphonema pumilum* var. *rigidum*; 17, *Navicula cohnii* (Hilse) Lange-Bertalot; 18, *Navicula laevissima* Kützing var. *laevissima*; 19, *Navicula mutica* Kützing var. *mutica*; 20, *Navicula subplacentula* Hustedt; 21, *Navicula tripunctata* (O. F. Müller) Bory; 22, *Stauroneis producta* Grunow; 23, *Nitzschia bremensis* Hustedt; 24, *Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs; 25, *Surirella spiralooides* Ehrenberg; 26, *Surirella splendida* (Ehrenberg) Kützing

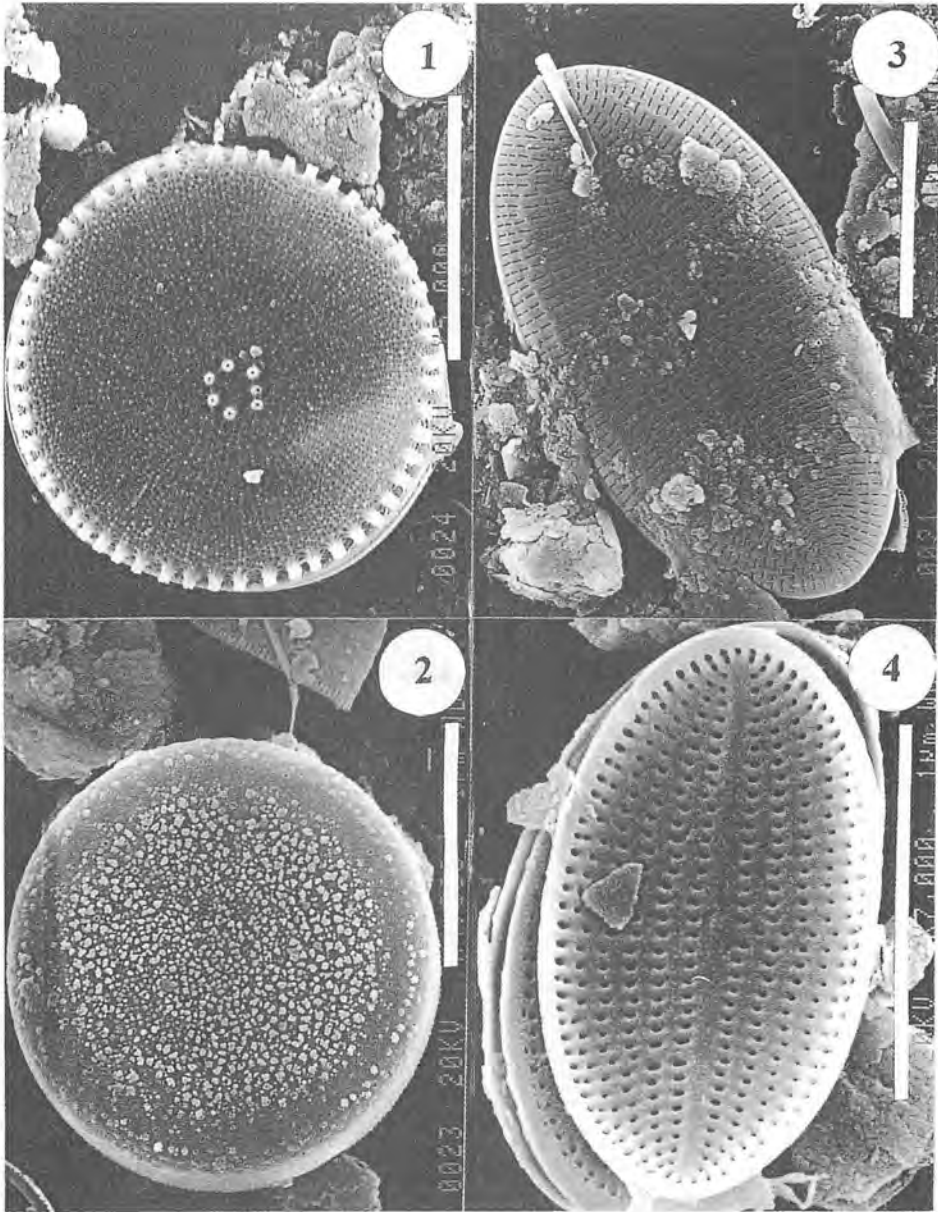


Figure 4. SEM Micrographs (scale bars = 10  $\mu$ )

- 1, *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle; 2, *Melosira varians* Agardh (valve view); 3, *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow; 4, *Cocconeis placentula* var. *pseudolineata* Geitler

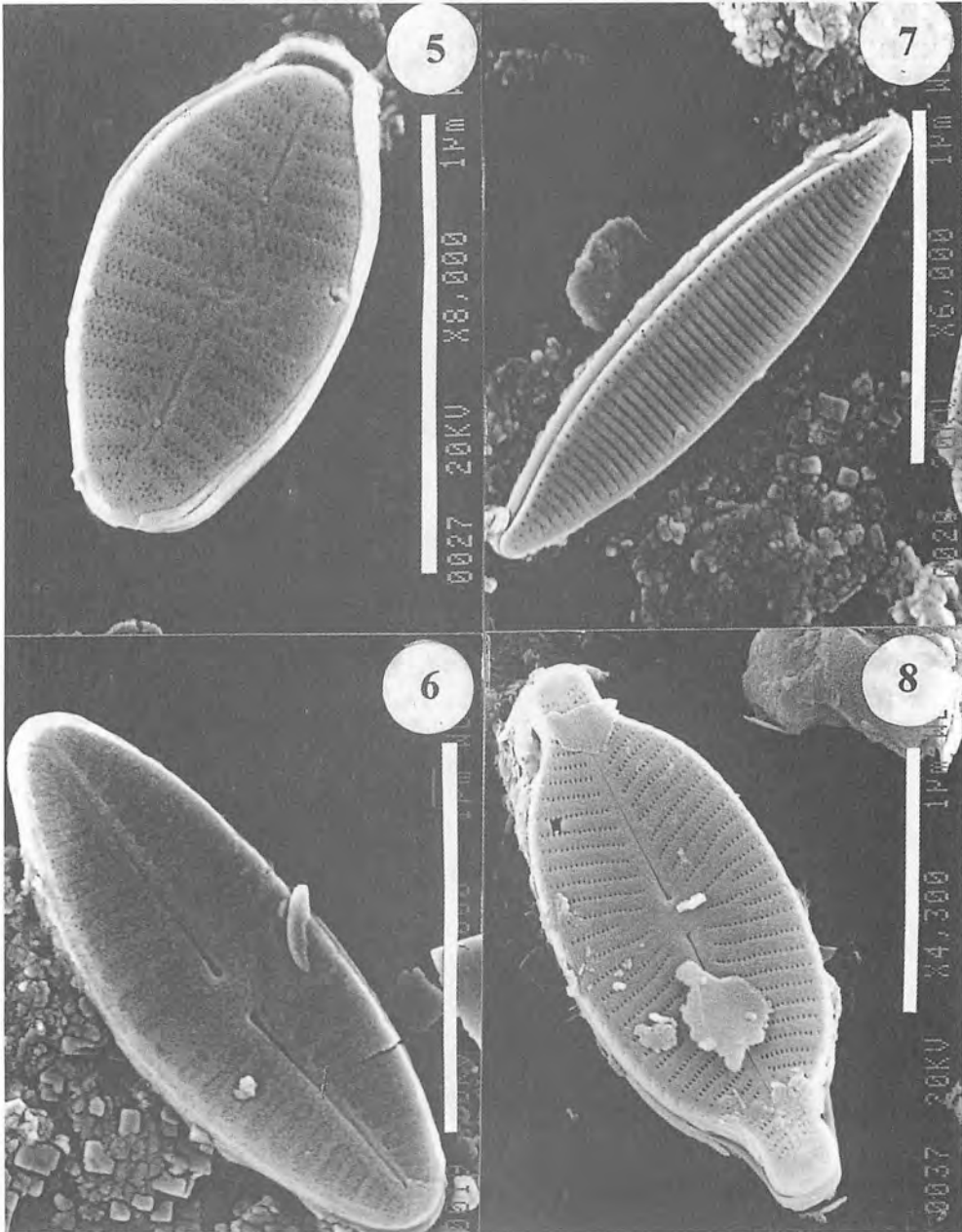


Figure 5 SEM Micrographs (scale bars = 10  $\mu$ )

5, *Achmanthes lanceolata* (Brébisson) Grunow? (raphaeless valve); 6, *Achmanthes lanceolata* (Brébisson) Grunow (raphae valve); 7, *Nitzschia* sp.; 8, *Navicula elginensis* (Gregory) Ralfs var. *elginensis*



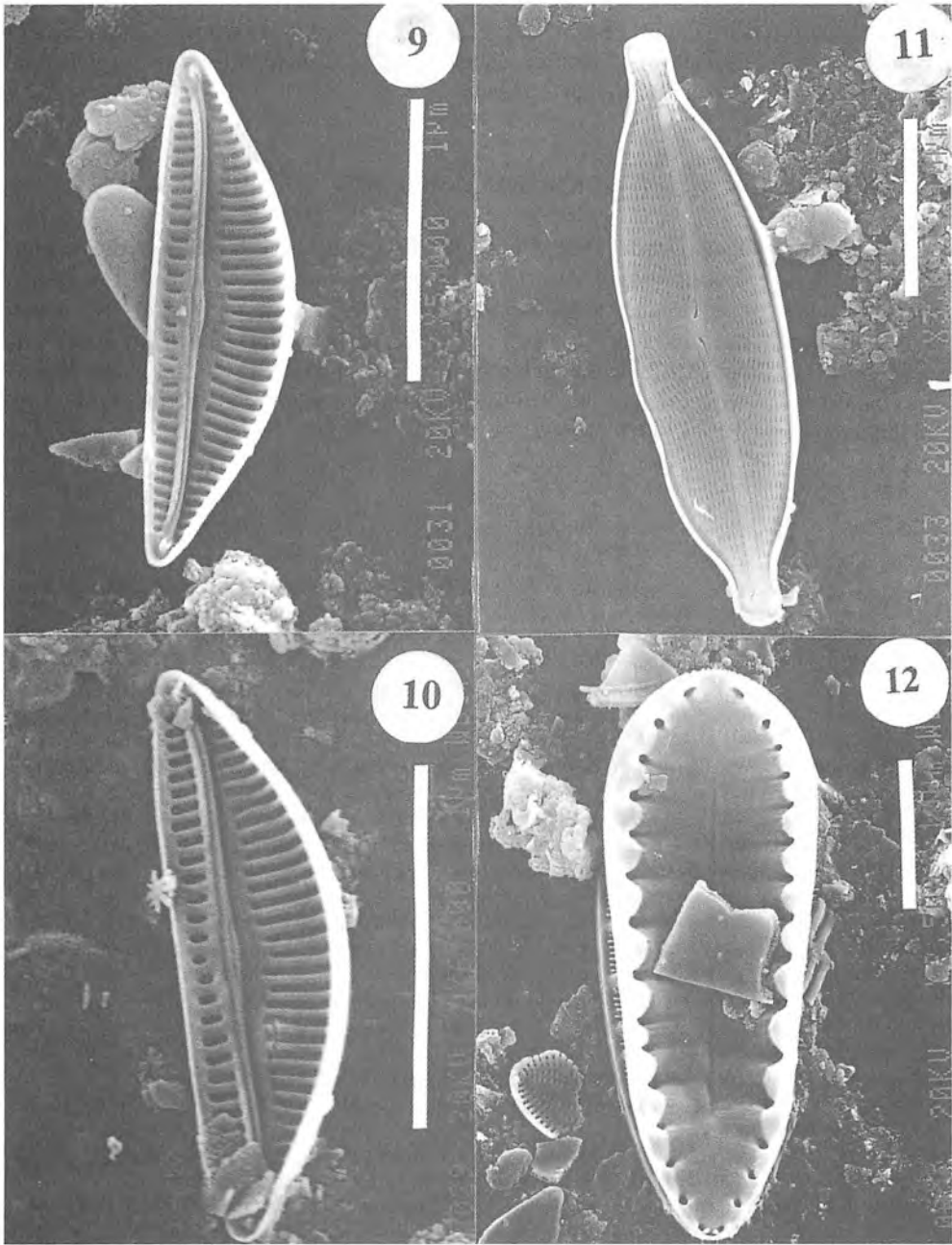


Figure 6. SEM Micrographs (scale bars = 10  $\mu$ )  
9–10, *Cymbellopsis* sp.; 11, *Navicula* sp.; 12, *Surirella* sp.

Most work in Thailand is on plankton and most research has been done in lakes and reservoirs. Benthic algae are more significant in river than in lakes. This work was done on both phytoplankton and benthic algae. The present study reports a total of 87 phytoplankton species and 172 benthic diatom species. Among these, 68 new diatom species records have been added for Thailand.

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