BIODIVERSITY OF BENTHIC DIATOMS AND THEIR APPLICATION IN MONITORING WATER QUALITY OF MAE SA STREAM DOI SUTHEP-PUI NATIONAL PARK CHIANG MAI

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DOCTOR OF PHILOSOPHY
IN BIOLOGY

GRADUATE SCHOOL
CHIANG MAI UNIVERSITY
MAY 2002

Biodiversity of Benthic Diatoms and Their Application in Monitoring Water Quality of Mae Sa Stream Doi Suthep-Pui National Park Chiang Mai

TRAI PEKTHONG

A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN

PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

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30 May 2002

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TRAI PEKTHONG

ชื่อเรื่องวิทยานิพนธ์ ความหลากหลายทางชีวภาพของเบนทิคไดอะตอมและการประยุกต์เพื่อติดตามตรวจสอบคุณภาพน้ำในลำน้ำแม่สา อุทยานแห่งชาติดอยสุเทพ-ปุย เชียงใหม่

ชื่อผู้เขียน นายตรัย เป๊กทอง

วิทยาศาสตรดุษฎีบัณฑิต สาขาวิชาชีววิทยา

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ผศ. ดร.บัญญัติ มนเทียรอาสน์	กรรมการ

บทคัดย่อ

การศึกษาความหลากหลายทางชีวภาพของเบนทิคไดอะตอมและการประยุกต์ใช้เพื่อติดตามตรวจสอบคุณภาพน้ำในลำน้ำแม่สา อุทยานแห่งชาติดอยสุเทพ-ปุย จังหวัดเชียงใหม่ ระหว่างเดือนเมษายน พ.ศ. 2541 ถึงเดือนกันยายน พ.ศ. 2542 โดยกำหนดจุดเก็บตัวอย่าง 5 จุดจากต้นลำน้ำถึงปลายลำน้ำ พบไดอะตอม 34 genera 278 species ในจำนวนนี้ 51 สปีซีส์เป็นสปีซีส์ที่พบใหม่ในประเทศไทย ไดอะตอมที่พบเป็นชนิดเด่นคือ *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Cocconeis placentula* Ehrenberg, *Gyrosigma scalproides* (Rabenhorst) Cleve, *Gomphonema parvulum* (Kützing) Kützing, *Achnanthes oblongella* Oestrup, *Navicula schroeterii* Meister และ *Bacillaria paradoxa* Gmelin พบไดอะตอมที่เป็นดัชนีบ่งชี้คุณภาพน้ำสะอาดได้แก่ *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Eunotia minor* (Kützing) Grunow และ *Gomphonema clevei* Fricke ซึ่งพบในบริเวณต้นน้ำ พบไดอะตอมที่

เป็นดัชนีบ่งชี้คุณภาพน้ำเสียได้แก่ *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Melosira varians* Agardh, *Gyrosigma scalproides* (Rabenhorst) Cleve และ *Bacillaria paradoxa* Gmelin คุณภาพน้ำในลำน้ำแม่สาเมื่อจัดตามความมากน้อยของสารอาหารพบว่ามีความแตกต่างกันทั้งในจุดเก็บตัวอย่างและฤดูกาลโดยอยู่ในระดับสารอาหารน้อย-ปานกลาง (oligotrophic-mesotrophic) จนกระทั่งถึงสารอาหารมาก (eutrophic)

ได้จัดทำ Diatom Index ของลำน้ำแม่สาโดยใช้โปรแกรมสถิติทางนิเวศวิทยา Multivariate Statistical Package (MVSP) เวอร์ชั่น 3.1 โดยเฉพาะ Principal Correspondence Analysis (PCA) และ Canonical Correspondence Analysis (CCA) ได้นำมาใช้ในการหาไดอะตอมชนิดที่สามารถบ่งชี้คุณภาพน้ำตามลำดับคะแนนสำหรับใช้ใน Mae Sa Diatom Index จำนวน 25 species และเมื่อนำมาใช้ประเมินคุณภาพน้ำในลำน้ำแม่สาพบว่าสามารถบ่งชี้คุณภาพน้ำได้อย่างเหมาะสมสอดคล้องกับคุณภาพน้ำทางกายภาพและเคมี แต่ยังต้องมีการศึกษาหาชนิดของไดอะตอมที่ใช้เป็นดัชนีเพิ่มขึ้นเพื่อให้ Diatom Index นี้มีประสิทธิภาพมากขึ้น

Thesis Title	Biodiversity of Benthic Diatoms and Their Application in Monitoring Water Quality of Mae Sa Stream Doi Suthep-Pui National Park Chiang Mai
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ABSTRACT

A study of the benthic diatom diversity and its application for use as indicator species to monitoring water quality in Mae Sa stream, Doi Suthep-Pui National Park, Chiang Mai was carried out from April 1998 to September 1999. Five sampling sites were located from upstream to downstream. Thirty four genera compiled with 278 species of diatoms were found, 51 species of which have never been recorded in Thailand before. The dominant species were *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Cocconeis placentula* Ehrenberg, *Gyrosigma scalproides* (Rabenhorst) Cleve, *Gomphonema parvulum* (Kützing) Kützing, *Achnanthes oblongella* Oestrup, *Navicula schroeterii* Meister and *Bacillaria paradoxa* Gmelin. The species of diatoms indicative of clean water and found upstream were *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Eunotia minor* (Kützing) Grunow and *Gomphonema clevei* Fricke.

The species indicated polluted water quality were *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Melosira varians* Agardh, *Gyrosigma scalproides* (Rabenhorst) Cleve and *Bacillaria paradoxa* Gmelin. The water quality of Mae Sa Stream could be classified into oligotrophic-mesotrophic to eutrophic depending on sampling site and seasonal changes.

The computer statistical package for ecological studies were employed to develope Mae Sa Diatom Index. Multivariate Statistical Package (MVSP) version 3.1 for window particularly Principal Correspondence Analysis (PCA) and Canonical Correspondence Analysis (CCA) were used to determine the indicator and dominant species. Twenty five species of diatoms were scored and listed in Mae Sa Diatom Index and could be properly used to indicate the physico-chemical property of water quality. However, more indicator species should be compiled for the more efficient used of Mae Sa Diatom Index.

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ABBREVIATIONS

Abbreviation of diatoms specie checklist

Species name	Code	Species name	Code
Achnanthes brevipes var. *intermedia* (Kützing) Cleve	Achbre	*Amphora coffeaeformis* (Agardh) Kützing var. *coffeaeformis*	Ampcof
Achnanthes chlidanos Hohn & Hellermann	Achchl	*Amphora dusenii* Brun	Ampdus
Achnanthes crenulata Grunow	Achcre	*Amphora libyca* Ehrenberg	Amplib
Achnanthes aff. *delicatula* ssp. *Hauckiana* (Grunow) Lange-Bertalot	Achdel	*Amphora ovalis* (Kützing) Kützing	Ampova
Achnanthes exigua Grunow var. *exigua*	Achexi	*Amphora pediculus* (Kützing) Grunow	Ampped
Achnanthes helvetica (Hustedt) Lange-Bertalot	Achhel	*Amphora* sp.1	Ampsp1
Achnanthes inflata (Kützing) Grunow	Achinf	*Amphora* sp.2	Ampsp2
Achnanthes lanceolata var. *boyei* (Oestrup) Lange-Bertalot	Achlbo	*Amphora* sp.3	Ampsp3
Achnanthes lanceolata var. *frequentissima* Lange-Bertalot	Achlfr	*Amphora* sp.4	Ampsp4
Achnanthes lanceolata var. *haynaldii* (Schaarschmidt) Cleve	Achlha	*Amphora* sp.5	Ampsp5
Achnanthes lanceolata var. *lanceolata* (Brébisson) Grunow	Achlla	*Amphora* sp.6	Ampsp6
Achnanthes lanceolata var. *rostrata* (Oestrup) Lange-Bertalot	Achlro	*Aulacoseira granulata* (Ehrenberg) Simonsen	Aulgra
Achnanthes minutissima Kützing	Achmin	*Bacillaria paradoxa* Gmelin	Bacpar
Achnanthes pusilla (Grunow) De Toni	Achpus	*Caloneis bacillum* (Grunow) Cleve	Calbac
Achnanthes oblongella Oestrup	Achobl	*Caloneis lauta* Carter & Bailey-Watts	Callau
Achnanthes pseudoswazi Carter	Achpse	*Caloneis silicula* (Ehrenberg) Cleve	Calsil
Achnanthes undata Meister	Achund	*Caloneis* sp.1	Calsp1
Achnanthes sp.1	Achsp1	*Caloneis* sp.2	Calsp2
Achnanthes sp.2	Achsp2	*Caloneis* sp.3	Calsp3
Achnanthes sp.3	Achsp3	*Caloneis* sp.4	Calsp4
Achnanthes sp.4	Achsp4	*Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow	Cocpeu
Achnanthes sp.5	Achsp5	*Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck	Cocpli
Achnanthes sp.6	Achsp6	*Cocconeis placentula* Ehrenberg var. *placentula*	Cocppl
Achnanthes sp.7	Achsp7	*Cocconeis placentula* var. *pseudolineata* Geitler	Cocpps
Achnanthes sp.8	Achsp8	*Craticula* sp.1	Crasp1
Achnanthes sp.9	Achsp9	*Cyclotella meneghiniana* Kützing	Cycmen
Achnanthes sp.10	Achsp10	*Cyclotella stelligera* Cleve & Grunow	Cycste
Achnanthes sp.11	Achsp11	*Cyclotella* sp.1	Cycsp1
Achnanthes sp.12	Achsp12	*Cyclotella* sp.2	Cycsp2
Actinocyclus normanii (Gregory) Hustedt	Actnor	*Cymatopleura solea* (Brébisson) W. Smith	Cymsol
Amphora aequalis Krammer	Ampaeq	*Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs	Cymsap

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Species name	Code	Species name	Code
Cymbella affinis Kützing	Cymaff	*Fragilaria elliptica* Schumann	Fraell
Cymbella amphicephala Naegeli	Cymamp	*Fragilaria lanceolata* (Kützing) Reichardt	Fralan
Cymbella hustedtii Krasske	Cymhus	*Fragilaria ulna* (Nitzsch) Lange-Bertalot	Frauln
Cymbella minuta Hilse	Cymmin	*Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot	Frauac
Cymbella naviculiformis (Auerswald) Cleve	Cymnav	*Fragilaria* sp.1	Frasp1
Cymbella tumida (Brébisson) Van Heurck	Cymtum	*Fragilaria* sp.2	Frasp2
Cymbella turgidula Grunow	Cymtur	*Fragilaria* sp.3	Frasp3
Cymbella sp.1	Cymsp1	*Frustulia rhomboides* (Ehrenberg) De Toni	Frurho
Cymbella sp.2	Cymsp2	*Frustulia weinholdii* Hustedt	Fruwei
Cymbella sp.3	Cymsp3	*Frustulia* sp.1	Frusp1
Cymbellopsis cf. *lanceolata* Krammer	Cymlan	*Frustulia* sp.2	Frusp2
Diatoma ehrenbergii Kützing	Diaehr	*Frustulia* sp.3	Frusp3
Diatoma moniliformis Kützing	Diamon	*Frustulia* sp.4	Frusp4
Diatoma vulgaris Bory	Diavul	*Gomphonema affine* Kützing	Gomaff
Diploneis elliptica (Kützing) Cleve	Dipell	*Gomphonema augur* Ehrenberg	Gomaug
Diploneis oblongella (Naegeli) Cleve-Euler	Dipobl	*Gomphonema augur* var. *turris* (Ehrenberg) Lange-Bertalotq	Gomatu
Diploneis ovalis (Hilse) Cleve	Dipova	*Gomphonema clevei* Fricke	Gomcle
Encyonema cf. *latereolatum* Krammer	Enclat	*Gomphonema gracile* Ehrenberg	Gomgra
Encyonema silesiacum (Bleisch) D. G. Mann	Encsil	*Gomphonema lingulatiforme* Lange-Bertalot & Reichardt	Gomlin
Encyonema sp.1	Encsp1	*Gomphonema minutum* (Agardh) Agardh	Gommin
Encyonema sp.2	Encsp2	*Gomphonema parvulum* (Kützing) Kützing	Gompar
Encyonema sp.3	Encsp3	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	Gompum
Encyonema sp.4	Encsp4	*Gomphonema truncatum* Ehrenberg	Gomtru
Encyonema sp.5	Encsp5	*Gomphonema* sp.1	Gomsp1
Epithemia sp.1	Episp1	*Gomphonema* sp.2	Gomsp2
Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris*	Eunbil	*Gomphonema* sp.3	Gomsp3
Eunotia minor (Kützing) Grunow	Eunmin	*Gomphonema* sp.4	Gomsp4
Eunotia soleirolii (Kützing) Rabenhorst	Eunsol	*Gomphonema* sp.5	Gomsp5
Eunotia sp.1	Eunsp1	*Gomphonema* sp.6	Gomsp6
Eunotia sp.2	Eunsp2	*Gomphonema* sp.7	Gomsp7
Eunotia sp.3	Eunsp3	*Gomphonema* sp.8	Gomsp8
Fragilaria biceps (Kützing) Lange-Bertalot	Frabic	*Gyrosigma scalproides* (Rabenhorst) Cleve	Gyrsca
Fragilaria bidens Heiberg	Frabid	*Gyrosigma spencerii* (Quekett) Griffith & Henfrey	Gyrspe

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Species name	Code	Species name	Code
Hantzschia amphioxys (Ehrenberg) Grunow	Hanamp	*Navicula* sp.4	Navsp4
Hantzschia distinctepunctata (Hustedt) Hustedt	Handis	*Navicula* sp.5	Navsp5
Melosira varians Agardh	Melvar	*Navicula* sp.6	Navsp6
Navicula bacillum Ehrenberg	Navbac	*Navicula* sp.7	Navsp7
Navicula clementis Grunow	Navcle	*Navicula* sp.8	Navsp8
Navicula concentrica Carter	Navcon	*Navicula* sp.9	Navsp9
Navicula cohnii (Hilse) Lange-Bertalot	Navcoh	*Navicula* sp.10	Navsp10
Navicula cryptotenella Lange-Bertalot	Navcry	*Navicula* sp.11	Navsp11
Navicula elginensis (Gregory) Ralfs var. *elginensis*	Navelg	*Navicula* sp.12	Navsp12
Navicula gastrum (Ehrenberg) Kützing var. *gastrum*	Navgas	*Navicula* sp.13	Navsp13
Navicula goeppertiana var. *dapaliformis* (Hustedt) Lange-Bertalot	Navgda	*Navicula* sp.14	Navsp14
Navicula goeppertiana var. *monita* (Hustedt) Lange-Bertalot	Navgmo	*Navicula* sp.15	Navsp15
Navicula insociabilis Krasske	Navins	*Navicula* sp.16	Navsp16
Navicula jaagii Meister	Navjaa	*Navicula* sp.17	Navsp17
Navicula laevissima Kützing var. *laevissima*	Navlae	*Navicula* sp.18	Navsp18
Navicula leptostriata Jørgensen	Navlep	*Navicula* sp.19	Navsp19
Navicula medioconvexa Hustedt	Navmed	*Navicula* sp.20	Navsp20
Navicula mobiliensis Boyer	Navmob	*Navicula* sp.21	Navsp21
Navicula mutica Kützing	Navmut	*Neidium affine* (Ehrenberg) Pfitzer	Neiaff
Navicula mutica Kützing var. *mutica*	Navmmu	*Neidium* cf. *affine* var. *humerus* Reimer	Neiahu
Navicula porifera var. *opportuna* (Hustedt) Lange-Bertalot	Navpor	*Neidium ampliatum* (Ehrenberg) Krammer	Neiamp
Navicula pupula var. *mutata* (Krasske) Hustedt	Navpup	*Neidium binodis* (Ehrenberg) Hustedt	Neibin
Navicula radiosa Kützing	Navrad	*Neidium gracile* Hustedt	Neigra
Navicula schroeterii Meister	Navsch	*Neidium iridis* (Ehrenberg) Cleve	Neiiri
Navicula subplacentula Hustedt	Navsub	*Neidium septentrionale* Cleve-Euler	Neisep
Navicula trivialis Lange-Bertalot	Navtri	*Neidium* sp.1	Neisp1
Navicula viridula var. *germainii* (Wallace) Lange-Bertalot	Navvgr	*Neidium* sp.2	Neisp2
Navicula viridula var. *linearis* Hustedt	Navvli	*Neidium* sp.3	Neisp3
Navicula viridula var. *rostellata* (Kützing) Cleve	Navvro		
Navicula viridula (Kützing) *Ehrenberg* var. *viridula*	Navvvi	*Neidium* sp.4	Neisp4
Navicula sp.1	Navsp1	*Neidium* sp.5	Neisp5
Navicula sp.2	Navsp2	*Neidium* sp.6	Neisp6
Navicula sp.3	Navsp3	*Nitzschia* cf. *acula* Hantzsch	Nitacu

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Species name	Code	Species name	Code
Nitzschia angustatula Lange-Bertalot	Nitang	*Pinnularia schoenfelderi* Krammer	Pinsch
Nitzschia bremensis Hustedt	Nitbre	*Pinnularia subgibba* Krammer	Pinsub
Nitzschia brevissima Grunow	Nitbrv	*Pinnularia subinterrupta* Krammer & Schroeter	Pinsui
Nitzschia capitellata Hustedt	Nitcap	*Pinnularia viridis* (Nitzsch) Ehrenberg	Pinvir
Nitzschia coarctata Grunow	Nitcoa	*Pinnularia* sp.1	Pinsp1
Nitzschia dissipata (Kützing) Grunow	Nitdis	*Pinnularia* sp.2	Pinsp2
Nitzschia dubia W. Smith	Nitdub	*Pinnularia* sp.3	Pinsp3
Nitzschia fonticola Grunow	Nitfon	*Pinnularia* sp.4	Pinsp4
Nitzschia fonticola var. *palagica* Hustedt	Nitfpa	*Pinnularia* sp.5	Pinsp5
Nitzschia geitleri Hustedt	Nitgei	*Pinnularia* sp.6	Pinsp6
Nitzschia hantzschiana Rabenhorst	Nithan	*Pinnularia* sp.7	Pinsp7
Nitzschia levidensis (W. Smith) Grunow var. *levidensis*	Nitlev	*Pinnularia* sp.8	Pinsp8
Nitzschia palea (Kützing) W. Smith	Nitpal	*Pinnularia* sp.9	Pinsp9
Nitzschia sigmoidea (Nitzsch) W. Smith	Nitsig	*Pinnularia* sp.10	Pinsp10
Nitzschia sublinearis	Nitsub	*Pinnularia* sp.11	Pinsp11
Nitzschia umbonata (Ehrenberg) Lange-Bertalot	Nitumb	*Reimeria sinuata* (Gregory) Kociolek & Stoermer	Reisin
Nitzschia sp.1	Nitsp1	*Rhopalodia acuminata* Krammer	Rhoacu
Nitzschia sp.2	Nitsp2	*Rhopalodia brebissonii* Krammer	Rhobre
Nitzschia sp.3	Nitsp3	*Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba*	Rhoggi
Nitzschia sp.4	Nitsp4	*Rhopalodia gibba* var. *parallela* (Grunow) Fryxell & Hasle	Rhogpa
Nitzschia sp.5	Nitsp5	*Rhopalodia gibberula* (Ehrenberg) O. Müller	Rhogib
Nitzschia sp.6	Nitsp6	*Rhopalodia rupestris* (W. Smith) Krammer	Rhorup
Nitzschia sp.7	Nitsp7	*Rhopalodia sorex* Kützing	Rhosor
Nitzschia sp.8	Nitsp8	*Rhopalodia* sp.1	Rhosp1
Nitzschia sp.9	Nitsp9	*Rhopalodia* sp.2	Rhosp2
Nitzschia sp.10	Nitsp10	*Rhopalodia* sp.3	Rhosp3
Nitzschia sp.11	Nitsp11	*Rhopalodia* sp.4	Rhosp4
Nitzschia sp.12	Nitsp12	*Sellaphora pupula* (Kützing) Mereschkowsky	Selpup
Nitzschia sp.13	Nitsp13	*Sellaphora* sp.1	Selsp1
Pinnularia acrosphaeria W. Smith	Pinacr	*Stauroneis anceps* Ehrenberg	Staanc
Pinnularia appendiculata (Agardh) Cleve	Pinapp	*Stauroneis smithii* Gronow	Stasmi
Pinnularia borealis var. *scalaris* (Ehrenberg) Rabenhorst	Pinbor	*Surirella angusta* Kützing	Surang
Pinnularia mesolepta (Ehrenberg) W. Smith	Pinmes	*Surirella bifrons* Ehrenberg	Surbif
Pinnularia platycephala (Ehrenberg) Cleve	Pinpla	*Surirella biseriata* Brébisson	Surbis

ABBREVIATIONS

Abbreviation of diatoms specie checklist

Species name	Code	Species name	Code
Surirella capronii Brébisson	Surcap	*Surirella* sp.4	Sursp4
Surirella elegans Ehrenberg	Surele	*Surirella* sp.5	Sursp5
Surirella ovalis Brébisson	Surova	*Surirella* sp.6	Sursp6
Surirella roba Leclercq	Surrob	*Surirella* sp.7	Sursp7
Surirella robusta Ehrenberg	Surrou	*Surirella* sp.8	Sursp8
Surirella spiraloides Hustedt	Surspi	*Surirella* sp.9	Sursp9
Surirella tenera Gregory	Surten	*Synedra lanceolata* Kützing	Synlan
Surirella sp.1	Sursp1	*Synedra ulna* (Nitzsch) Ehrenberg	Synuln
Surirella sp.2	Sursp2	*Synedra ulna* var. *aequalis* (Kützing) Hustedt	Synuae
Surirella sp.3	Sursp3	*Thalassiosira weissflogii* (Grunow) Fryxell & Hasle	Thawei

Environmental variable abbreviations

Environmental variable	Abbre.	Unit
Alkalinity	Alk	$mg.l^{-1}$ as $CaCO_3$
Biochemical Oxygen Demand	BOD	$mg.l^{-1}$
Conductivity	Cond	$\mu S.cm^{-1}$
Dissolved Oxygen	DO	$mg.l^{-1}$
Ammonium nitrogen	NH4	$\mu g.l^{-1}$
Nitrite nitrogen	NO2	$\mu g.l^{-1}$
Nitrate nitrogen	NO3	$\mu g.l^{-1}$
Total Dissolved solids	TDS	$mg.l^{-1}$
Water velocity	Vel	$m.sec^{-1}$
Water temperature	Temp	^{o}C

ABBREVIATIONS

List of sampling site and sampling period

Sampling site and period	Abbre.	Sampling site and period	Abbre.
Site 1 Month 1 (April 1998)	S1M1	Site 3 Month 10 (January 1999)	S3M10
Site 1 Month 2 (May 1998)	S1M2	Site 3 Month 11 (February 1999)	S3M11
Site 1 Month 3 (June 1998)	S1M3	Site 3 Month 12 (March 1999)	S3M12
Site 1 Month 4 (July 1998)	S1M4	Site 3 Month 13 (April 1999)	S3M13
Site 1 Month 5 (August 1998)	S1M5	Site 3 Month 14 (May 1999)	S3M14
Site 1 Month 6 (September 1998)	S1M6	Site 3 Month 15 (June 1999)	S3M15
Site 1 Month 7 (October 1998)	S1M7	Site 3 Month 16 (July 1999)	S3M16
Site 1 Month 8 (November 1998)	S1M8	Site 3 Month 17 (August 1999)	S3M17
Site 1 Month 9 (December 1998)	S1M9	Site 3 Month 18 (September 1999)	S3M18
Site 1 Month 10 (January 1999)	S1M10	Site 4 Month 1 (April 1998)	S4M1
Site 1 Month 11 (February 1999)	S1M11	Site 4 Month 2 (May 1998)	S4M2
Site 1 Month 12 (March 1999)	S1M12	Site 4 Month 3 (June 1998)	S4M3
Site 1 Month 13 (April 1999)	S1M13	Site 4 Month 4 (July 1998)	S4M4
Site 1 Month 14 (May 1999)	S1M14	Site 4 Month 5 (August 1998)	S4M5
Site 1 Month 15 (June 1999)	S1M15	Site 4 Month 6 (September 1998)	S4M6
Site 1 Month 16 (July 1999)	S1M16	Site 4 Month 7 (October 1998)	S4M7
Site 1 Month 17 (August 1999)	S1M17	Site 4 Month 8 (November 1998)	S4M8
Site 1 Month 18 (September 1999)	S1M18	Site 4 Month 9 (December 1998)	S4M9
Site 2 Month 1 (April 1998)	S2M1	Site 4 Month 10 (January 1999)	S4M10
Site 2 Month 2 (May 1998)	S2M2	Site 4 Month 11 (February 1999)	S4M11
Site 2 Month 3 (June 1998)	S2M3	Site 4 Month 12 (March 1999)	S4M12
Site 2 Month 4 (July 1998)	S2M4	Site 4 Month 13 (April 1999)	S4M13
Site 2 Month 5 (August 1998)	S2M5	Site 4 Month 14 (May 1999)	S4M14
Site 2 Month 6 (September 1998)	S2M6	Site 4 Month 15 (June 1999)	S4M15
Site 2 Month 7 (October 1998)	S2M7	Site 4 Month 16 (July 1999)	S4M16
Site 2 Month 8 (November 1998)	S2M8	Site 4 Month 17 (August 1999)	S4M17
Site 2 Month 9 (December 1998)	S2M9	Site 4 Month 18 (September 1999)	S4M18
Site 2 Month 10 (January 1999)	S2M10	Site 5 Month 1 (April 1998)	S5M1
Site 2 Month 11 (February 1999)	S2M11	Site 5 Month 2 (May 1998)	S5M2
Site 2 Month 12 (March 1999)	S2M12	Site 5 Month 3 (June 1998)	S5M3
Site 2 Month 13 (April 1999)	S2M13	Site 5 Month 4 (July 1998)	S5M4
Site 2 Month 14 (May 1999)	S2M14	Site 5 Month 5 (August 1998)	S5M5
Site 2 Month 15 (June 1999)	S2M15	Site 5 Month 6 (September 1998)	S5M6
Site 2 Month 16 (July 1999)	S2M16	Site 5 Month 7 (October 1998)	S5M7
Site 2 Month 17 (August 1999)	S2M17	Site 5 Month 8 (November 1998)	S5M8
Site 2 Month 18 (September 1999)	S2M18	Site 5 Month 9 (December 1998)	S5M9
Site 3 Month 1 (April 1998)	S3M1	Site 5 Month 10 (January 1999)	S5M10
Site 3 Month 2 (May 1998)	S3M2	Site 5 Month 11 (February 1999)	S5M11
Site 3 Month 3 (June 1998)	S3M3	Site 5 Month 12 (March 1999)	S5M12
Site 3 Month 4 (July 1998)	S3M4	Site 5 Month 13 (April 1999)	S5M13
Site 3 Month 5 (August 1998)	S3M5	Site 5 Month 14 (May 1999)	S5M14
Site 3 Month 6 (September 1998)	S3M6	Site 5 Month 15 (June 1999)	S5M15
Site 3 Month 7 (October 1998)	S3M7	Site 5 Month 16 (July 1999)	S5M16
Site 3 Month 8 (November 1998)	S3M8	Site 5 Month 17 (August 1999)	S5M17
Site 3 Month 9 (December 1998)	S3M9	Site 5 Month 18 (September 1999)	S5M18

ABBREVIATIONS

	Abbre.
Areolae	AR
Diameter	D
Diversity Index	DI
Fibulae	FI
Multivariate Statistical Package	MVSP
Puncta, Punctae	PU
Raphe	RA
Ribs	RI
Striae	ST
Saprobic Index	SI
Trophic Diatom Index	TDI

CHAPTER 1
INTRODUCTION

1.1 Diatoms as natural aquatic resources in ecosystem

Two-thirds of the earth's surface is covered by oceans and seas. In them live the photosynthetic organism, algae, which is attached to the bottom (benthic species), or live suspended in the water itself (planktonic species) (van den Hoek *et al.,* 1995). Algae are important as primary producers of elaborate organic materials, and thus play a critical role in the economy of the seas and freshwaters (Round, 1973). As estimated, about 90 percent of the total photosynthetic activity on our planet is performed by algae (Singh and Kashyap, 1978).

Diatoms are microscopic unicellular, sometimes colonial or pseudofilamentous algae (Lee, 1999) which range in size from approximately 5 μm to 500 μm and can live in any moist habitat, even on soils (Barber and Haworth, 1981). They are pigmented and photosynthetic eukuaryote, abundant in marine and freshwater habitat. In the oceans, diatoms form a major component of the plankton which is responsible for 40-45% of the total primary production on earth (Kelly, 2000).

In freshwater, diatoms are importance in river and stream ecosystem because of their fundamental role in food webs, oxygenation of surface waters and linkage in biogeochemical cycles. As one of the species-rich components of river and stream communities, diatoms are important elements of biodiversity and genetic resources in rivers and streams.

The division Bacillariophyta belongs to the diatoms and is characterized by an exquisitely sculptured part of the cell wall, in term frustule, composed of silica, which is highly resistant to degradation, usually remaining long after the death of the cell and decay of its organic contents (Barber and Haworth, 1981). The terms diatomaceous earth or diatomite are used to define the fossils.

Diatomite have been applied in 300 to 500 commercial applications. (Schroeder, 1970; Durham, 1973 cited by Harwood,1999). Principle uses include filtration, insulation, fine abrasion, absorption, building materials, mineral filters, catalysts, carriers, coatings and also as a pesticide, food additive and anti-caking agent. Diverse industrials make use of diatomite-food in beverages, pharmaceuticals, chemicals, paints, plastics, paper, construction, drycleaning, recreation, sewage treatment and in the field of agriculture among many other uses (Cummins, 1975 cited by Harwood,1999).

Diatoms are being used increasingly in a wide range of applications, and the number of diatomists and their publications continues to increase rapidly. An application aspect of algae, especially diatoms group, is that they are important indicators of pollution in aquatic habitats. Diatoms are valuable indicators of environmental conditions in rivers and streams, because they respond directly and sensitively to many physical, chemical, and biological changes in river and stream ecosystems, such as nutrient concentrations. The sensitivity of diatoms to so many habitat conditions can make them highly valuable indicators, particularly if effects of specific factors can be distinguished. Knowing the hierarchical relations among factor effects will help to make diatom indicators more precise.

Diatom play a small but important part in the ecosystem and were defined as a valuable natural aquatic resources in ecosystem.

1.2 Diversity of diatoms and the use as bioindicator

Diatoms are abundant in marine and freshwater habitats, in the benthos, and as epiphytes on large algae or higher plants. About 12,000 species of diatoms, belonging to over 250 genera, have been described from marine, freshwater and terrestrial habitats so far, but there may be as many as 100,000 species in total (van den Hoek *et al.,* 1995). About 80 genera are likely to be encountered in temperate freshwaters, where they are found both suspended in the water as plankton or living as part of the benthos on the bottom and other surfaces.

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 and Wynne, 1985). Benthic diatoms could be used successfully in practical work. The diatom indices are based on diatom composition. These give more precise and valid predictions than benthic macroinvertebrates because they react directly to organic pollutants (Whitton *et al.*, 1991).

The first and most essential criteria in using benthic diatom to monitor the water quality in the river is the group of organisms used. The suitable group of organisms should be present throughout the river, growing in a specific well-defined habitat, easily sampled and present in abundance, found in the river at all stages of life cycles, highly sensitive and rapidly react to water chemistry changes, largely cosmopolitan in distribution and have a well-studied taxonomy and ecology (Round, 1991). Diatoms have one of the shortest generation times of all biological indicators. They reproduce and respond rapidly to environmental change and provide early warning indicators of both pollution increase and habitat restoration success. Diatoms can be found in almost all aquatic habitats, so that the same group of organisms can be used for comparison of streams, lakes, wetlands, oceans, esturies and even some ephemeral aquatic habitats. Diatoms can be found on substrata in streams, even when the stream is dry, so they can be sampled at most times of the year (Stoermer and Smol, 1999).

Diatoms have been extensively used as indicators of environmenntal changes e.g. eutrophication, acidification, metal contamination, salinification, thermal effluents, forest fires and land use changes. A variety of indices have been proposed to quantify some of these relationships (Dixit *et al.*, 1992).

Routine biological monitoring is carried out in many countries (Europe and United State) to complement or supplement chemical monitoring in order to assess pollution for example van Dam works in the low land freshwater in the Netherlands (van Dam *et al.,* 1994) and Rott works in stream and river in Austria (Rott *et al.,* 1997).

For Thailand, the status of phytoplankton and benthic algae study is in 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 details.

Most work concern with algae in Thailand is on plankton and most research done in lakes and reservoirs. As mention, benthic algae are more significant in river than in lakes. This research was conducted in stream ecosystem. Mae Sa Stream was investigated for benthic diatom diversity and their changes in composition. The Trophic Diatoms Index (TDI) of European were applied to monitoring water qualities. in this stream. The attempt to develop Mae Sa Index was established.

1.3 Purposes of the Study

1. To investigate biodiversity of benthic diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai.
2. To study the species distribution and changes of species composition of benthic diatoms community in relation to water quality.
3. To study some physical and chemical parameters of water quality and assess the trophic status.
4. To apply the diatom index for assessing the trophic status of the stream for the water quality monitoring.
5. To extend the knowledge of biodiversity in Thailand

Chapter 2
Literature Reviews

2.1 Diversity of algae

Biodiversity refers to the variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species, to arrays of genera, families and still higher taxonomic levels. It includes the variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live (Wilson, 1988).

Algae belong to a highly diverse group of photoautotrophic organisms with chlorophyll-a and unicellular reproductive structures that have important functions in aquatic habitats. By various taxonomic schemes, the number of algal divisions range from 4 to 13, with as many as 24 classes, and about 26,000 species (Bold and Wynne, 1985). Algae range in size from microscopic singles cells to seaweeds, sometimes reaching 30 m in length. They show considerable variation in their cellular structures, in the arrangement of their cells to form multicellular bodies or thalli, and in their pigments for photosynthesis (Sze, 1986).

The number of recognized species probably greatly underestimates the actual number of species because many habitats and regions have not been extensively sampled and many algae are very small and hard to distinguish from each other. There is no accurate estimate of the number of diatom species. Estimates on the order of 10,000 are given by Guillard and Kilham, and Mann and Droop point out that this estimate would be raised to at least 100,000 by the application of modern species concepts (Stoermer and Smol, 1999).

An approximate number of diatoms was given by van den Hoek *et al.,* there may be as many as 100,000 species in total, about 12,000 species of diatoms, belonging to over 250 genera, have been described from marine, freshwater and terrestrial habitats (van den Hoek *et al.,* 1995).

Diatoms are important components of many algal communities. They are common in both marine and freshwaters, as parts of benthic and planktonic communities. These groups are widespread and vary in both morphologic and ecologic diversity.

2.2 The study of diatoms

Diatoms are photosynthetic eukaryote, although some at least can live heterotrophically in the dark if supplied with a suitable source of organic carbon (Round *et al.*, 1990). The chloroplasts of diatoms are olive green to brown in colour and possess chlorophylls a and c with fucoxanthin and acetylenic carotenoids (Chapman and Chapman, 1973). Daitoms contain alpha, beta and epsilon carotene (Trainor, 1978; van den Hoek *et al.*, 1995) and several xanthophylls, with diatoxanthin as the dominant one. They also contain the xanthophylls fucoxanthin and diadinoxanthin (Trainor, 1978; van den Hoek *et al.*, 1995). Attached diatoms can be characterized by the brown scum found on various kinds of substrata, as well as the fluffy brown growths caused by abundant epiphytic diatoms (Lee, 1980). Epilithic diatoms grow on hard, relatively inert substrata, such as gravel, pebbles, cobbles and boulders. Diatoms growing on inorganic or organic sediments are called epipellic (Stevenson *et al.*, 1996).

The diatoms are generally classified into two orders, the Pennales and Centrales. The Pennales are characterized by a bilateral symetry, their gliding motion and sexual reproduction by an amoeboid isogammy. The Centrales are radially symetrical, lack the gliding motion and demonstrate anisogamy or oogamy with motile male gametes (Chapman and Chapman, 1973).

The structure of diatom frustules has been investigated in great detail with light and electron microscopy. The classification of diatoms are almost entirely based upon the structure and ornamentation of the cell wall. The diatoms are generally classified into two orders, the Pennales and Centrales. Centrales, or Centric diatoms, are typically round but take on a variety of interesting and beautiful shapes. Pennales, or Pennate diatoms, may be long or pen-shaped, or may be broadened in the middle until almost round. Unlike Centrales they have bilateral symmetry; their valve is composed of two mirror-image halves. They will typically have a raphe or groove usually lined with cilia down one side. The broad lines of splitting Pennate diatoms are easily defined by the frustule structures and the form and positioning of the raphe (Chapman and Chapman, 1973; Dodge, 1973; Round, 1973; Werner, 1977; Singh and Kashyap, 1978; Lee, 1980; Barber and Haworth, 1981; Dixit *et al.*, 1992 and Cox, 1996).

Diatoms are interesting organisms, the first description of diatoms occurred in the latter half of the 18th century and were given Latin binomials. The work of O. F. Müller is worth a special mention because it was one of his species *Vibrio paxillifer*, that served as the first recorded diatom genus *Bacillaria* Gmelin. To Müller, *V. paxillifer* and the other *Vibrio* species were animals; he called them animalcula infusoria. Müller recorded *Vibrio paxillifer* into the same classification as ciliates, amoeba, *Volvox*, dinoflagellates (Round *et. al.*, 1990). The serious study of diatoms began early in the 19th century, with work by Ehrenberg, Ralfs, Kützing and W. Smith and was continued by numerous others, including Grunow, Cleve, Schmidt, van Heurck and Cleve-Euler. During the 20th century Hustedt published many works concerning freshwater diatom floras, mainly in German; only two of his publications are in English. Foged has also produced numerous works identifying diatoms, including "Freshwater Diatoms in Thailand" in 1971 (Barber and Haworth, 1981).

The history of ecological studies centering on diatoms can be roughly categorized as consisting of three eras. The first era is of exploration (1830-1900), inwhich most research focused on diatoms as objects of study. Work during this period was largely descriptive, be it the topic the discovery of new taxa, or the discovery of their life cycles and basic physiology. This was the basic information concerning the concept of indicator species. The second era is the era of systematization (1900-1970), which developed the basic information necessary to create the simple indices for predicting environmental conditions (halobion, saprobion, pH, temperature, etc.).

The current era is focusing on diatoms as the age of objectification, which given the computational tools now generally available, it is possible to more accurately determine which variables affect diatom occurrence and growth and more importantly, do so quantitatively, reproductively, and with measurable precision. Thus, applied studies based on diatoms have been used as powerful tools which can interpret many ecological and practical problems (Stoermer amd Smol, 1999).

2.3 The study of diatoms in Thailand

The diatom flora of Thailand has been investigated by foreign scientists for a hundred years from a checklist of algae in Thailand published by Lewmanomont *et al.* in 1995 . The checklist of algae has been prepared through a compilation of various publications including survey reports, scientific papers and results from the Environment Impact Assessment supported by the Office of Environmental Policy and Planning (OEPP) and Danish Cooperation on Environment and the Development (DANCED) (Lewmanomont *et. al.*, 1995).

The checklist of the Algae in Thailand was compiled from 53 publications, lists 161 genera, 1001 species, 287 varieties and 63 forms. The checklist reported marine algae and freshwater algae separately. The diatom flora was recorded in Division Chromophyta Class Bacillariophyceae. 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 in 1902 recorded 81 different diatom from the island of Koh Chang in the Gulf of Thailand (Östrup, 1902). The material was collected by a Danish Expedition to Thailand during 1899–1900.

Patrick in 1936 reported a total of 185 diatom species in the study of the intestinal contents of tadpoles from Thailand and the Federal Malay States (Patrick, 1936). From 1961–1962, the material collected by the Joint Thai-Japanese Biological Expedition to Southeast Asia was identified by Hirano. In 1967 he published an account of 143 diatom species, 114 of them were found in the samples from Thailand.

Most of these samples were collected in the Chiang Mai area and the others from localities in the central and southern parts of Thailand (Hirano, 1967).

In freshwater samples collected by Foged in 1966 in central and northern parts of Thailand, about 378 taxa were recorded and published in his work. Among these, 8 new species, 5 new varieties and 2 new forms were additionally recorded (Foged, 1971).

From 1971 to date, Thai scientists also worked on diatoms but not as intensively as before. Most work has been done on plankton and reported in "The Status of Phytoplankton Diversity in Thailand" (Wongrat, 1998). The material studied was collected from all parts of Thailand but mostly from the northern and northeastern parts of the country, such as Ph.D. thesis works of Peerapornpisal in 1996 which studied phytoplankton included planktonic diatoms in the reservoirs of Huai Hong Khrai Royal Development Study Centre in Chiang Mai Province (Peerapornpisal, 1996). In 1999, she continued her work concern with water quality and phytoplankton distribution in the reservoir of Mae Kuang Udomtara Dam, Chiang Mai. The phytoplankton included diatoms which were investigated during August 1996 to January 1998 (Peerapornpisal *et al.*, 1999). The diversity of phytoplankton and benthic algae in a Mae Sa stream, Doi Suthep-Pui National Park were investigated during April 1997 to February 1998 by Peerapornpisal, *et al.* From the results it was implied that the majority of phytoplankton and benthic algae were diatoms (Peerapornpisal *et al.*, 2000). With the same stream Pekthong and Peerapornpisal reported fifty one newly recorded species of freshwater diatoms for Thailand (Pekthong and Peerapornpisal, 2001).

There were also some studies about phytoplankton and benthic algae from Chiang Mai. Pekthong (1998) reported 87 species of phytoplankton and 172 species of benthic algae in the Mae Sa stream, Doi Suthep-Pui National Park, Chiang Mai. Waiyaka (1998) report 102 species of phytoplankton and 106 species of benthic algae in the same stream. Diatoms were found to be the majority of phytoplankton and benthic algae of both studies.

The study of the relationship between diatoms and water runoff was conducted by Hempattarasuwon in 2001. The diversity of the diatoms in the Pasak river was investigated during February to September 2000 (Hempattarasuwon, 2001). Another research project by a Thai scientist is the publication of Fungladda *et al.* in 1983 which was conducted in the Hawaiian islands. The diversity of diatoms were investigated from five major Hawaiian islands from 1980 to 1982 (Fungladda *et al.*, 1983).

Among the additional records for Thailand from 1971 to date, works on diatoms have been carried out by Thai scientists in various universities and institutions, however, these research are not in-depth. Most of these works are studies of plankton made by Lewmanomont and her staff (Lewmanomont *et al.*, 1995).

The general availability of electron microscopes opened new orders of magnitude in the resolution of the structure of diatoms , which made it obvious that many of the older, radically condensed, classification schemes were untenable. This released a virtual flood of new, rediscovered and reinterpreted entities which continues to grow today (Round, *et al.*, 1990) and helps to distinguish related species for establishing a new genera or taxa (Lange-Bertalot, 1993).

There were some works in Thailand related to the use of electron microscopes for morphological investigation of diatoms, for example the research work of Pekthong and Peerapornpisal in 1998, 1999 and 2002.

The study of the morphology of diatoms under scanning electron microscopes for species identification and the scanning electron micrographs of freshwater diatoms in diatomite from Lampang Province, Thailand were published in the Journal of Electron Microscopy Society of Thailand (Pekthong and Peerapornpisal, 1998, 1999, 2002). There are also unpublished works by Chamnansilp concerning the preparation of diatoms for light and scanning electron microscope from Kasetsart University (Chamnansilp, unpublish).

Further more, there are some works in Thai about the used of diatom in aquaculture for feeding molluscs and crustaceans, reported by Powtongsook in 2001 and published in the report submitted to the Thailand Research Fund under the title "Utilisation of Algae: A Research and Development Potential in Thailand". They use *Chaetoceros muelleri* Lemmermen, *Chaetoceros calcitrans* Paulsen, *Skeletonema costatum* (Greville) Cleve, *Thalassiosira pseudonana* Hasle & Heimdal, and many species of *Nitzschia* spp. and *Navicula* spp. to feed molluscs and crustacean (Powtongsook, 2001).

Several ongoing projects on the diversity of phytoplankton are presently underway in Thailand. Most projects are supported by Research Organizations in Thailand, particularly the Program for Biodiversity Research & Training (BRT) financed by the National Center for Engineering & Biotechnology. These research studies will extend knowledge on the diversity of freshwater algae in Thailand, by Thai scientists.

BRT was supported by the Thailand Research Fund (TRF), the National Center for Genetic Engineering and Biotechnology, and the National Science and Technology Development Agency (BIOTEC/NSTDA). Its objectives are to develop the potential of young researchers such that they can apply their skills to produce quality biodiversity research and also focus on educating others about the need for bioresource conservation, and lay the foundation for future research.

According to the reports, it is obvious that Thailand makes slow progress in freshwater algae biodiversity studies. If we consider the aquatic environment more intimately, we shall see that the most important producers are algae in either planktonic or benthic forms. Therefore, extensive biodiversity study of freshwater algae is urgently needed as supporting knowledge for all biological sciences and for the development of the country as well.

2.4 Classification of diatoms

The diatoms in this thesis are arranged following the classification of Simonsen (1979) cited by Krammer and Lange-Bertalot (1986) which divides the

Bacillariophyta into 2 Order, Centrales and Pennales. All genera are listed below (Table 1), and represent only presented genera in this thesis.

Table 1 Classification of diatoms

Division	Orders	Suborders	Families	Genera
Bacillariophyta				
	Centrales			
		Coscinodiscineae		
			Thalassiosira	
				Aulacoseira
				Cyclotella
				Thalassiosira
			Melosiraceae	
				Melosira
			Hemidiscaceae	
				Actinocyclus
	Pennales			
		Araphidineae		
			Fragilariaceae	
				Diatoma
				Fragilaria
				Synedra
		Raphidineae		
			Eunotiaceae	
				Eunotia
			Achnanthaceae	
				Achnanthes
				Cocconeis
			Naviculaceae	
				Amphora
				Caloneis
				Craticula
				Cymbella
				Cymbellopsis
				Diploneis
				Encyonema
				Frustulia
				Gomphonema
				Gyrosigma
				Navicula
				Neidium
				Pinnularia
				Reimeria
				Sellaphora
				Stauroneis
			Epithemiaceae	
				Epithemia
				Rhopalodia
			Bacillariaceae	
				Bacillaria
				Hantzschia
				Nitzschia
			Surirellaceae	
				Cymatopleura
				Surirella

2.5 Trophic Diatom Index (TDI)

The observation of the changing of the diatom communities from different conditions are significant in determining the indicator species and have been developed into indices that are used for routine water quality monitoring (Kelly, 2000). The use of indices based on benthic communities, especially diatoms has been applied widely (Whitton and Kelly, 1995).

Benthic algae refers to algae living on the bottom of water environments or associated with substrata in aquatic habitats. Benthic algal communities are usually species-rich relative to other aquatic groups. A few square centimeters of substratum may support in excess of 100 different species of algae. Each species has its own set of environmental tolerances and preferences. Thus, the entire assemblage represents an information-rich system for environmental monitoring. Benthic algae are on the substrate surface, thus unable to avoid potential pollutants through migration. Moreover, their relatively short life cycles cause a rapid response to the shifts in environmental conditions. For these reasons, they must either tolerate their surrounding abiotic environment or perish.

The first and most essential criteria in using benthic diatom to monitor the water quality in the river, is the specific group of organisms used in the monitoring procedure. The suitable group of organisms should be present throughout the river, grow in a specific well-defined habitat, are easily sampled, and present in abundance, are found in the river at all stages of the cycle life, must be highly sensitive and rapidly react to water chemistry changes, largely cosmopolitan in distribution and have a well-studied taxonomy and ecology (Round, 1991).

There are many applications of taxonomic information of algae, specifically the diatoms group. As the bioindicators, algae were used to indicate the trophic status of a lake or river. Biological methods are used for monitoring water quality for a variety of reasons, most of which have been well documented (e.g. Hellawell, 1978 cited by Whitton *et al.*, 1991). Routine biological monitoring is carried out in many rivers to complement or supplement chemical monitoring in order to assess pollution.

For instance, straightforward use of the saprobien system provides data about organic pollution parallel to the data produced from water chemistry. Saprobic index (SI) values are available for most common algae species which thrive in flowing waters. Benthic diatoms have an advantage over most other algal groups in that their taxonomy has been better studied. The diatom index based on benthic diatom composition give more precise and valid predictions because they react directly to organic pollutants. Diatoms have been extensively used as indicators of environmental changes e.g. eutrophication, acidification, metal contamination, salinification, thermal effluents, forest fires and land use changes (Dixit *et al.*, 1992). Diatoms are sensitive to many environmental variables, including light, moisture levels, temperature, current velocity, salinity, pH, oxygen concentration, inorganic nutrients (carbon, phosphorus, nitrogen, silica), and organic nitrogen (van Dam *et al.*, 1994).

Being the main primary producers of most rivers in temperate regions, the algae have been used for monitoring environmental contamination or long term change. Many countries such as Austria, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom use algae to monitor environmental change. (Whitton *et al.*, 1991).

There are some studies on the biodiversity of diatoms and their applications for monitoring the water quality such as Pfister in 1992 which studied the phytobenthos of 2 natural, fast flowing mountain streams in Tyrol. The main subject covered in this paper is the taxonomy of diatoms as the group of algae with the highest number of species, 163 taxa of diatoms had been found. The largest part of the species is well known from oligosaprobic, nutrient poor, fast flowing mountian streams in the Alps (Pfister, 1992).

Schiefele and Kohmann in 1993 assessed the trophic state of running waters and developed a trophic index with chemical, physical and biological (diatom) data from 31 different sampling sites of 5 western German aquatic habitats. In total 389 different diatom taxa were found. It was possible to classify 105 of them according to their tolerance of ammonia, nitrate, phosphate and total phosphorus. Applying these classifications of salgae it is possible to value the trophic states of rivers and streams.The Trophic Diatom Index (TDI) has seven classes. The aim of this new index is to complement the German Saprobic System, which indicates the degree of organic pollution in running water and the biological oxygen demand. The Trophic Diatom Index is the trophic counterpart of the Saprobic Index (SI) (Schiefele and Kohmann, 1993).

Prygiel and Coste, in 1993, applied six diatom indices to evaluate water quality in the Artois-Picardie water basin in France. These were the Specific Pollution Sensitivity Index (SPI), the Generic Diatom Index (GDI), Descy's Index (DES), Slá deček's Index (SLA), Leclercq & Maquet's Index (LMI) and the Commission for Economical Community Index (CEC). Results show that all of them satisfactorily assess organic pollution which is the main phenomenon responsible for the degradation of water quality throughout the year. However, only the SPI, GDI and CEC indexes show significant correlations with ion strength (expressed by chlorides, sulphate and conductivity) and eutrophication (expressed by chlorophylle and nitrates) (Prygiel and Coste, 1993).

Furthermore, they represent the antagonistic production (trophic state) and decomposition (saprobic state) processes. Benavides in 1994 also used diatoms for assessing the trophic status of the river. She studied the epilithic diatom communities of a polluted river (Rio Grand de Tarcoles basin) and of an unpolluted river (Rio Savegre) in the Central and Southern part of Costa Rica. The taxonomy of diatoms and the most abundant group of algae found in both rivers is discussed. Altogether 125 diatom taxa were identified in the periphyton communities of these two rivers. The investigation has been done to look for the species list of diatoms which are characterised as tolerant towards organic pollution, eutrophication and high turbidity (Benavides, 1994).

In July 1986 Eloranta began monitoring 56 fast flowing rivers in Finland and published his finding of analyse diatom communities in 1994 using "Omnidia" software which calculates, besides other variables, eight different pollution indices as follows: Specific Pollution Sensitivity Index (SPI), Sládeček's Index, Generic Diatom Index (GDI), Schiefele & Schreiner's Index and Watanabe's Index (Eloranta, 1994).

And the list of diatom species preferred nitrogen poor waters that were clear and unpolluted. Similarly, Rott in 1995 studied the diatoms from the Grand River, in Ontario, Canada in the spring and summer of 1994 from headwaters at approximately 500 m altitude down to the sites near the mount on Lake Erie at 380 m.

Altogether 138 taxa were found these was in contrast to an earlier investigation where species numbers increased downstream. This actual investigation shows a clear separation of the benthic diatom flora into three zones. Firstly, an oligotrophic flora with some components typical of those flora found in mountain streams at the uppermost reaches. Secondly, a flora typical of enriched rivers in the middle section and lastly, a flora with components typical of silted, well buffered, lowland waters usually near the river mouth. Compared to the results of the earlier study almost 70% of the taxa were recorded. The remaining 30% include both taxa difficult to identify, and taxa which indicate the progressing nutrient enrichment of the river (Rott, 1995).

A brief account is given of the methods developed for use of algae to monitor rivers and streams. The methods fall broadly into those based on features of populations of representative species, those based on part or all of the whole photosynthetic community and those based on various types of bioassay and ecotoxicological test. Among community-based methods for monitoring, the measurement of biomass is used widely for phytoplankton, but seems of little use for benthos. The use of indices based on benthic communities, especially diatoms, has, however, been applied widely. The earlier indices based on diversity have been replaced almost entirely by ones integrating ecological information from component species. (Whitton and Kelly, 1995)

For the method of data evaluation, there are 5 steps to evaluate the data. They are as follows:

1.) Using the number of individuals counted per species from an established species list.

2.) Calculating relative abundance of species from the formula below:

$$\text{Relative abundance} = \frac{\text{Number of individuals} \times 100}{\text{Sum of individuals}}$$

3.) By refering to species classifications in previosly compiled indicator species lists. There are many indicator species lists that can be used for data evaluations. Such as the indicator species list of Krammer & Lange-Bertalot (1986) and Rott *et.al.* (1997) which can be used to evaluate the saprobic water quality class, Schiefele & Kohmann (1993), van Dam *et al.* (1994) and Pipp (1997) for evaluating trophic state as well as other environmental conditions.

4.) Calculating sample classification from species classifications by using the following formula:

$$ID = \frac{\Sigma\, a_j i_j v_j}{\Sigma\, a_j v_j}$$

(i) = sensitivity classes

(v) = indicator value groups

(a) = relative abundance

(Zelinka & Marvar, 1961 cited by Eloranta, 1994)

5.) By referencing the level of human impact indicated by sample classification.

2.5.1 Trophic index of Schiefele and Kohmann (Schiefele and Kohmann, 1993)

The trophic index of Schiefele and Kohmann published in 1993 is used to classify the trophic state by using the indicator weight evaluation method. Their works were developed from the study of mainly calcareous streams and rivers in Germany. The broad tolerance range euryoecious species will have a low indicator weight value and as a result be a bad indicator. The narrow tolerance range stenoecious species will have a high indicator weight value and as a result be a good indicator. Good indicators are given more influence on the sample index.

Calculate sample index by using the formula below:

$$\text{Sample index} = \frac{\sum \text{Rel.Abund. X Index X Indicator weight}}{\sum \text{Rel.Abund. X Indicator weight}}$$

From the formula, multiply the relative abundance of each species (except those without index value) with its indicator weight. Calculate the sum of these equations and multiply the relative abundance of each species with its index and with its indicator weight. Calculate the sum of these equations and then, divide the sum of abundances multiplied by indices times the indicator weight, by the sum of the abundances multiplied by the indicator weight. Look up the saprobic water quality class or the trophic level in the lists belows:

Table 2 Trophic state list of Schiefele and Kohmann Trophic Index

Sample index	Trophic state	Level of impact
1.0 - 1.4	oligotrophic	no impact
1.5 - 1.8	oligo- to mesotrophic	little impact
1.9 - 2.2	mesotrophic	distinct impact
2.3 - 2.7	meso- to eutrophic	critical impact
2.8 - 3.1	eutrophic	significant impact
3.2 - 3.5	eu- to hypereutrophic	strong impact
3.6 - 4.0	hypereutrophic	very strong impact

*** indicator weights from 1 - 7

MIP = Index base on total phosphorous only

WIP = corresponding indicator weights

MIPN = Index base on total phosphorous , nitrate and ammonia

WIPN = corresponding indicator weights

2.5.2 Trophic index of van Dam (van Dam *et al.*, 1994)

The trophic index of van Dam published in 1994 is also use to classify the trophic state by using indicator weight evaluation. Their works were developed from the study of low land freshwater sites in the Netherlands.

Calculate the sample index from the formula below:

$$\text{Sample index} = \frac{\sum \text{Rel.Abund.X Index}}{\sum \text{Rel.Abund.}}$$

Calculate the sum of the relative abundances of all species except those without index value or with index value 7 and then multiply the relative abundance of each species with its index. Calculate the sum of these products and divide the sum of abundances times indices by the sum of the abundances. Look up the trophic level in the list, that follows.

Table 3 Trophic state list of van Dam Trophic Index

Categories	Species	Sample index	Trophic State
1	oligotraphentic	1.0 - 1.5	oligotrophic
2	oligo-mesotraphentic	1.5 - 2.5	oligo-mesotrophic
3	mesotraphentic	2.5 - 3.5	mesotrophic
4	meso-eutraphentic	3.5 - 4.5	meso-eutrophic
5	eutraphentic	4.5 - 5.5	eutrophic
6	hypereutraphentic	5.5 - 6.0	hypereutrophic
7	indifferent		

2.5.3 Saprobic index of Rott *et al.* (Rott *et al.*, 1997)

The methods of index and indicator weight were also used in the saprobic water quality classification of Rott *et al.* in 1997. Their works were developed from the study of streams and rivers in Austria. Calculate the sample index by using the same formula of van Dam in 1994, but with a different reference list, as shown below.

Table 4. Trophic state list of Rott *et al.* Saprobic Index

Sample index	Categories	water Quality class	Saprobic level
< 1.3	I or better	-no or very little impact	oligosaprobic
1.4 - 1.7	I - II	-little impact	oligo- to betamesosaprobic
1.8 - 2.1	II	-moderate impact	betamesosaprobic
2.2 - 2.5	II - III	-moderate to strong impact	beta- to alphamesosaprobic
2.6 - 3.0	III	-strong impact	alphamesosaprobic
3.1 - 3.4	III - IV	-strong to very strong impact	alphameso- to polysaprobic
>3.5	IV	-very strong impact	polysaprobic

2.6 Multivariate Statistical Package (MVSP)

The environmental variables from the Mae Sa Stream sampling sites were statistically examined and transformation was applied when necessary to improve normality. The physico-chemical parameters of each sampling site were compared by univariate analyzes, parametric statistical analysis (one-way ANOVA and LSD test) had been used.

Multivariate techniques are available in MVSP program for windows version 3.1 developed by Kovach Computing Services (KCS) company. Details of each method are as follows:

2.6.1 Principal Components Analysis (PCA)

The assessment of algal response to pollution, especially to non-point source pollution, may require more sophisticated multivariate statistical approaches such as ordination. Ordination, such as PCA arrange sites along axes according to species composition. The end product of ordination is a few dimensions (often two or three) graphical summary of species data. The sites with similar species composition are close together in the ordination diagram (Lowe and Pan, 1996).

PCA is one of the best known and earliest ordination methods, first described by Karl Pearson in 1901. Mathematically, PCA consists of an eigenanalysis of a covariance or correlation matrix calculated on the original measurement data. Graphically, it can be described as a rotation of a swarm of data points in multidimensional space so that the longest axis (the axis with the greatest variance) is the first PCA axis, the second longest axis perpendicular to the first is the second PCA axis, and so forth. Thus these first few PCA axes represent the greatest amount of variation in the data set and contain some patterns of significance.

2.6.2 Canonical Correspondence Analysis (CCA)

One of the most commonly used approaches to constrained ordination is CCA. CCA incorporates ordination and multiple regression into one technique. CCA does exactly the same thing as ordination, but with the axes constrained to be linear combinations of environmental variables. Such analysis is also refered to as direct gradient analysis, incontrast to PCA, which are two-step indirect gradient analyses. CCA is extremely powerful for detecting patterns of species distribution related to associated physical and chemical parameters (Lowe and Pan, 1996).

CCA is a multivariate direct gradient analysis method that has become very widely used in ecology. This method is derived from correspondence analysis. It is calculated using the reciprocal averaging form of correspondence analysis. All the other ordination methods in MVSP are indirect gradient analysis methods. In these, the data are subjected to some type of mathematical manipulation in order to reveal the most important trends in the data. These trends are then often compared to other data relating to the same samples to determine are relationship between the two.

The results of CCA can be presented in a diagram contain the environmental variables plotted as arrows emanating from the center of the graph, along with points for the samples and taxa. The relationships between the samples and species are as in CA. The arrows representing the environmental variables indicate the direction of maximum change of that variable across the diagram. The position of the species points indicates the environmental preference of the species.

Barnett studied pollution of River Derwent to assess eutrophication of the river and to test the Trophic Diatom Index. The collected data was processed in many ways. The raw data of the cell counts of diatom were put into the Multivariate Statistical Package (MVSP). This was to find similarities between the sample sites, and which species of diatoms were dominant. This was done using Cluster analysis and Principal Component Analysis (PCA) (Barnett, 2000).

2.6.3 Diversity Indices

There are three diversity indices commonly used in ecology, Simpson's, Shannon's, and Brillouin's. The formula for Shannon Diversity Indice are as follow:

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

Where H'= Shannon's diversity Index

pi = Proportion of species i in the community

s = Number of species

2.7 Mae Sa Stream

Research was conducted at the Mae Sa Stream located in Mae Sa Watershed which is situated in the Mae Rim District of Chiang Mai Province. Part of the watershed belongs to Doi Suthep–Pui National Park, which is one of the world's largest area of biodiversity, where natural forests and other wildlife resources are being preserved and protected (Gray *et al.*, 1991). Doi Suthep–Pui has beautiful scenery and good climatic conditions and is considered to be one of the most famous tourist destinations in Thailand and a productive area for high value crops like vegetables, cut flowers and fruits. Due to the increasing activities leading towards agro-industrialization and tourism development, Mae Sa Watershed is expected to be increasingly affected. Basic information on benthic diatom diversity may be applicable in assessing the change of water quality.

Based on the investigations by Master of Science in Environmental Risk Assessment (ERA) for tropical ecosystems group at the Faculty of Science, Chiang Mai University, Chiang Mai, Thailand, it can be concluded that the majority of the Doi Suthep–Pui National park areas are facing preliminary consequences of deforestation such as rill and gully erosion, and land degradation. However, the results from the water quality assessment indicate that no serious water pollution problem is present. Nevertheless, there are certain areas of concern such as the problems of like sewage discharge, solid waste disposal and soil erosion which may likely lead to a decline in the present water quality. Likewise, other indicators suggest that the intensive use of fertilizers and pesticides in the area, if left uncontrolled, could lead to deterioration of the aquatic ecosystem (ERA, 1996).

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

Chapter 3
Materials and Methods

3.1 Site description

The Mae Sa Watershed is situated in Mae Rim District, Chiang Mai Province. Part of the watershed lies within Doi Suthep–Pui National Park. Doi Suthep–Pui National Park was established in 1981and has an area of 261 km^2. 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.

Five sites were studied monthly for a period of 18 months, from April 1998 to September 1999. The sites were selected along the Mae Sa stream (Fig. 1). The name and details of each site are given in Table 5.

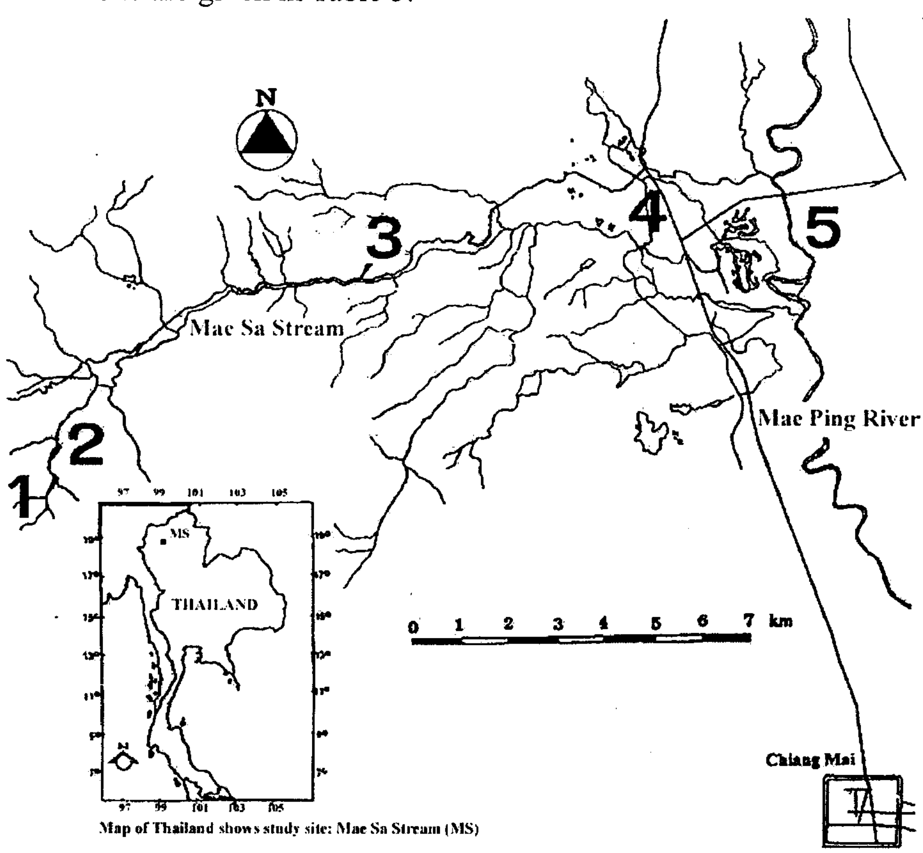


Figure 1. Map of the Mae Sa Stream showing the sampling sites (1-5).

Table 5. Site names, altitudes (m a.s.l.) and descriptions.

Site names	Altitudes (m)	Description	Co-Ordinates
1. Kong Hae Village, Pong Yang Subdistrict, Mae Rim District	1,075	agricultural and residential area	18°51′18″N 98°48′38″E
2. Entrance to Kong Hae Village, Pong Yang Subdistrict, Mae Rim District	1,000	agricultural and residential area	18°51′44″N 98°48′42″E
3. Mae Sa Elephant Camp, Pong Yang Subdistrict, Mae Rim District	550	tourist attraction	18°53′53″N 98°52′48″E
4. Cholaprathan Bridge, Mae Sa Subdistrict, Mae Rim District	330	residential area	18°54′16″N 98°56′33″E
5. Mae Sa Luang Village, Mae Sa Subdistrict, Mae Rim District	340	agricultural and residential area	18°53′31″N 98°58′22″E

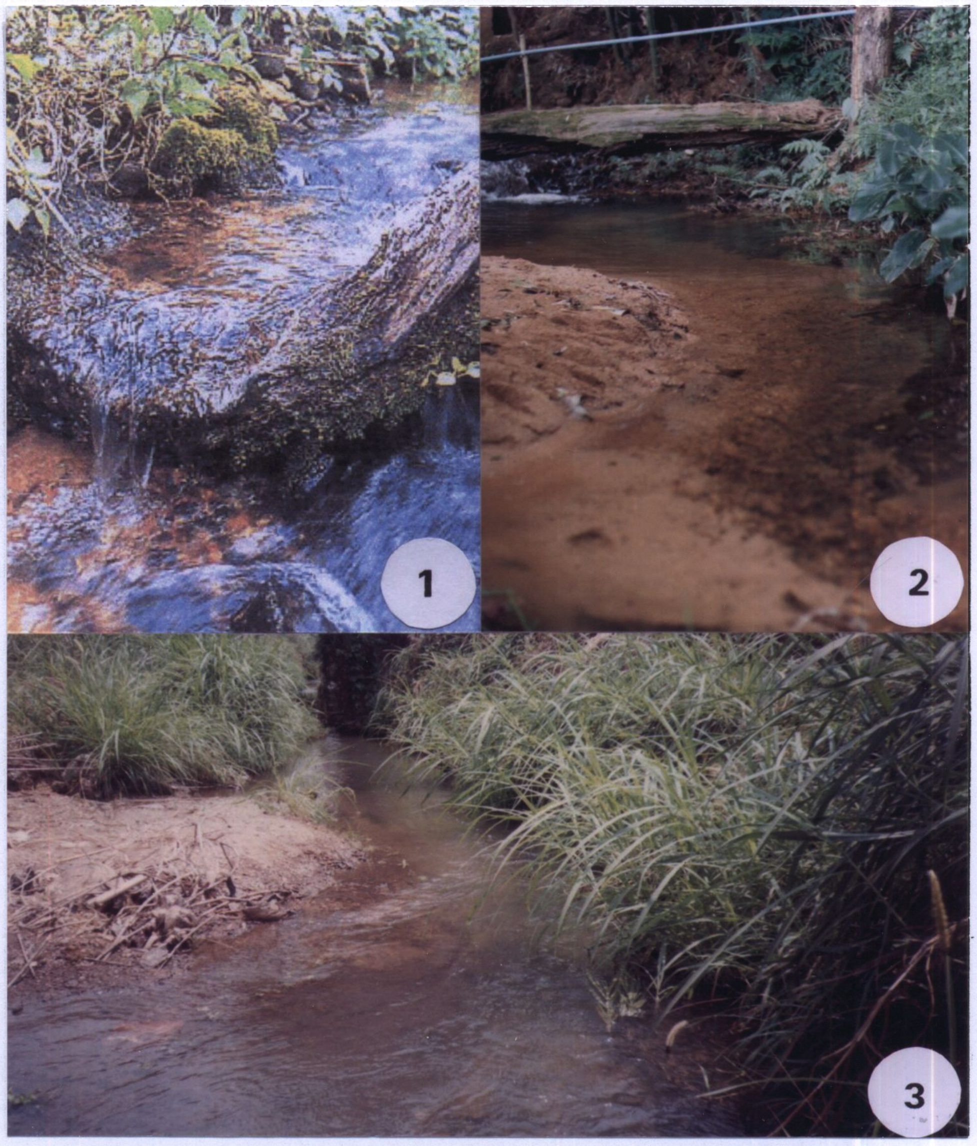


Figure 2. Sampling sites at Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.
1-site 1 (Kong Hae Village)
2-site 2 (Entrance to Kong Hae Village)
3-site 3 (Pang Chang Elephant Camp).

Figure 3. Sampling sites at Mae Sa Stream, Doi Suthep-Pui National Park,
Chiang Mai, Thailand.
4-site 4 (Cholapratarn Bridge)
5-site 5 (Mae Sa Loung Village)

3.2 Water sampling procedure

3.2.1 Collect the water sample using a polyethylene bottle for the following purposes:

3.2.1.1 Alkalinity analysis by using Phenolpthalein methyl orange indicator method (APHA, AWWA and WEF, 1998)

3.2.1.2 Turbidity analysis by using turbidimeter

3.2.1.3 Silica analysis by using Molybdosilicate Method (APHA, AWWA and WEF, 1998)

3.2.1.4 Iron analysis by using Phenanthroline Method (APHA, AWWA and WEF, 1998)

3.2.1.5 Nutrient analysis as follows:

a) nitrate nitrogen by using Cadmium Reduction method

b) nitrite nitrogen by using Colorimetric method

c) ammonium nitrogen by using Phenate method

d) soluble reactive phosphorus (SRP) and total phosphorus (TP) by using Ascorbic acid method

(APHA, AWWA and WEF, 1998)

3.2.2 Collect the water sample using a glass bottle for the following purposes:

3.2.2.1 Dissolved oxygen (DO)

3.2.2.2 Biochemical oxygen demand (BOD_5)

Analyze DO and BOD_5 by using Azide modification method (APHA, AWWA and WEF, 1998).

3.2.3 Take measurements of some physical and chemical parameters of the water's quality

3.2.3.1 Water depth measurement taken in the middle of the stream width.

3.2.3.2 Substrate investigation by assessing the percentage of substrate type (Boulder, Gravel, Sand, Silt, Bedrock or Clay) from one side of the stream to another within a section of 5 parts along the stream width. Five sections in 5 meter lengths of each sampling site should be measured (Robert , 1996).

3.2.3.3 Water temperature and air temperature measurement by use of thermometers

3.2.3.4 Gage stream current by using a velocity meter (Swoffer model 2100)

3.2.3.5 Record altitude measurement with a GPS Receiver (Batch Meridian XL)

3.2.3.6 Conductivity measurement taken by using a conductivity meter (electrode kit of WTW company)

3.2.3.7 pH measurement by using a pH meter (electrode kit of WTW company)

3.2.3.8 Total dissolved solids or TDS measurement by using a conductivity meter (electrode kit of WTW company)

3.3 Benthic diatoms gathering and slide preparation procedure

3.3.1 Collecting of the benthic diatoms sample (Rott *et al.*, 1997; Krammer and Lange-Bertalot, 1986 and Barber and Haworth, 1981)

3.3.1.1 Epilithic diatom samples scraped from 5–10 stones per site with a toothbrush. The surface area of the selected stones should be estimated. Epipelic diatom samples are taken by skimming the mud surface with a spoon.

3.3.1.2 Make a compound sample in a polyethylene bottle. Store the sample in a cool and dark storage until microscopy and preparation will be done. Fix with Lugol ' s solution 1 ml per 100 ml sample or with 2% formalin solution.

3.3.2 Preparating of the benthic diatoms sample (modified from Rott *et al.*, 1997)

3.3.2.1 Separation of the diatom samples from sedimentation using centrifuge to isolate diatom cell from gravel and sand. Centrifuge the samples at 2,500–3,000 rpm. for 15 minutes. Remove the brown portion above the sediment and put it into a test tube.

3.3.2.2 Samples are cleaned by boiling the sample with concentrated acid or oxidizing agents (hydrochloric acid, nitric acid, hydrogen peroxide, potassium permanganate or potassium dichromate) for 15–30 minutes. Boil for half an hour on a hot plate. Wash the samples after all cleaning steps, rinse frequently with distilled water and centrifuge at 2,300–3,000 rpm. for 5 minutes.

3.3.3 Slide preparation

3.3.3.1 Prepare samples for light microscope investigation by placing 1–4 drops of a cleaned sample, depending upon the density of the sample, on a round coverslip. To reduce concentration, samples may be dispersed in distilled water . Dry samples on a hotplate with gentle heat (about 50–100 °C) to fix diatoms to the glass. Add 1–2 drops of Naphrax or Dyrax on the labeled slide. Then place the coverslide face down on a prepared slide. Replace the slide on the hotplate for 1–2 seconds to remove toluene. After that, cool the slide. Gently tap the coverslip with a forcep tip to remove any bubbles (modified from Rott *et al.*, 1997). The mounts should finally be dried at room temperature overnight before being observed under a light microscope in oil immersion, at 100X magnification. Light micrographs can be made with an Olympus BX-40 microscope.

3.3.3.2 Prepare samples for SEM micrographs by dropping the cleaned diatom sample on a coverslip and drying it on a hotplate. Keep it in a desiccator overnight and fix it on a stub (Nopanit, 1984). Scanning electron micrographs can be made with a JEOL JSM-840A microscope, operated at 8–20 KV. Black and white film should be used (Kodak Verichromepan ISO 125).

3.3.4 Identification

3.3.4.1 The taxonomic classification system of the Süßwasserflora Mitteleuropas by Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Krammer (1986, 1992, 1997a, 1997b), Lange-Bertalot and Krammer (1989), Lange-Bertalot (1993, 1995) and Reichardt (1984), Huber-Pestalozzi (1942), Hustedt (1937) were followed. In some cases, however, the relevant keys in books or theses of some tropical studies, such as Foged (1971,1974, 1975, 1976), Podzorski and Hakansson (1987), Vyverman (1991) and Benavides (1994) were used. Some small *Gomphonema* species were classification following Reichardt (1997). The hand-drawing procedure followed Barber and Carter (1996). Fresh material of some species were investigated following Cox (1996). The features of the diatom frustule were described in English following Barber and Haworth (1981) and Kelly (2000). Structural data presented such as diameter, length, width, striae, striae frequency in 10 μm and other features (raphe, puncta, areolae, fibulae, nodule, septa, costae, stigmata, rib, spine, wing and canals) were observed under light and scanning electron microscopes (Krammer and Lange-Bertalot, 1986, 1988, 1991a, 1991b; Krammer, 1986, 1992, 1997a, 1997b; Lange-Bertalot and Krammer, 1989; Lange-Bertalot, 1993, 1995; Reichardt, 1984; Huber-Pestalozzi, 1942; Hustedt, 1937; Foged, 1971, 1974, 1975, 1976; Podzorski and Hakansson, 1987; Vyverman, 1991; Benavides, 1994; Reichardt, 1997; Barber and Carter, 1996; Cox, 1996; Barber and Haworth, 1981; Kelly, 2000). A good quality microscope equipped with a mechanical stage and a 100X oil-immersion lens is required for all details.

3.3.5 Counting procedure

3.3.5.1 Permanent slides of epilithic diatoms should be counted and these figures should then be applied to the Diatoms Index (DI) for final calculation of water quality assessment. Counting begins with the relative counts that concentrate on relative portions of the species, until a total count of 100-300 specimens is reached, however the variability of the taxa in the counts depends on their dispersion and this can be checked by an ascending series of counts from 100 to 1,000. (modified from Rott *et al.*, 1997)

3.3.6 Fresh material investigation and illustration procedure

3.3.6.1 Although the taxonomy of diatoms are based on the morphology of the silica cell wall, other features such a chloroplast shape and number position within the living cell can used in the identification process (Cox, 1996). Screen the samples starting with living samples and continue with cleaned material and the mounted slides.

Observe the different chloroplast types on form, number and arrangement within the cells, described in the key book. Identification of Freshwater Diatoms from Live Material (Cox, 1996). Measure the length, width, thickness and process of the diatom cell under a light microscope. Make hand drawings and notes of the shape, size and structure of the specimens. Camera lucida and light photos can be used. The species that are unable to be identified by light microscope can be re-examined by SEM.

3.4 Data evaluation

3.4.1 Diversity Index (DI)

3.4.1.1 The species diversity index (H') and evenness (E) calculation follow Shannon (Odum, 1971).

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

When	H'	=	Shannon's diversity index
	p_i	=	Proportion of specie i in the community
	s	=	Number of species

$$E = \frac{H'}{\ln s}$$

When	E	=	Evenness
	H'	=	Shannon's diversity index
	s	=	number of species

3.4.2 Trophic Diatoms Index

3.4.2.1 Index systems are based on indicator species lists, which contain information on the autecological preferences of each species toward one ecological variable (e.g. pH, organic pollution, nutrient concentration). Information on the autecological preferences of each species is based, either on the analysis of a large number of samples (several hundreds of samples) of diatom species composition or environmental variables (e.g. Schiefele & Kohmann, 1993).The trophic index of van Dam (van Dam *et al.*, 1997) and the Saprobic index of Rott *et al.* (Rott *et al.*, 1997) are applied in counting the epilithic diatoms sample data of the Mae Sa Stream. Index value were shown in Table 20 and Table 21. Results of the calculation were presented in Table 22-23 and Figure 113-114.

3.4.3 Statistical analysis

3.4.3.1 The collected data of the counted cells and the water quality can be processed in many ways. The raw data of the cell counts should be put into the Multivariate Statistical Package (MVSP) for window version 3.1. This is to find similarities between the sample sites and which species of diatoms are dominant. This is done by using Principal Components Analysis (PCA), Canonical Correspondence Analysis (CCA), Diversity Indices were performed. For the PCA, the data was transformed to Log10 and the axes were extracted to Kaiser's rule.

3.4.3.2 The computer statistical package, SPSS for window version 6.0 is used to perform the following statistical analysis, analysis of Variance (ANOVA), Least Significant Difference (LSD), Correlation, Regression and Factor analysis are use for computering the water quality of the five sites using different chemical and biological parameters. The correlation between dominant species and some physico-chemical parameters were performed.

3.5 Mae Sa Index Development

The method used was adapted from Kelly (Kelly, 2000). With the former is a measure of the effect of nutrients (predominately phosphorus) on stream communities, whilst the latter is a more general measure of water quality, taking account of factors such as biochemical oxygen demand, ammonia and salinity alongside that of nutrients. Trophic Diatom Index is computed with the same way, using a "weight average" equation (Zelinka and Marvan, 1961 cited by Kelly, 2000). The formula for this equation is:

$$WMS = \frac{\sum avs}{\sum av}$$

Where a = relative abundance (proportion) of species in the sample

v = the indicator value (1-3)

s = pollution sensitivity (1-5) of the species

The environmental preferences of each dominant taxa which selected from PCA are summarized in the form of simple scatter with plotted for alkalinity, conductivity, nitrate nitrogen and soluble reactive phosphorus, inorder to avoid making too many generalizations. The relative abundance are indicated on the vertical axis, and the environmental determination on the horizontal axis. Patterns of the plot may show peak, indicator values depended on the spread of values around this peak (Whitton and Kelly, 1995). Sumarized information for each dominant species represented in Table 19, this will be use for calculate the Mae Sa index.

Chapter 4
Results

4.1 Diatoms diversity

4.1.1 Number of investigated species and species list

A total of 278 species of benthic diatoms were discovered and could be classified into 2 orders 3 suborders 10 families and 34 genera. Species list were classified systematically into categories and shown in Table 3. The star symbol after the species epithet name, indicates newly recorded species.

The most abundant were *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow and *Bacillaria paradoxa* Gmelin.

The common species which could be found in every sampling site were *A. crenulata* Grunow, *A. exigua* Grunow var. *exigua*, *A. lanceolata* (Brébisson) Grunow, *A. oblongella* Oestrup, *A. undata* Meister, *Amphora libyca* Ehrenberg, *B. paradoxa* Gmelin, *Cocconeis placentula* Ehrenberg, *Encyonema silesiacum* (Bleisch) D. G. Mann, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *F. ulna* var. *acus* (Kützing) Lange-Bertalot, *Frustulia weinholdii* Hustedt, *Gomphonema gracile* Ehrenberg, *G. parvulum* Kützing, *G. pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Gyrosigma scalproides* (Rabenhorst) Cleve, *Hantzschia amphioxys* (Ehrenberg) Grunow, *Melosira varians* Agardh, *Navicula cryptotenella* Lange-Bertalot, *N. elginensis* (Gregory) Ralfs var. *elginensis*, *N. leptostriata* Jørgensen, *N. mutica* Kützing, *N. schroeterii* Meister, *N. viridula* var. *germainii* (Wallace) Lange-Bertalot, *N. viridula* var. *rostellata* (Kützing) Cleve, *N. viridula* (Kützing) *Ehrenberg* var. *viridula*, *Nitzschia fonticola* Grunow, *N. palea* Kützing, *Pinnularia borealis* var. *scalaris* (Ehrenberg) Rabenhorst, *P. schoenfelderi* Krammer, *Sellaphora pupula* (Kützing) Mereschkowsky, *Stauroneis smithii* Gronow, *Surirella angusta* Kützing, *S. roba* Leclercq, *Synedra lanceolata* Kützing and *S. ulna* var. *aequalis* (Kützing) Hustedt

Light micrographs of living diatoms were shown in Figures 4-5, Light micrographic images of cleaned diatoms were shown in Figures 6-27, Scanning Electron Micrographs were shown in Figures 28-30 and hand-drawings of newly recorded diatoms were shown in Figures 31-34.

Table 6. Species list of diatoms in Mae Sa Stream, Doi Suthep–Pui National Park, Chiang Mai, Thailand.

Orders	Suborders	Families	Species
Centrales	Coscinodiscineae	Thalassiosiraceae	
			Aulacoseira granulata (Ehrenberg) Simonsen
			Cyclotella meneghiniana Kützing
			Cyclotella stelligera Cleve & Grunow*
			Cyclotella sp.1
			Cyclotella sp.2
			Thalassiosira weissflogii (Grunow) Fryxell&Hasle*
		Melosiraceae	
			Melosira varians Agardh
		Hemidiscaceae	
			Actinocyclus normanii (Gregory) Hustedt*
Pennales	Araphidineae	Fragilariaceae	
			Diatoma ehrenbergii Kützing*
			Diatoma moniliformis Kützing*
			Diatoma vulgaris Bory*
			Fragilaria biceps (Kützing) Lange-Bertalot*
			Fragilaria bidens Heiberg*
			Fragilaria elliptica Schumann*
			Fragilaria lanceolata (Kützing) Reichardt
			Fragilaria ulna (Nitzsch) Lange-Bertalot
			Fragilaria ulna var. *acus* (Kützing) Lange-Bertalot
			Fragilaria sp.1
			Fragilaria sp.2
			Fragilaria sp.3

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
Pennales	Araphidineae	Fragilariaceae	
			Synedra lanceolata Kützing
			Synedra ulna (Nitzsch) Ehrenberg
			Synedra ulna var. *aequalis* (Kützing) Hustedt
	Raphidineae	Eunotiaceae	
			Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris**
			Eunotia minor (Kützing) Grunow*
			Eunotia soleirolii (Kützing) Rabenhorst
			Eunotia sp.1
			Eunotia sp.2
			Eunotia sp.3
		Achnanthaceae	
			Achnanthes brevipes var. *intermedia* (Kützing) Cleve
			Achnanthes childanos Hohn & Hellermann*
			Achnanthes crenulata Grunow
			Achnanthes aff. *delicatula* ssp. *Hauckiana* (Grunow) Lange-Bertalot
			Achnanthes exigua Grunow var. *exigua**
			Achnanthes helvetica (Hustedt) Lange-Bertalot*
			Achnanthes inflata (Kützing) Grunow
			Achnanthes lanceolata var. *boyei* (Oestrup) Lange-Bertalot*
			Achnanthes lanceolata var. *frequentissima* Lange-Bertalot
			Achnanthes lanceolata var. *haynaldii* (Schaarschmidt) Cleve
			Achnanthes lanceolata var. *lanceolata* (Brébisson) Grunow
			Achnanthes lanceolata var. *rostrata* (Oestrup) Lange-Bertalot

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Achnanthaceae	
			Achnanthes minutissima Kützing
			Achnanthes pusilla (Grunow) De Toni
			Achnanthes oblongella Oestrup
			Achnanthes pseudoswazi Carter
			Achnanthes undata Meister*
			Achnanthes sp.1
			Achnanthes sp.2
			Achnanthes sp.3
			Achnanthes sp.4
			Achnanthes sp.5
			Achnanthes sp.6
			Achnanthes sp.7
			Achnanthes sp.8
			Achnanthes sp.9
			Achnanthes sp.10
			Achnanthes sp.11
			Achnanthes sp.12
			Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow
			Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck
			Cocconeis placentula Ehrenberg var. *placentula*
			Cocconeis placentula var. *pseudolineata* Geitler*
		Naviculaceae	
			Amphora aequalis Krammer
			Amphora coffeaeformis (Agardh) Kützing var. *coffeaeformis**

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Amphora dusenii Brun*
			Amphora libyca Ehrenberg*
			Amphora ovalis (Kützing) Kützing
			Amphora pediculus (Kützing) Grunow
			Amphora sp.1
			Amphora sp.2
			Amphora sp.3
			Amphora sp.4
			Amphora sp.5
			Amphora sp.6
			Caloneis bacillum (Grunow) Cleve
			Caloneis lauta Carter & Bailey-Watts*
			Caloneis silicula (Ehrenberg) Cleve*
			Caloneis sp.1
			Caloneis sp.2
			Caloneis sp.3
			Caloneis sp.4
			Craticula sp.1
			Cymbella affinis Kützing
			Cymbella amphicephala Naegeli*
			Cymbella hustedtii Krasske*
			Cymbella minuta Hilse
			Cymbella naviculiformis (Auerswald) Cleve
			Cymbella tumida (Brébisson) Van Heurck

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Cymbella turgidula Grunow*
			Cymbella sp.1
			Cymbella sp.2
			Cymbella sp.3
			Cymbellopsis cf. *lanceolata* Krammer*
			Diploneis elliptica (Kützing) Cleve
			Diploneis oblongella (Naegeli) Cleve-Euler
			Diploneis ovalis (Hilse) Cleve
			Encyonema cf. *latereolatum* Krammer
			Encyonema silesiacum (Bleisch) D. G. Mann*
			Encyonema sp.1
			Encyonema sp.2
			Encyonema sp.3
			Encyonema sp.4
			Encyonema sp.5
			Frustulia rhomboides (Ehrenberg) De Toni
			Frustulia weinholdii Hustedt*
			Frustulia sp.1
			Frustulia sp.2
			Frustulia sp.3
			Frustulia sp.4
			Gomphonema affine Kützing*
			Gomphonema augur Ehrenberg
			Gomphonema augur var. *turris* (Ehrenberg) Lange-Bertalot*

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Gomphonema clevei Fricke
			Gomphonema gracile Ehrenberg
			Gomphonema lingulatiforme Lange-Bertalot & Reichardt
			Gomphonema minutum (Agardh) Agardh*
			Gomphonema parvulum (Kützing) Kützing
			Gomphonema pumilum var. *rigidum* E. Reichardt et Lange-Bertalot*
			Gomphonema truncatum Ehrenberg
			Gomphonema sp.1
			Gomphonema sp.2
			Gomphonema sp.3
			Gomphonema sp.4
			Gomphonema sp.5
			Gomphonema sp.6
			Gomphonema sp.7
			Gomphonema sp.8
			Gyrosigma scalproides (Rabenhorst) Cleve
			Gyrosigma spencerii (Quekett) Griffith & Henfrey
			Navicula bacillum Ehrenberg
			Navicula clementis Grunow
			Navicula cohnii (Hilse) Lange-Bertalot*
			Navicula concentrica Carter*
			Navicula cryptotenella Lange-Bertalot*
			Navicula elginensis (Gregory) Ralfs var. *elginensis**
			Navicula gastrum (Ehrenberg) Kützing var. *gastrum*

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Navicula goeppertiana var. *dapaliformis* (Hustedt) Lange-Bertalot
			Navicula goeppertiana var. *monita* (Hustedt) Lange-Bertalot
			Navicula insociabilis Krasske
			Navicula jaagii Meister*
			Navicula laevissima Kützing var. *laevissima**
			Navicula leptostriata Jørgensen
			Navicula medioconvexa Hustedt
			Navicula mobiliensis Boyer
			Navicula mutica Kützing
			Navicula mutica Kützing var. *mutica**
			Navicula porifera var. *opportuna* (Hustedt) Lange-Bertalot
			Navicula pupula var. *mutata* (Krasske) Hustedt
			Navicula radiosa Kützing
			Navicula schroeterii Meister
			Navicula subplacentula Hustedt*
			Navicula trivialis Lange-Bertalot
			Navicula viridula var. *germainii* (Wallace) Lange-Bertalot
			Navicula viridula var. *rostellata* (Kützing) Cleve
			Navicula viridula (Kützing) Ehrenberg var. *viridula*
			Navicula sp.1
			Navicula sp.2
			Navicula sp.3
			Navicula sp.4
			Navicula sp.5

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Navicula sp.6
			Navicula sp.7
			Navicula sp.8
			Navicula sp.9
			Navicula sp.10
			Navicula sp.11
			Navicula sp.12
			Navicula sp.13
			Navicula sp.14
			Navicula sp.15
			Navicula sp.16
			Navicula sp.17
			Navicula sp.18
			Navicula sp.19
			Navicula sp.20
			Navicula sp.21
			Neidium affine (Ehrenberg) Pfitzer
			Neidium cf. *affine* var. *humerus* Reimer
			Neidium ampliatum (Ehrenberg) Krammer*
			Neidium binodis (Ehrenberg) Hustedt
			Neidium gracile Hustedt
			Neidium iridis (Ehrenberg) Cleve
			Neidium septentrionale Cleve-Euler
			Neidium sp.1

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Naviculaceae	
			Neidium sp.2
			Neidium sp.3
			Neidium sp.4
			Neidium sp.5
			Neidium sp.6
			Pinnularia acrosphaeria W. Smith
			Pinnularia appendiculata (Agardh) Cleve
			Pinnularia borealis var. *scalaris* (Ehrenberg) Rabenhorst
			Pinnularia mesolepta (Ehrenberg) W. Smith
			Pinnularia platycephala (Ehrenberg) Cleve
			Pinnularia schoenfelderi Krammer
			Pinnularia subgibba Krammer
			Pinnularia subinterrupta Krammer & Schroeter
			Pinnularia viridis (Nitzsch) Ehrenberg
			Pinnularia sp.1
			Pinnularia sp.2
			Pinnularia sp.3
			Pinnularia sp.4
			Pinnularia sp.5
			Pinnularia sp.6
			Pinnularia sp.7
			Pinnularia sp.8
			Pinnularia sp.9
			Pinnularia sp.10

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Epithemiaceae	
			Pinnularia sp.11
			Reimeria sinuata (Gregory) Kociolek & Stoermer*
			Sellaphora pupula (Kützing) Mereschkowsky*
			Sellaphora sp.1
			Stauroneis anceps Ehrenberg
			Stauroneis smithii Gronow
			Epithemia sp.1
			Rhopalodia acuminata Krammer
			Rhopalodia brebissonii Krammer
			Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba**
			Rhopalodia gibba var. *parallela* (Grunow) Fryxell & Hasle
			Rhopalodia gibberula (Ehrenberg) O. Müller
			Rhopalodia rupestris (W. Smith) Krammer
			Rhopalodia sp.1
			Rhopalodia sp.2
			Rhopalodia sp.3
			Rhopalodia sp.4
		Bacillariaceae	
			Bacillaria paradoxa Gmelin
			Hantzschia amphioxys (Ehrenberg) Grunow
			Hantzschia distinctepunctata (Hustedt) Hustedt*
			Nitzschia cf. *acula* Hantzsch
			Nitzschia angustatula Lange-Bertalot
			Nitzschia bremensis Hustedt

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Bacillariaceae	
			Nitzschia brevissima Grunow*
			Nitzschia capitellata Hustedt
			Nitzschia coarctata Grunow*
			Nitzschia dissipata (Kützing) Grunow
			Nitzschia dubia W. Smith
			Nitzschia fonticola Grunow
			Nitzschia fonticola var. *palagica* Hustedt
			Nitzschia geitleri Hustedt
			Nitzschia hantzschiana Rabenhorst*
			Nitzschia levidensis (W. Smith) Grunow var. *levidensis*
			Nitzschia palea (Kützing) W. Smith
			Nitzschia sigmoidea (Nitzsch) W. Smith
			Nitzschia sublinearis
			Nitzschia sp.1
			Nitzschia sp.2
			Nitzschia sp.3
			Nitzschia sp.4
			Nitzschia sp.5
			Nitzschia sp.6
			Nitzschia sp.7
			Nitzschia sp.8
			Nitzschia sp.9
			Nitzschia sp.10
			Nitzschia sp.11

* Newly recorded species

Table 6. Continued

Orders	Suborders	Families	Species
		Bacillariaceae	
			Nitzschia sp.12
			Nitzschia sp.13
		Surirellaceae	
			Cymatopleura solea (Brébisson) W. Smith
			Cymatopleura solea var. *apiculata* (W. Smith) Ralfs*
			Surirella angusta Kützing
			Surirella bifrons Ehrenberg
			Surirella biseriata Brébisson
			Surirella capronii Brébisson
			Surirella elegans Ehrenberg
			Surirella ovalis Brébisson
			Surirella roba Leclercq*
			Surirella robusta Ehrenberg
			Surirella spiraloides Hustedt*
			Surirella tenera Gregory
			Surirella sp.1
			Surirella sp.2
			Surirella sp.3
			Surirella sp.4
			Surirella sp.5
			Surirella sp.6
			Surirella sp.7
			Surirella sp.8
			Surirella sp.9

* Newly recorded species

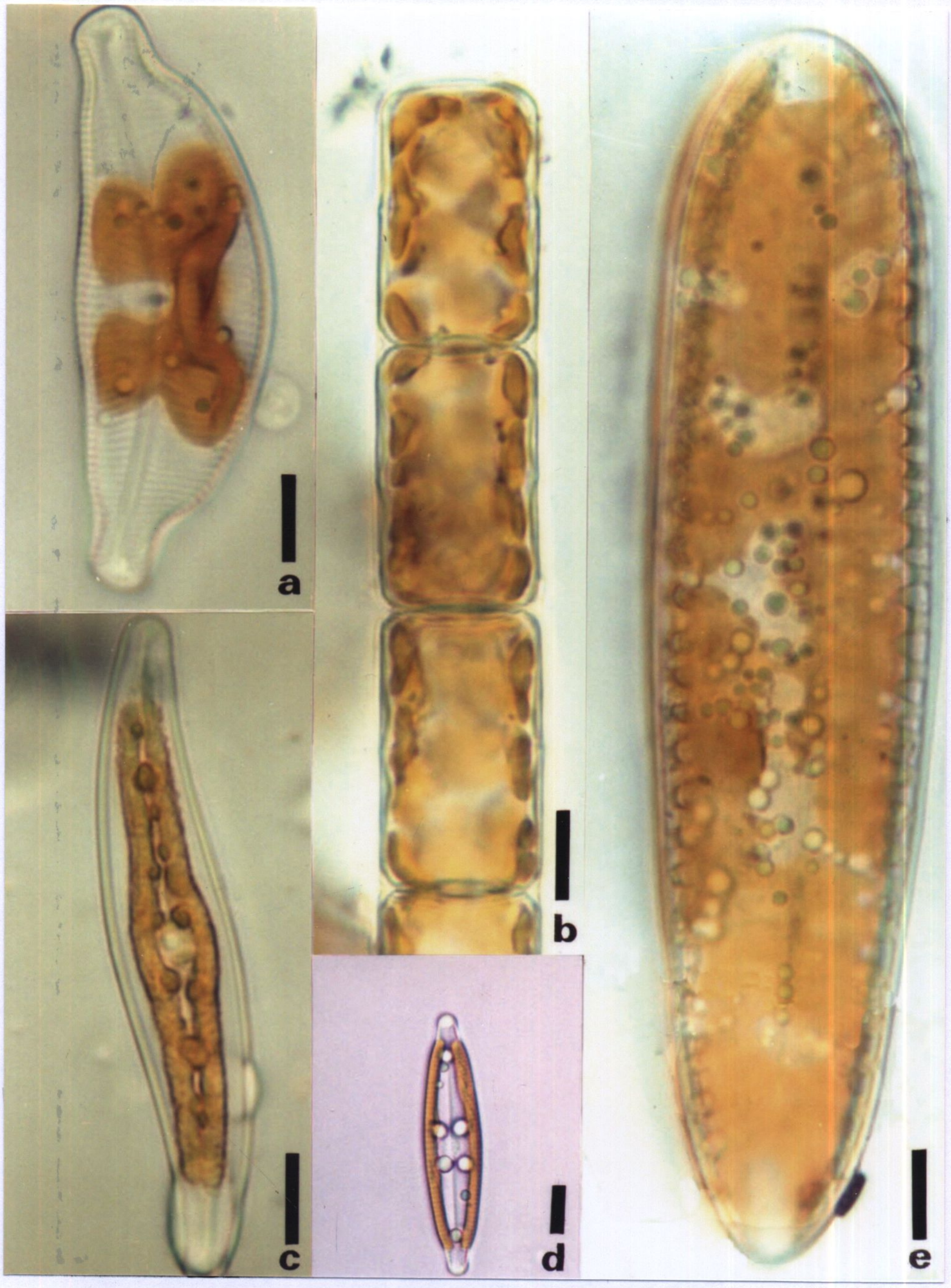


Figure 4. Light micrographs of living diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

a- *Cymbella tumida* (Brébisson) Van Heurck, b- *Melosira varians* Agardh, c- *Gyrosigma scalproides* (Rabenhorst) Cleve, d- *Navicula viridula* (Kützing) *Ehrenberg* var. *viridula*, e- *Surirella elegans* Ehrenberg

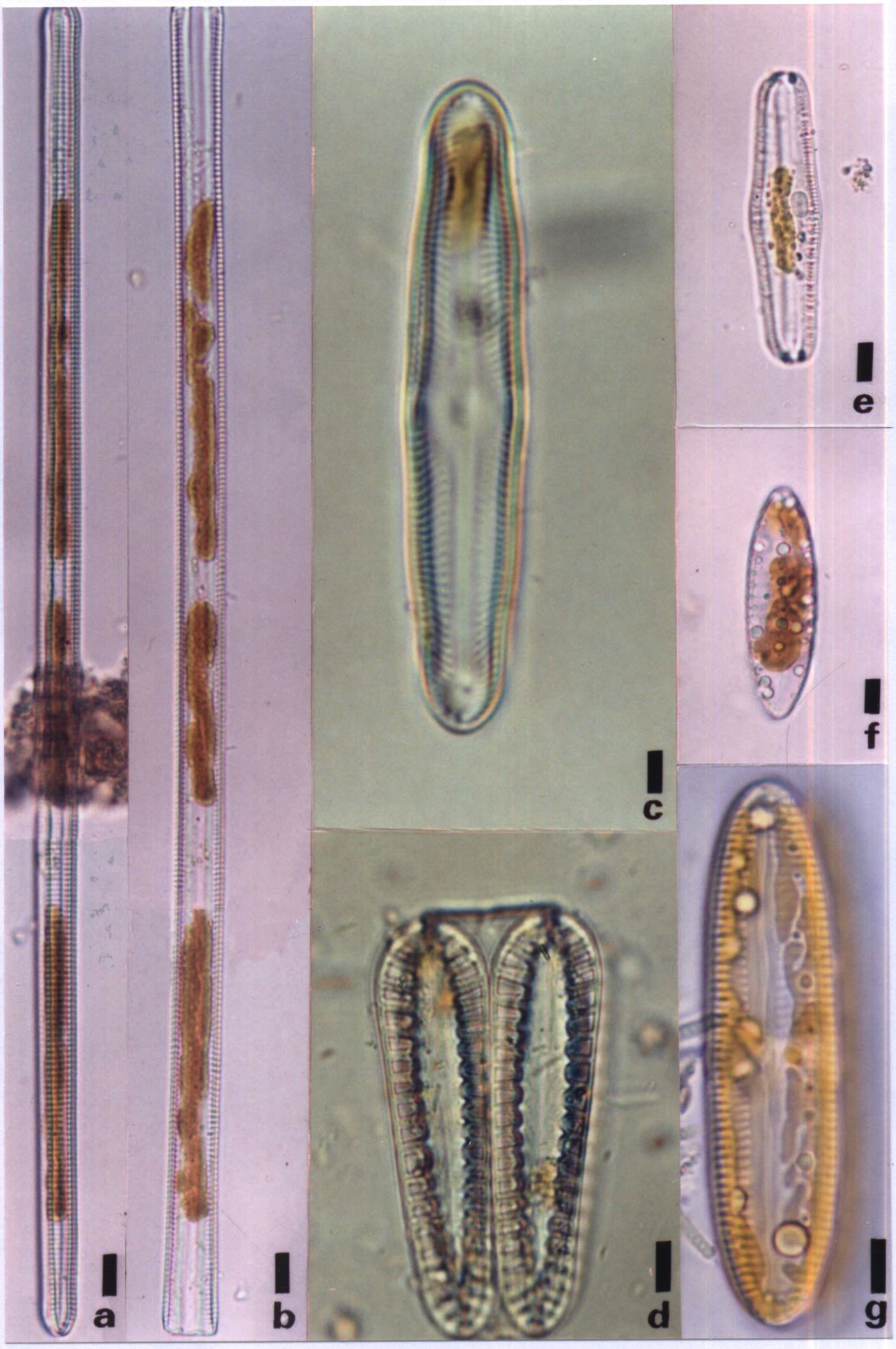


Figure 5. Light micrographs of living diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)
a- *Synedra ulna* var. *aequalis* (Kützing) Hustedt (valve view), b- *S. ulna* var. *aequalis* (Kützing) Hustedt (girdle view), c- *Pinnularia subgibba* Krammer, d- *Surirella elegans* Ehrenberg (girdle view), e- *Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba*, f- *Surirella roba* Leclercq, g- *Pinnularia viridis* (Nitzsch) Ehrenberg

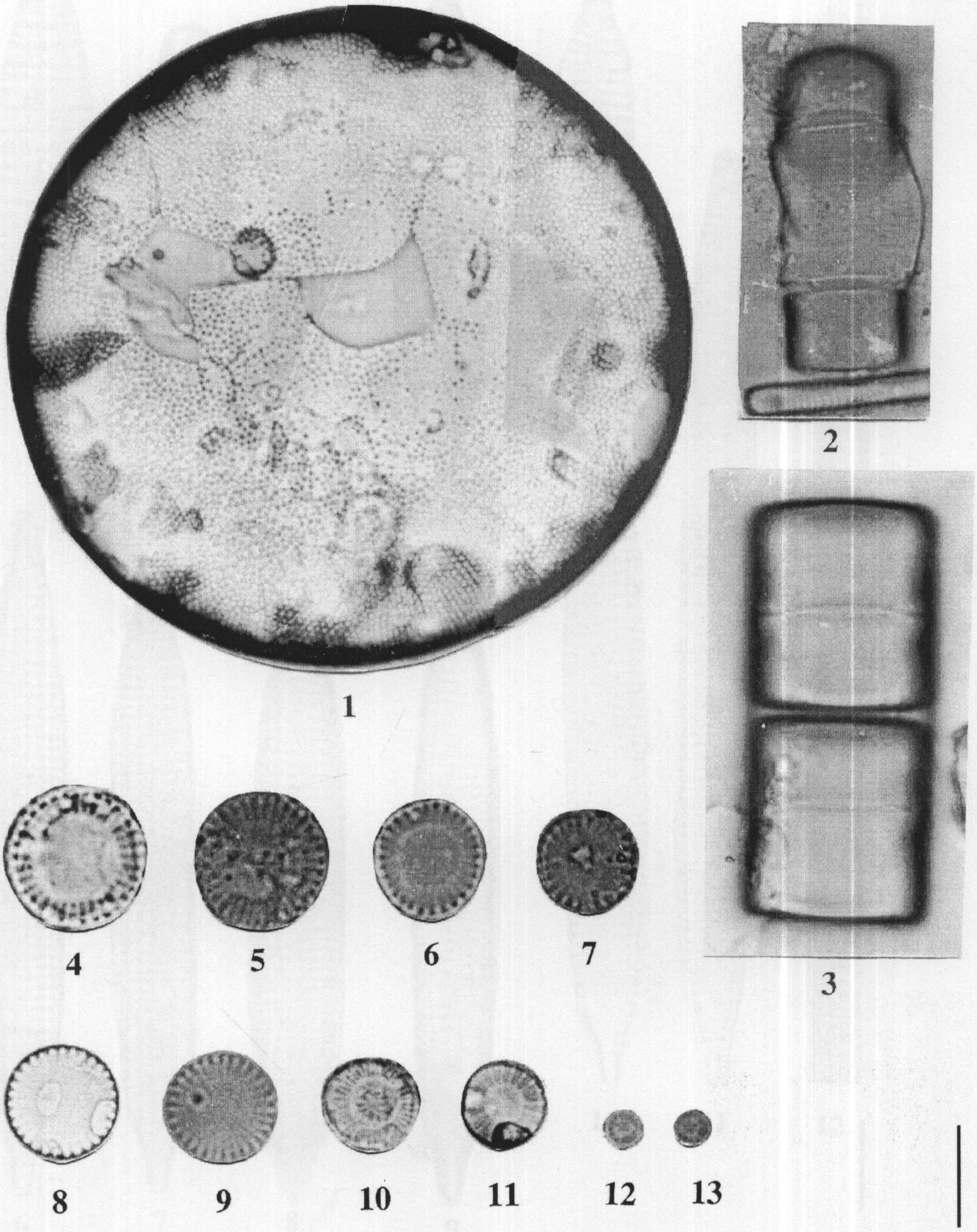


Figure 6. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1- *Actinocyclus normanii* (Gregory) Hustedt, 2-3- *Melosira varians* Agardh, 4-9- *Cyclotella meneghiniana* Kützing, 10- *C. stelligera* Cleve & Grunow, 11-13- *Cyclotella* spp.

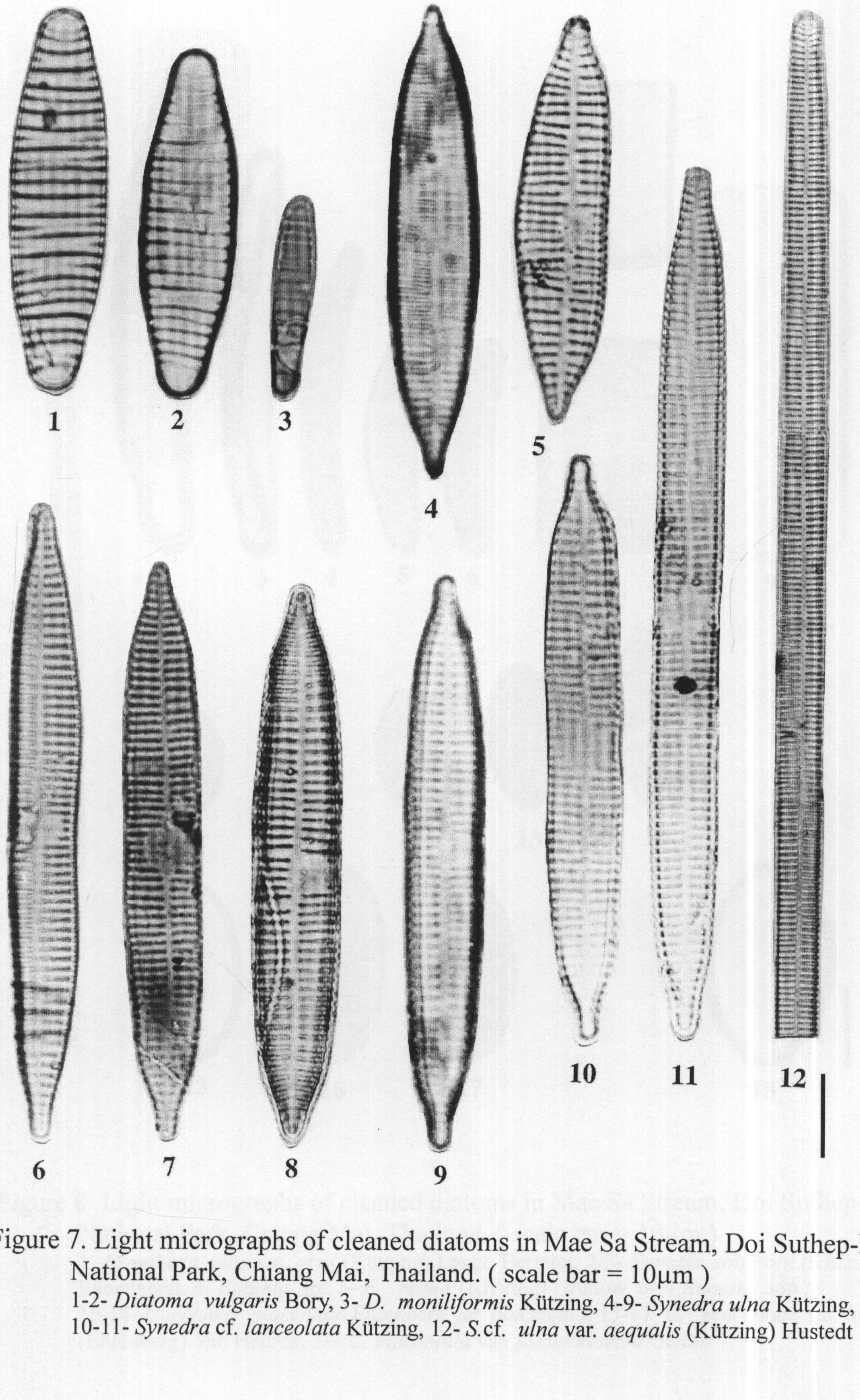


Figure 7. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-2- *Diatoma vulgaris* Bory, 3- *D. moniliformis* Kützing, 4-9- *Synedra ulna* Kützing, 10-11- *Synedra* cf. *lanceolata* Kützing, 12- *S.*cf. *ulna* var. *aequalis* (Kützing) Hustedt

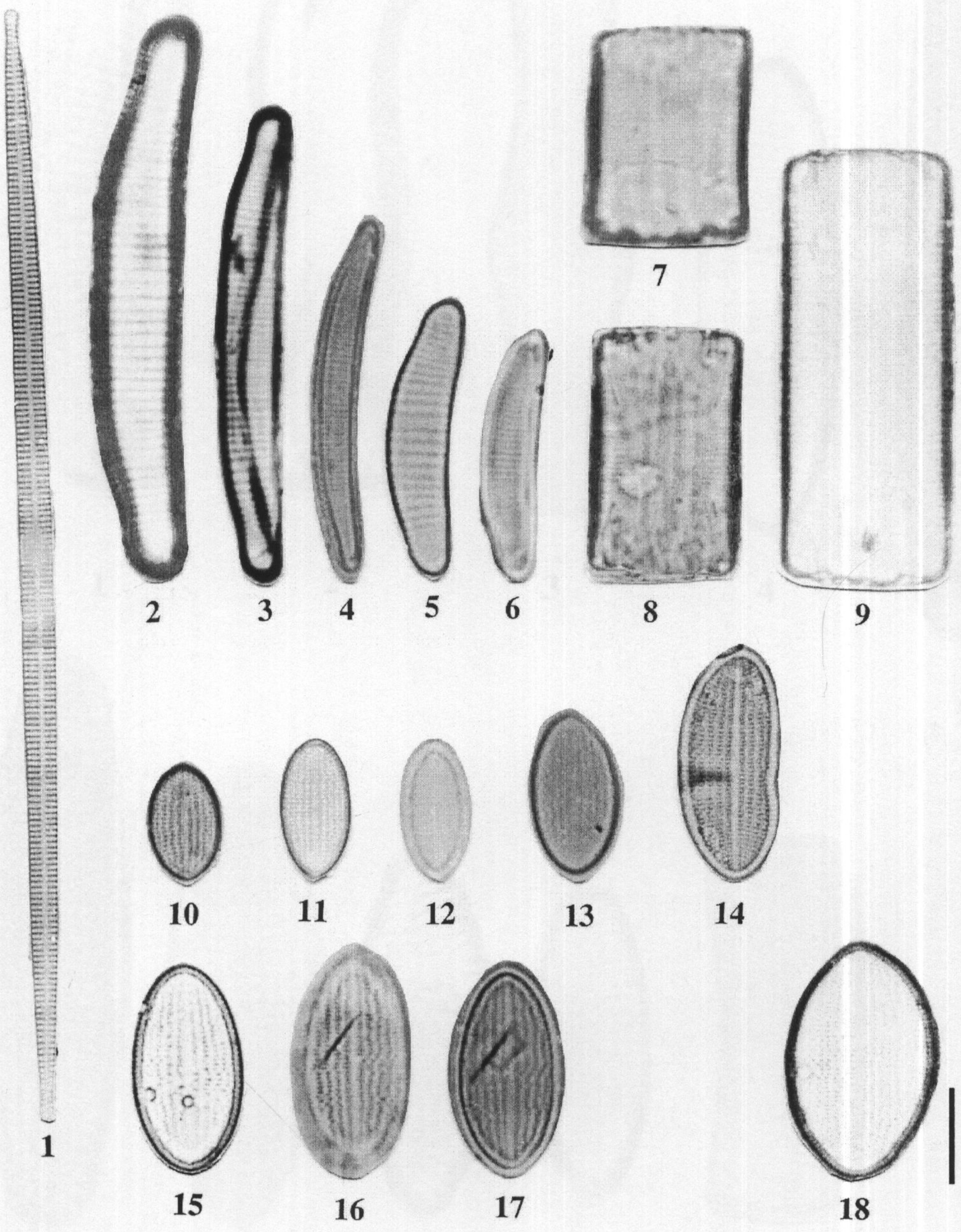


Figure 8. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1- *Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot, 2-3- *Eunotia soleirolii* (Kützing) Rabenhorst, 4- *Eunotia* sp., 5- *E. minor* (Kützing) Grunow, 6-9- *Eunotia* spp., 10-14- *Cocconeis placentula* Ehrenberg var. *placentula*, 15-17- *C. placentula* var. *lineata* (Ehrenberg) Van Heurck, 18- *C. placentula* var. *pseudolineata* Geitler

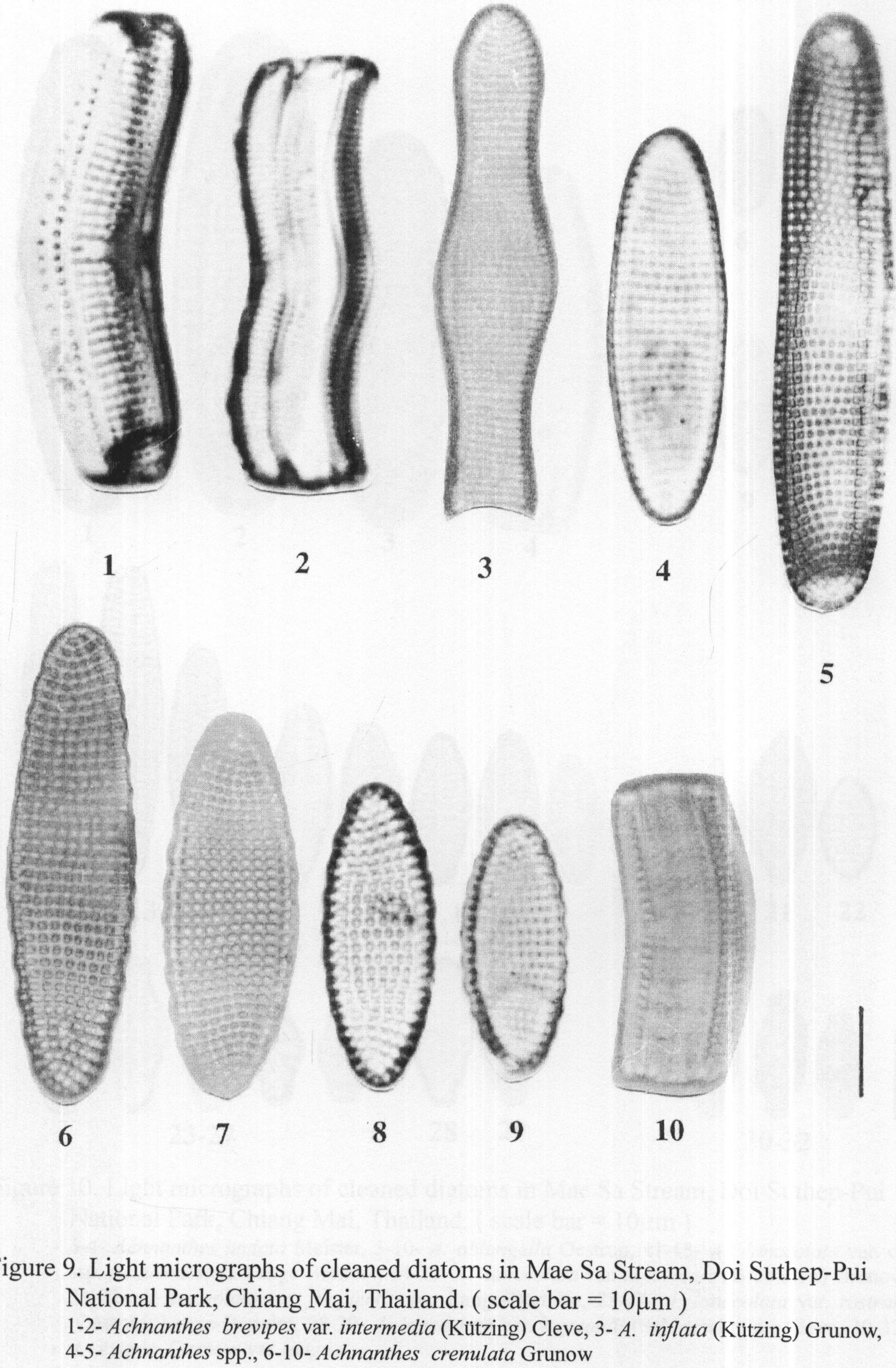


Figure 9. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)
1-2- *Achnanthes brevipes* var. *intermedia* (Kützing) Cleve, 3- *A. inflata* (Kützing) Grunow, 4-5- *Achnanthes* spp., 6-10- *Achnanthes crenulata* Grunow

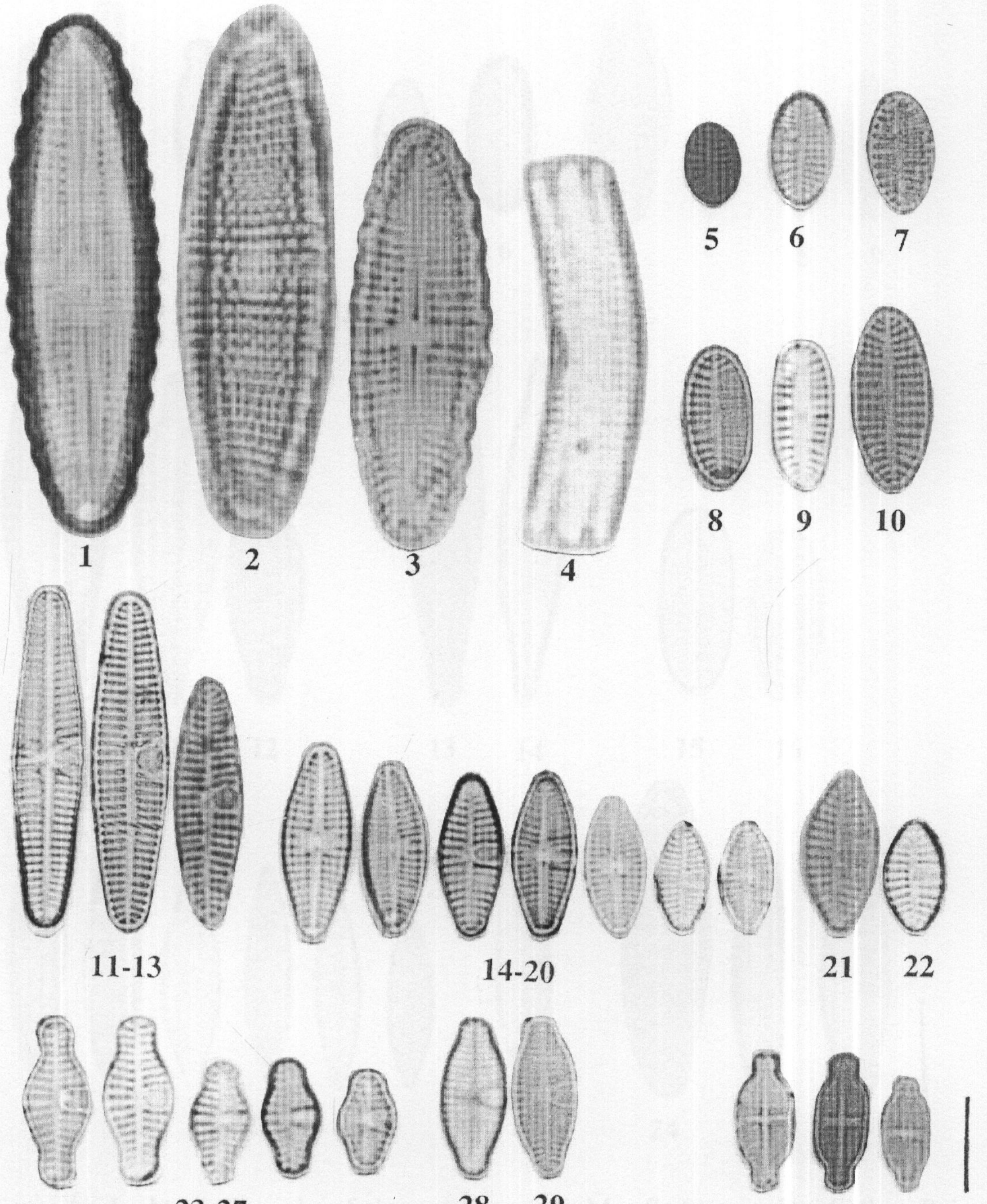


Figure 10. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)

1-4- *Achnanthes undata* Meister, 5-10- *A. oblongella* Oestrup, 11-13- *A. lanceolata* var. cf. ssp. *frequentissima* Lange-Bertalot, 14-20- *A. lanceolata* var. *lanceolata* (Brébisson) Grunow, 21-22- *A. lanceolata* var. *frequentissima* Lange-Bertalot, 23-27- *A. lanceolata* var. *rostrata* (Oestrup) Lange-Bertalot, 28-29- *A. lanceolata* var. *haynaldii* (Schaarschmidt) Cleve, 30-32- *A. exigua* Grunow var. *exigua*

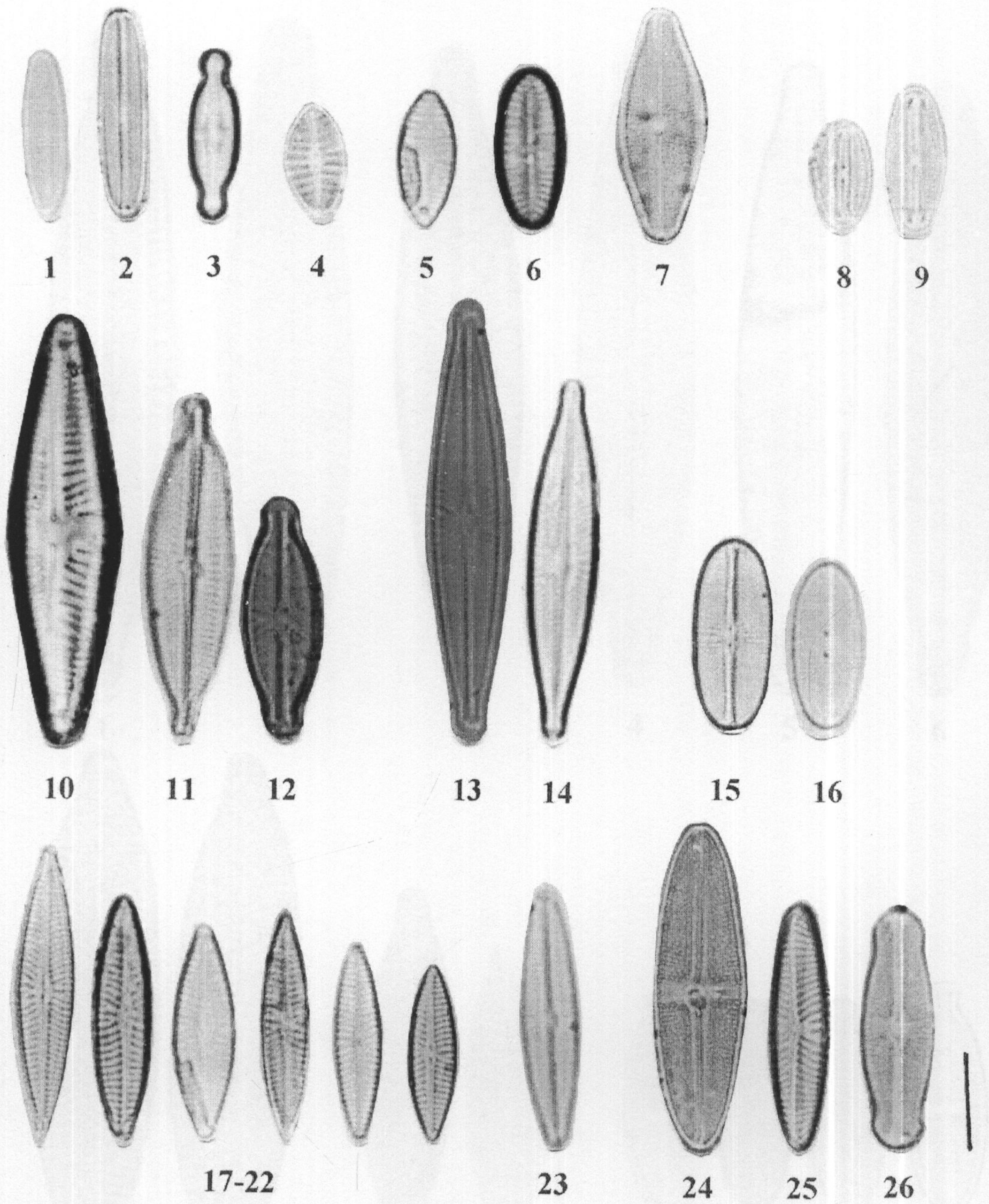


Figure 11. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1- *Achnanthes pusilla* (Grunow) De Toni, 2- *Achnanthes* sp., 3- *Achnanthes pseudoswazi* Carter, 4- *A.* aff. *delicatula* ssp. *hauckiana* (Grunow) Lange-Bertalot,5-6- *Achnanthes* spp., 7- *Navicula pupula* var. *mutata* (Krasske) Hustedt, 8-9- *Navicula insociabilis* Krasske, 10- *N. goeppertiana* var. *dapaliformis* (Hustedt) Lange-Bertalot, 11- *Navicula* sp., 12- *Navicula* cf. *viridula* var. *rostellata* (Kützing) Cleve, 13-16- *Navicula* spp., 17-22- *N. cryptotenella* Lange-Bertalot, 23- *N. schroeterii* Meister, 24- *N. goeppertiana* var. *monita* (Hustedt) Lange-Bertalot, 25- *Navicula* sp., 26- *Sellaphora pupula* (Kützing) Mereschkowsky

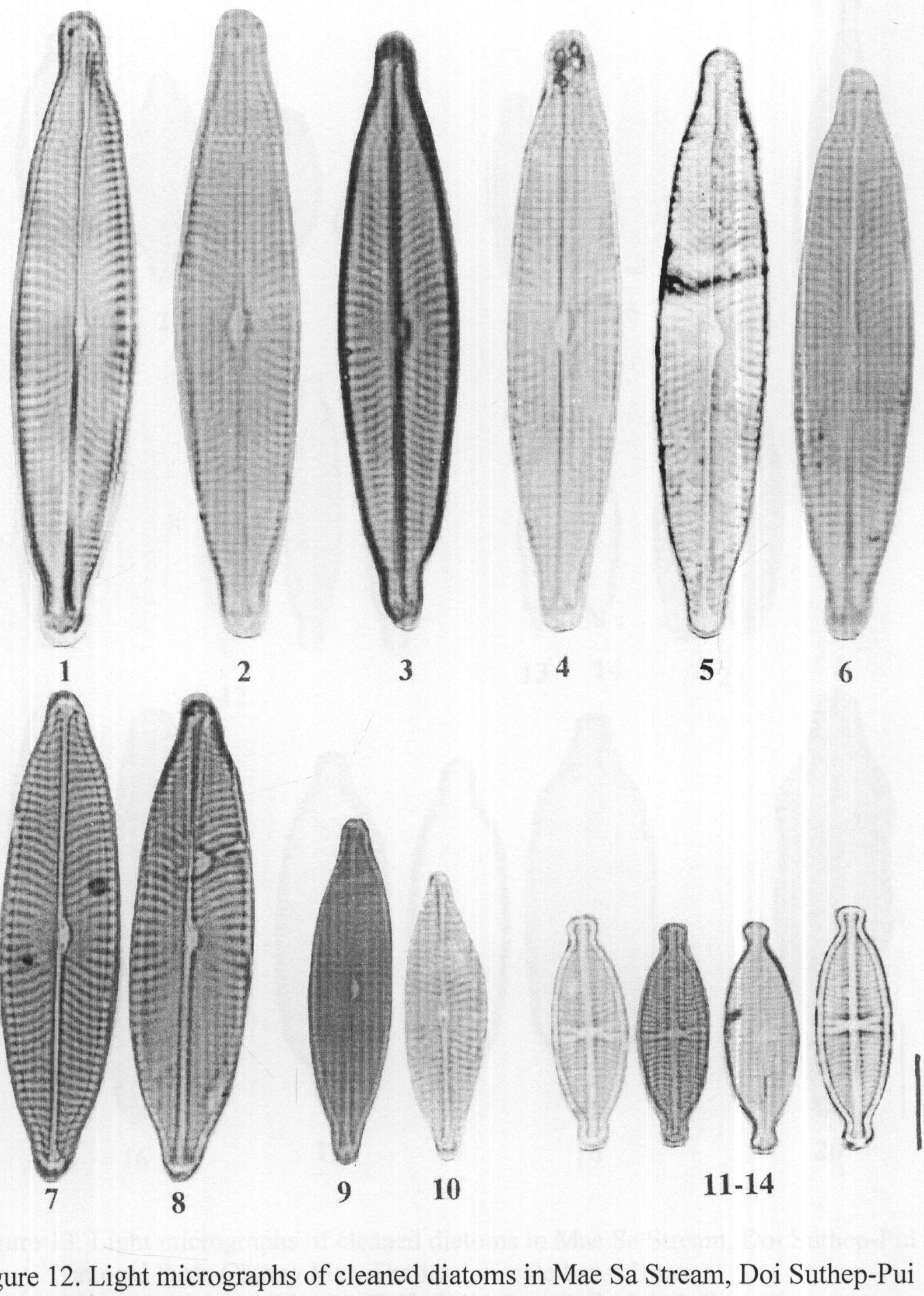


Figure 12. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1-6- *Navicula viridula* (Kützing) Ehrenberg var. *viridula*, 7-8- *N. viridula* var. *rostellata* (Kützing) Cleve, 9-10- *N. viridula* var. *germainii* (Wallace) Lange-Bertalot, 11-14- *Navicula* sp.

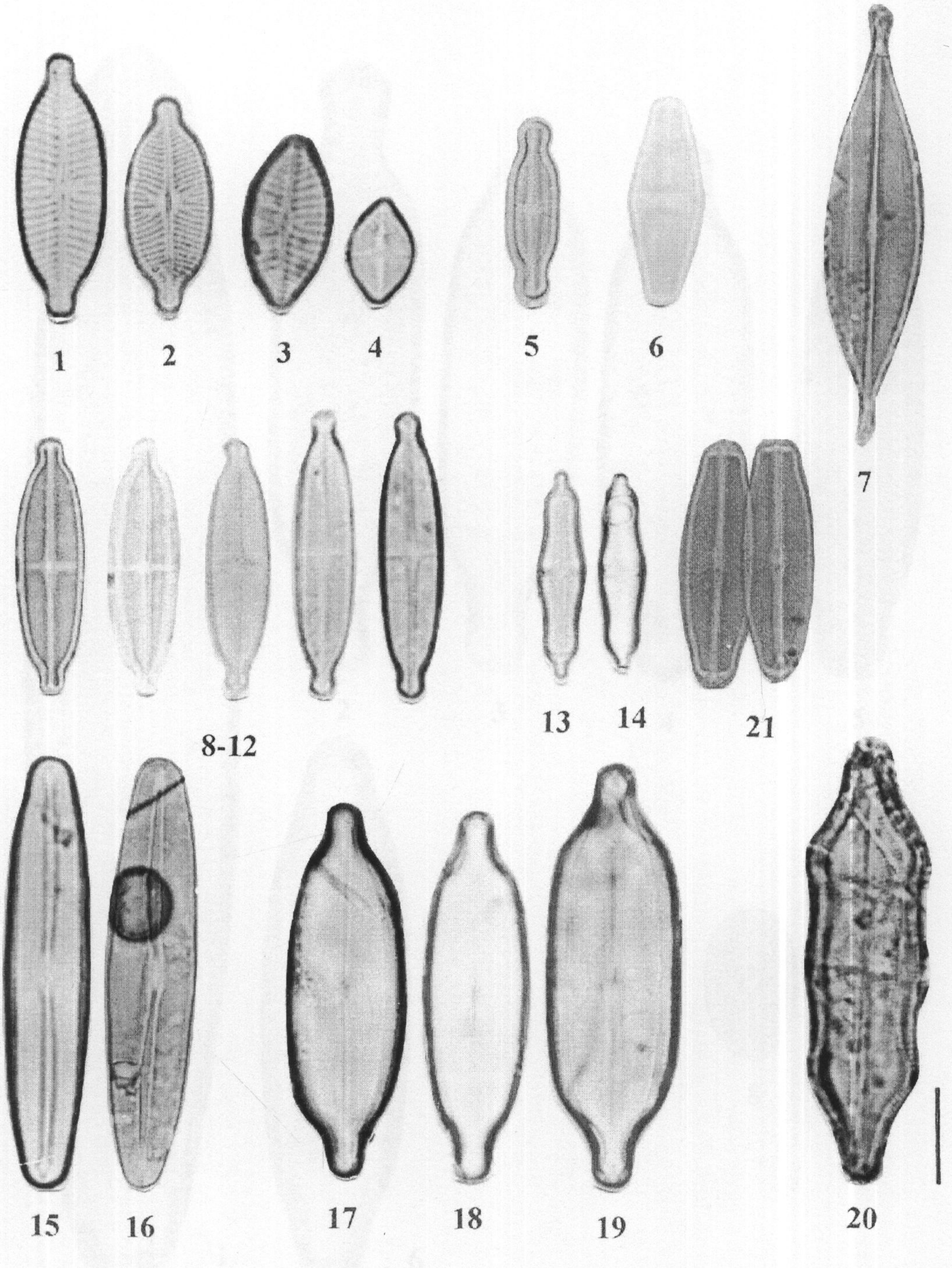


Figure 13. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)

1- *Navicula elginensis* (Gregory) Ralfs, 2- *N. clementis* Grunow, 3- *N. porifera* var. *opportuna* (Hustedt) Lange-Bertalot, 4- *Navicula* sp., 5- *N. medioconvexa* Hustedt, 6- *N. cohnii* (Hilse) Lange-Bertalot, 7- *Craticula* sp., 8-12- *Stauroneis* sp., 13-14- *S. smithii* Grunow, 15-16- *Frustulia weinholdii* Hustedt, 17-19- *Neidium* cf. *affine* var. *humerus* Reimer, 20- *N. gracile* Hustedt fo. *aequalis* Hustedt

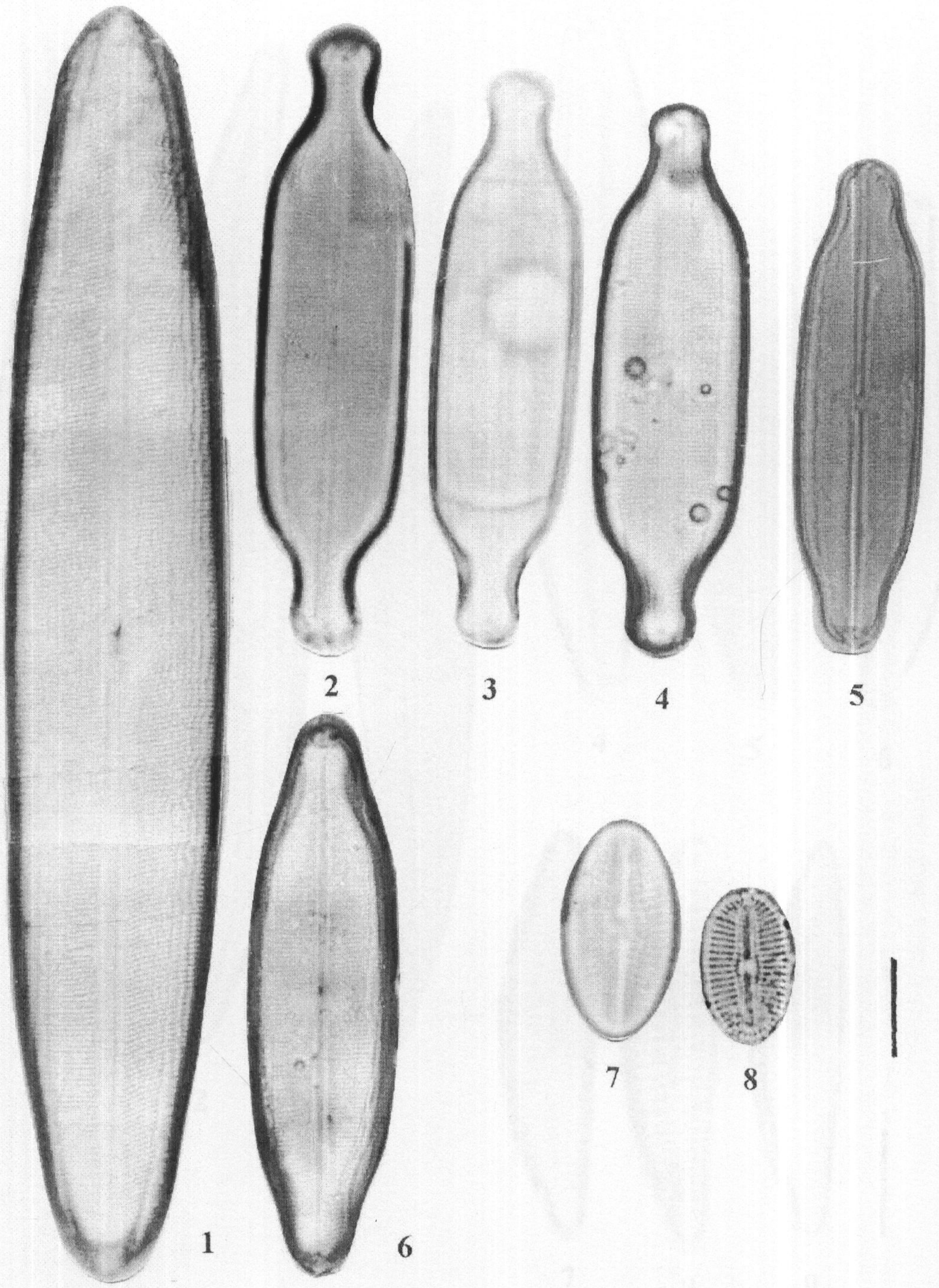


Figure 14. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1- *Neidium iridis* (Ehrenberg) Cleve, 2-5- *Neidium* spp., 6- *N. ampliatum* (Ehrenberg) Krammer, 7- *Diploneis elliptica* (Kützing) Cleve, 8- *Diploneis oblongella* (Naegeli) Cleve-Euler

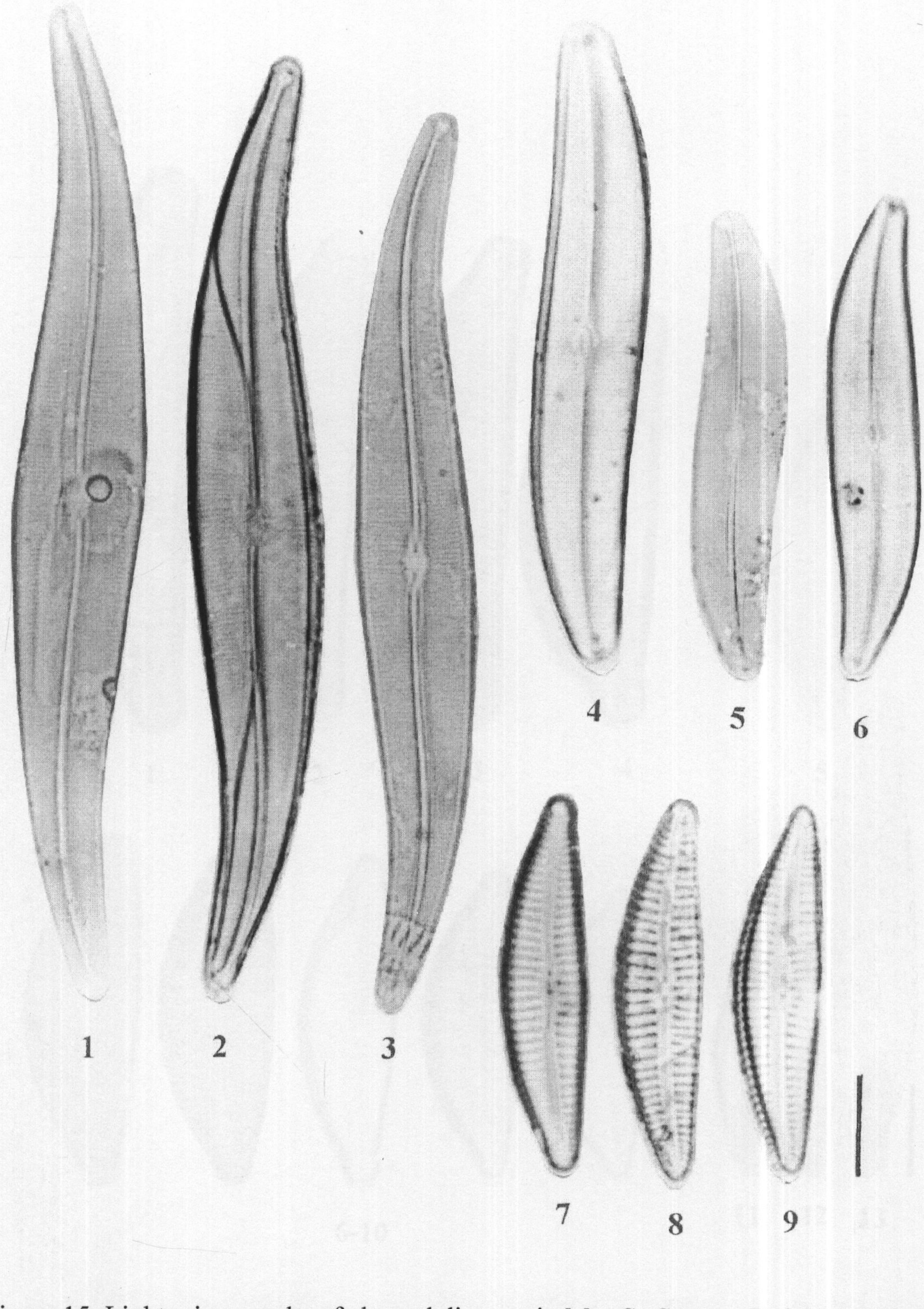


Figure 15. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-3- *Gyrosigma spencerii* (Quekett) Griffith & Henfrey, 4-6- *G. scalproides* (Rabenhorst) Cleve, 7-9- *Cymbella affinis* Kützing

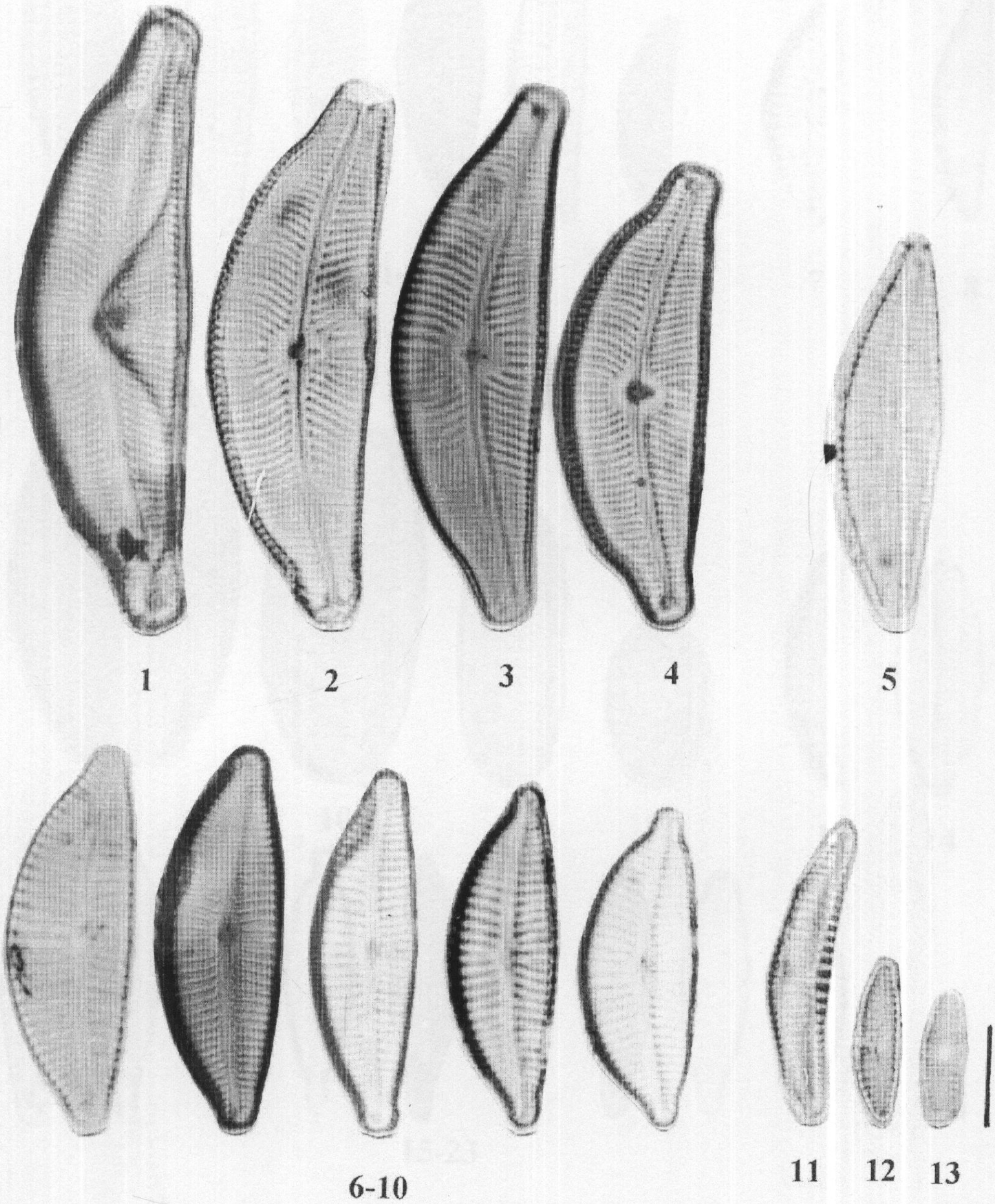


Figure 16. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1-4- *Cymbella tumida* (Brébisson) Van Heurck, 5- *Cymbella* sp., 6-10- *C. turgidula* Grunow, 11-12- *Cymbella* spp., 13- *Reimeria sinuata* Gregory

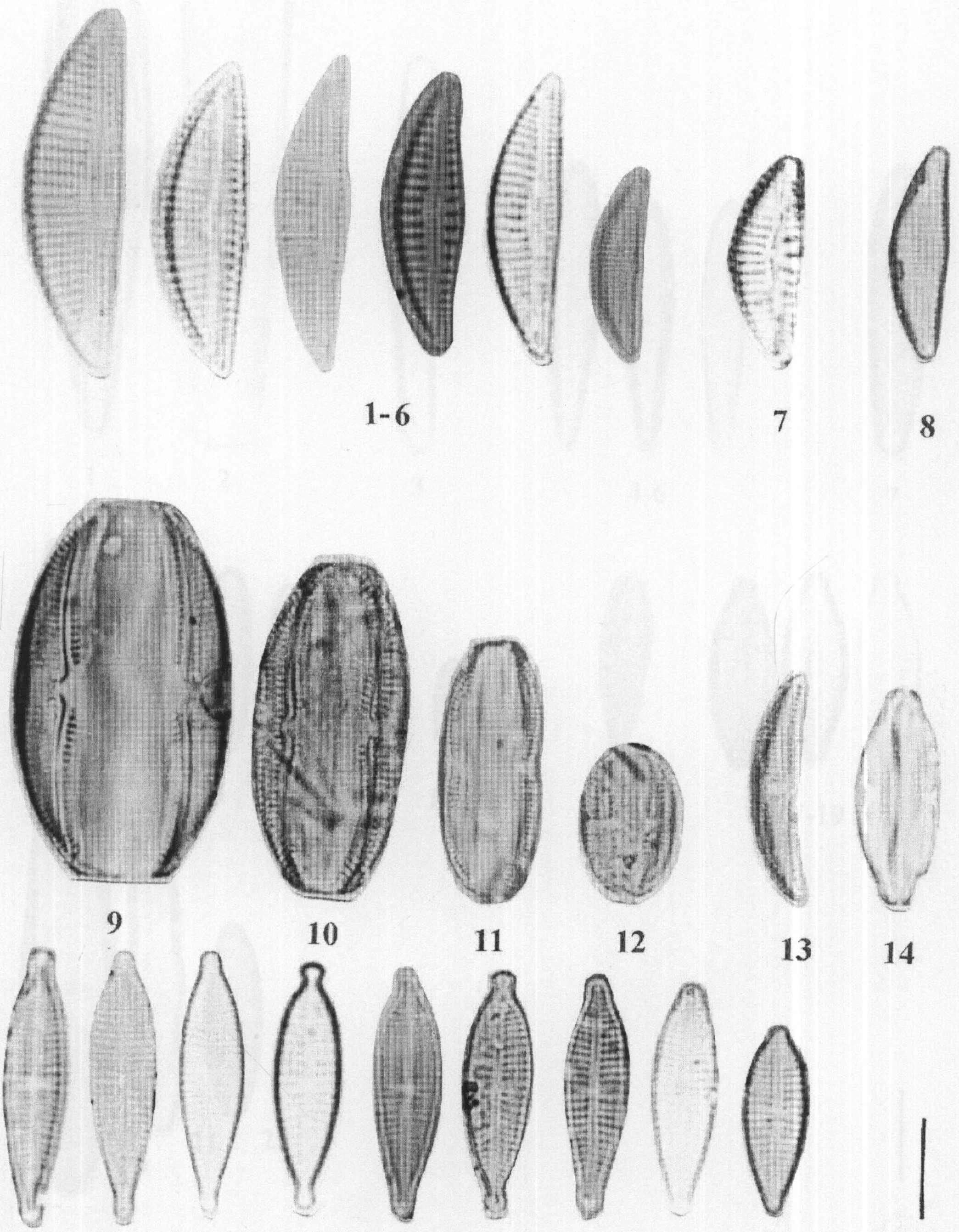


Figure 17. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1-6- *Encyonema silesiacum* (Bleisch) D. G. Mann, 7- *Cymbella minuta* Hilse, 8- *Encyonema* cf. *latereolatum* Krammer, 9- *Amphora ovalis* (Kützing) Kützing, 10,13- *A. libyca* Ehrenberg, 11- *A. aequalis* Krammer, 12- *A. pediculus* (Kützing) Grunow, 14- *Amphora* sp., 15-23- *Gomphonema parvulum* (Kützing) Kützing

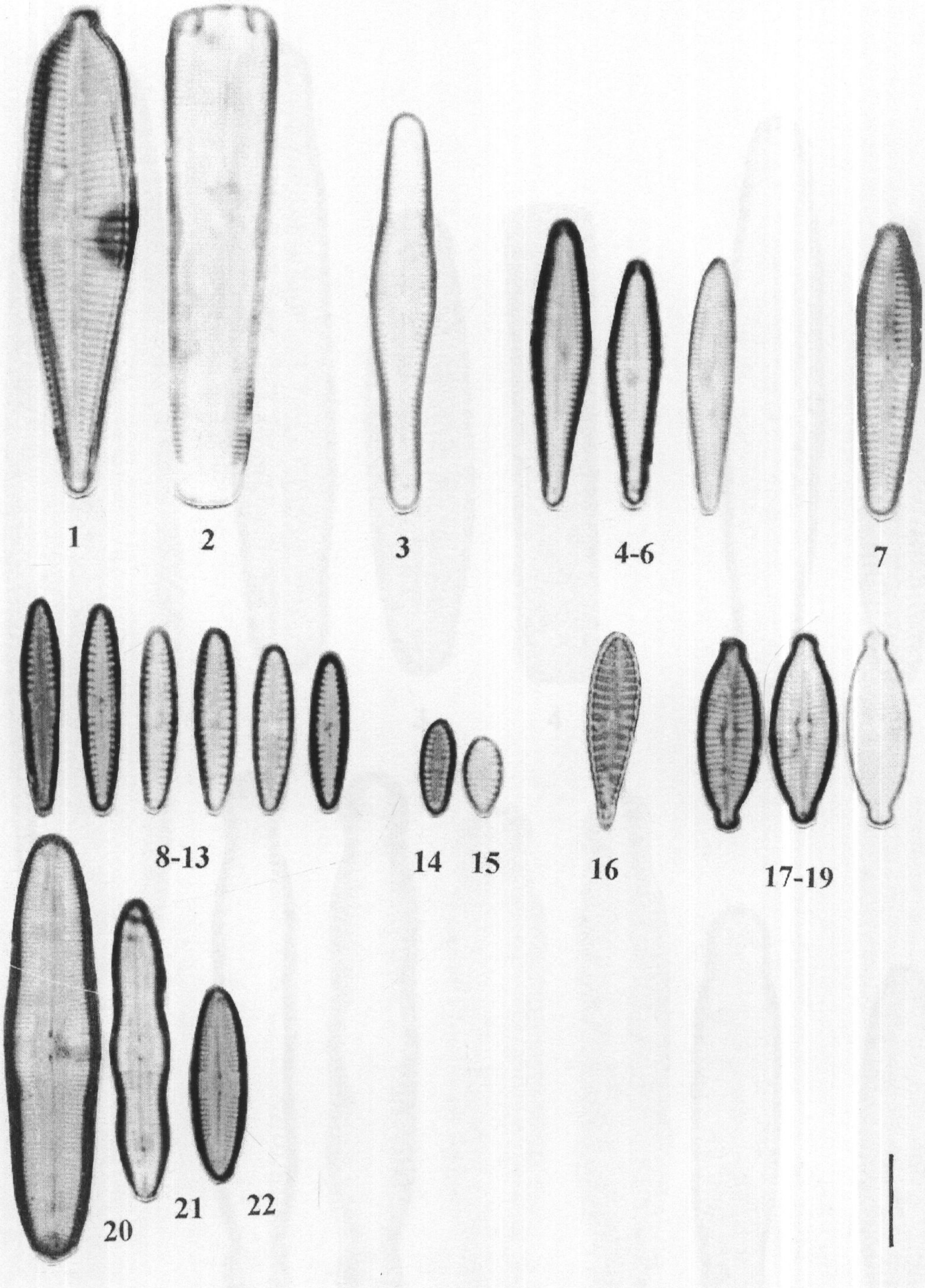


Figure 18. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-2- *Gomphonema gracile* Ehrenberg, 3- *G. lingulatiforme* Lange-Bertalot & Reichardt, 4-6- *G. clevei* Fricke, 7- *Gomphonema* sp., 8-13- *G. pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, 14-15- *Gomphonema* sp., 16- *Gomphonema* sp., 17-19- *Gomphonema* sp., 20-21- *Caloneis silicula* (Ehrenberg) Cleve, 22- *C. bacillum* (Grunow) Cleve

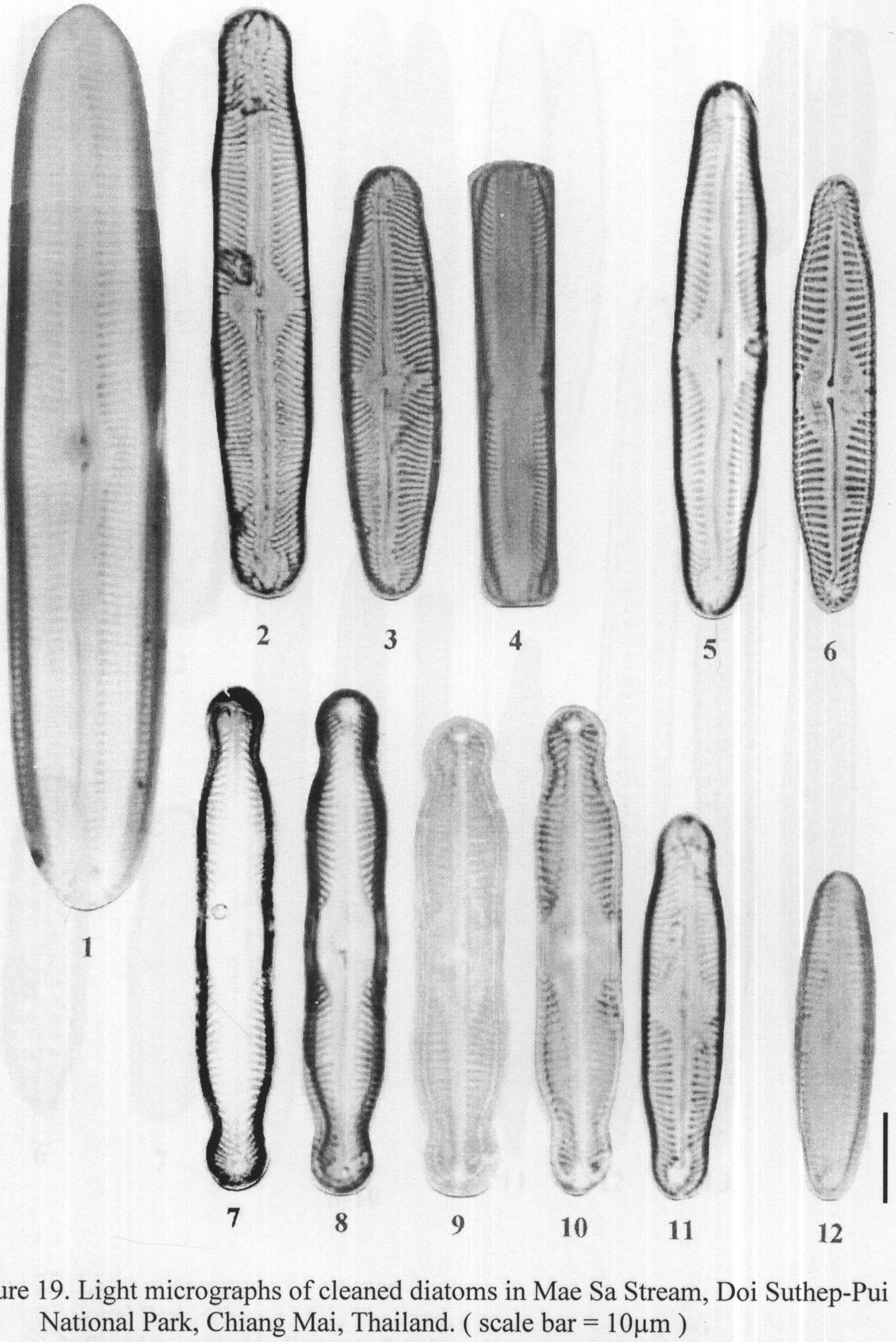


Figure 19. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1- *Pinnularia viridis* (Nitzsch) Ehrenberg, 2-4- *P. platycephala* (Ehrenberg) Cleve, 5-6- *P. subgibba* Krammer, 7-11- *P. mesolepta* (Ehrenberg) W. Smith, 12- *P. schoenfelderi* Krammer

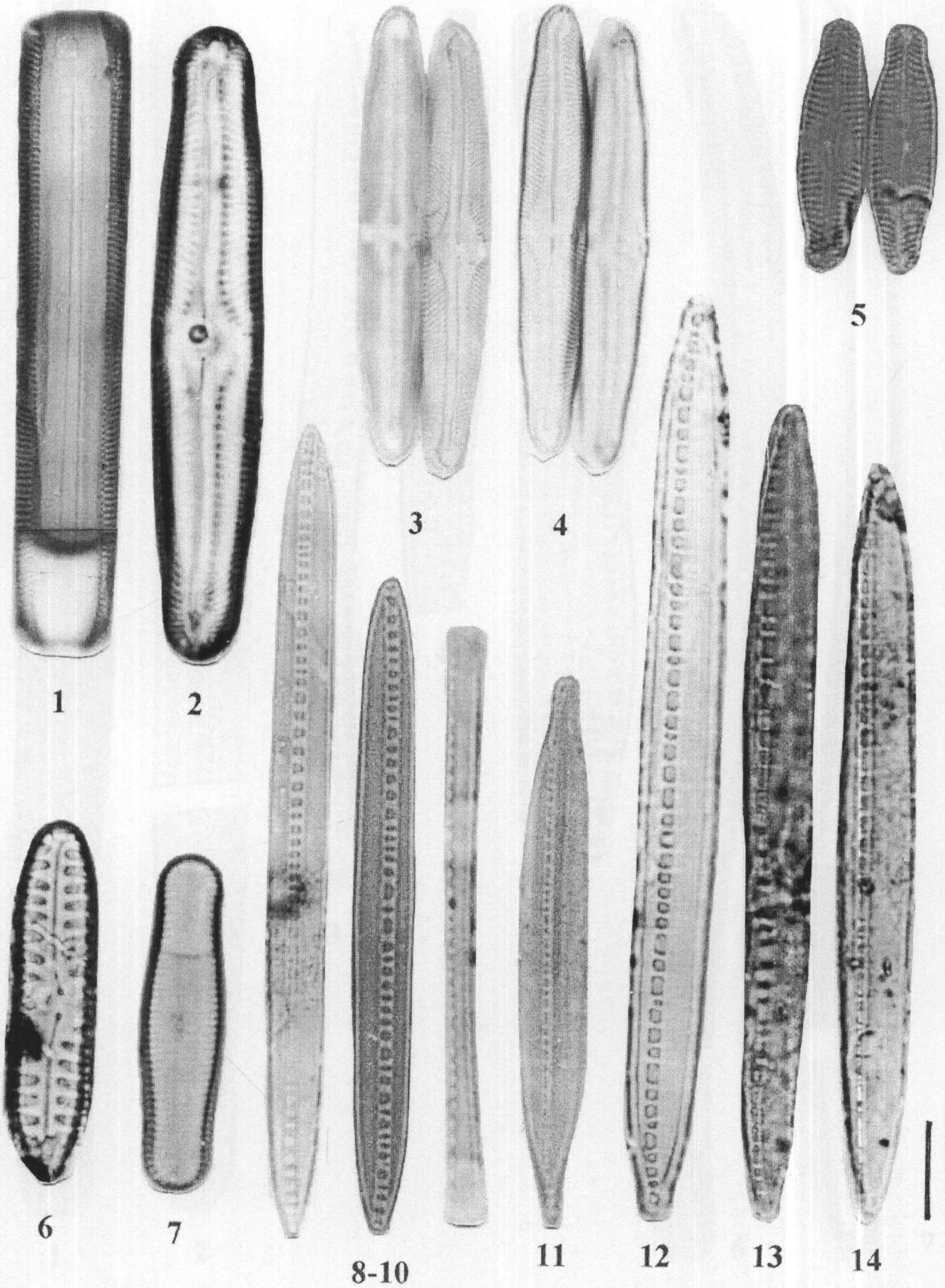


Figure 20. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-2- *Pinnularia subgibba* Krammer, 3-4- *Pinnularia* spp., 5- *P. subinterupta* Krammer & Schroeter,6- *P. borealis* var. *scalaris* (Ehrenberg) Rabenhorst, 7- *P. acrosphaeria* W. Smith, 8-10- *Bacillaria paradoxa* Gmelin, 11-14- *Nitzschia dissipata* (Kützing) Grunow

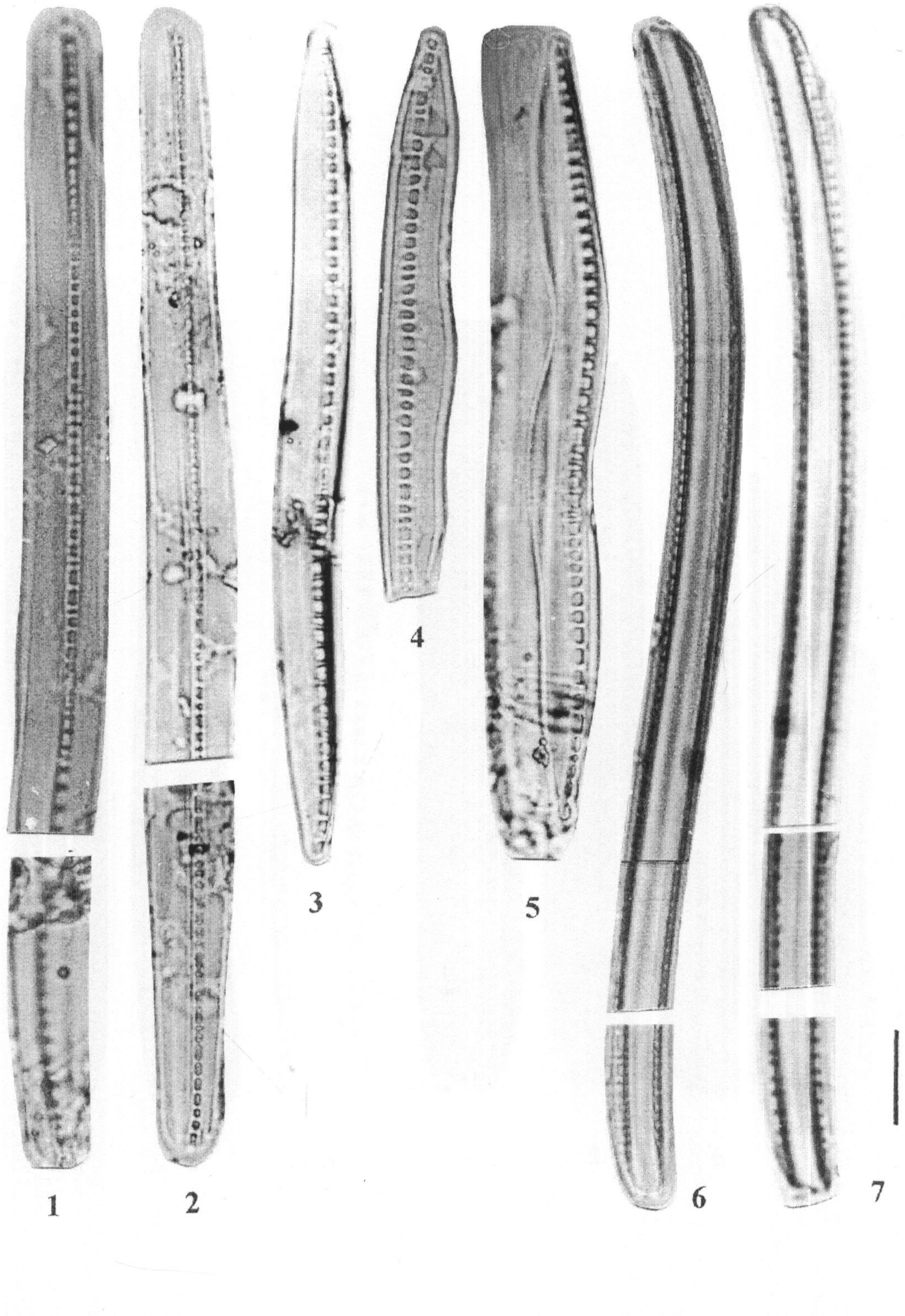


Figure 21. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-2- *Nitzschia geitleri* Hustedt, 3-5- *N. dissipata* (Kützing) Grunow, 6-7- *N. sigmoidea* (Ehrenberg) W. Smith

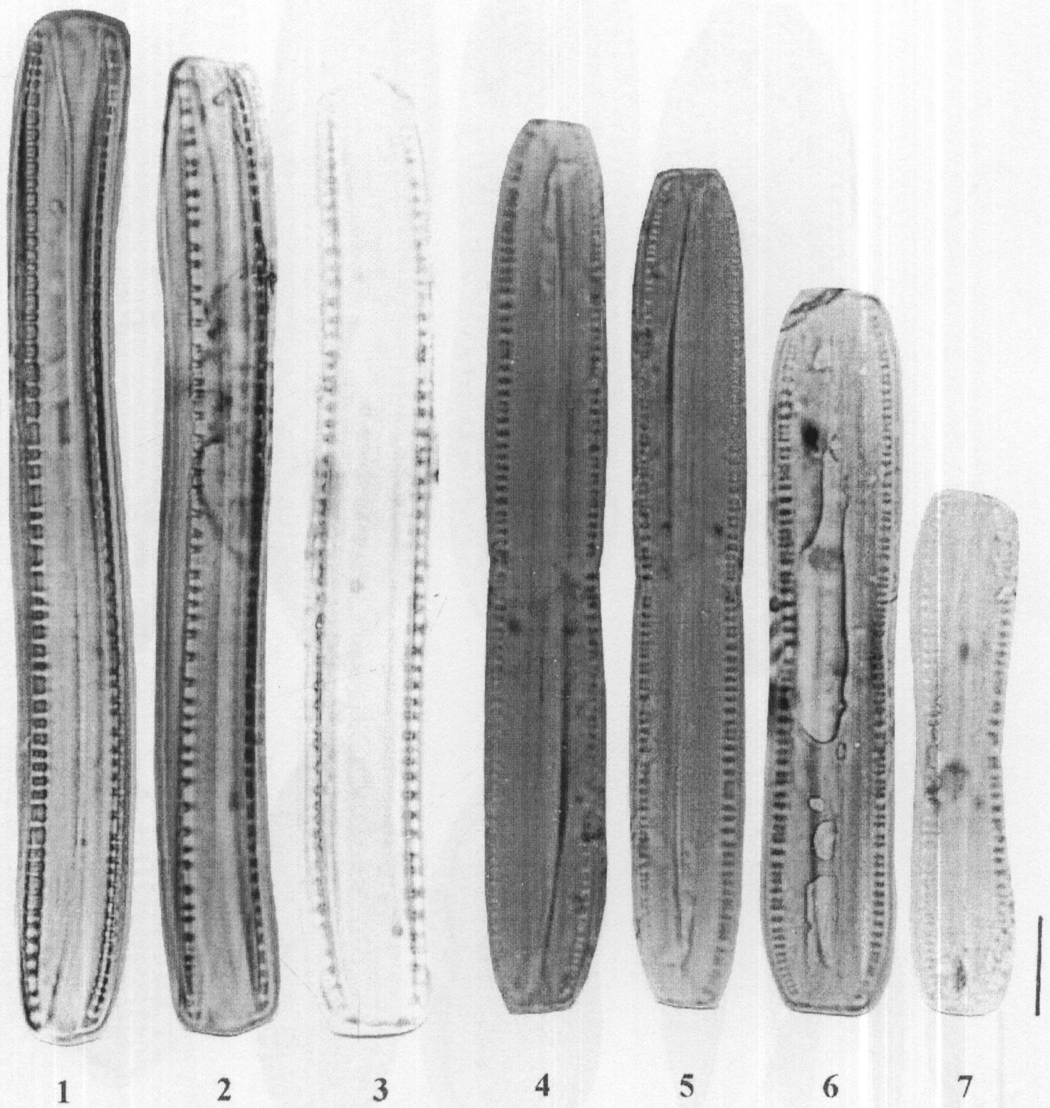


Figure 22. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)
1-7- *Nitzschia* spp.

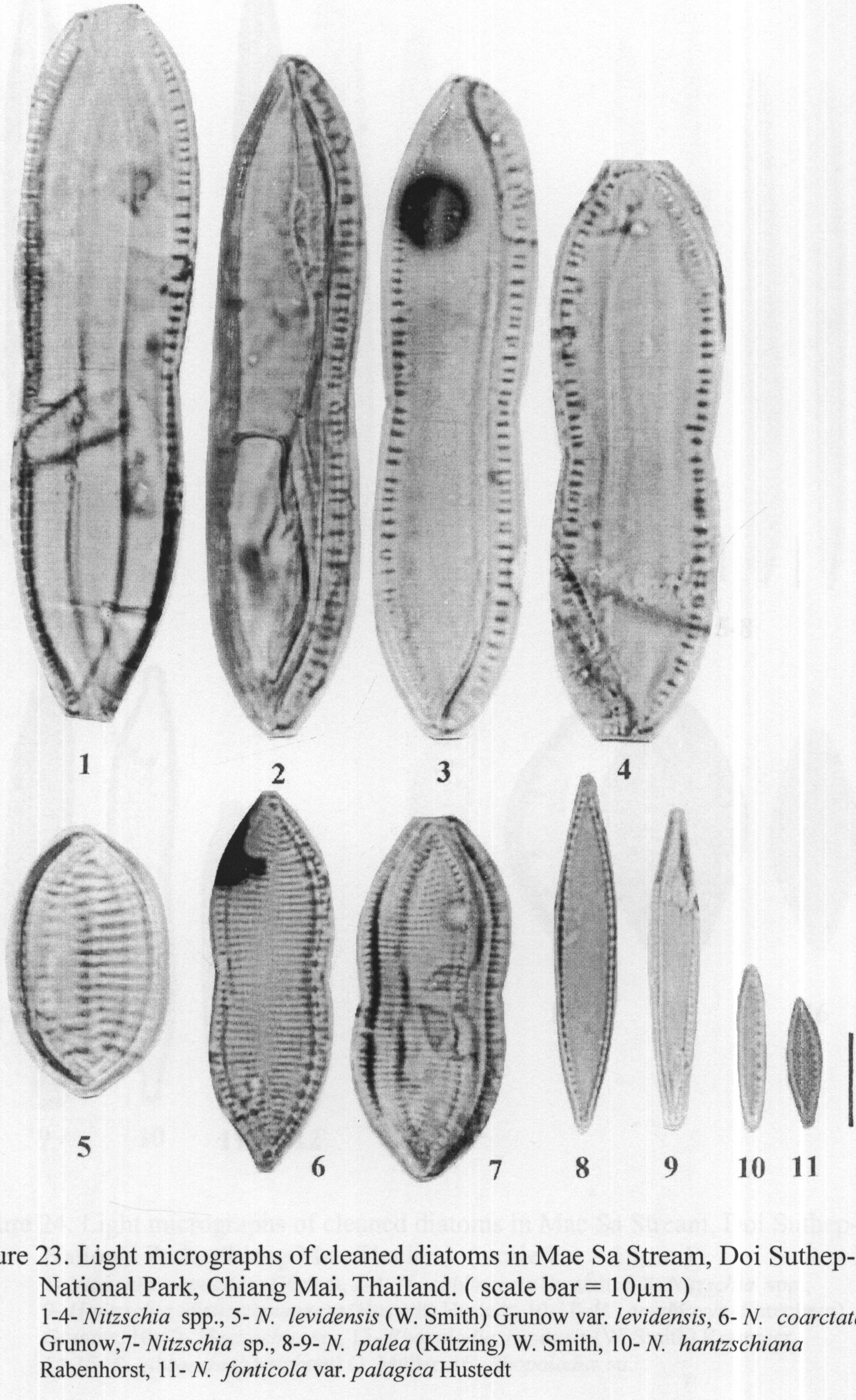


Figure 23. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1-4- *Nitzschia* spp., 5- *N. levidensis* (W. Smith) Grunow var. *levidensis*, 6- *N. coarctata* Grunow,7- *Nitzschia* sp., 8-9- *N. palea* (Kützing) W. Smith, 10- *N. hantzschiana* Rabenhorst, 11- *N. fonticola* var. *palagica* Hustedt

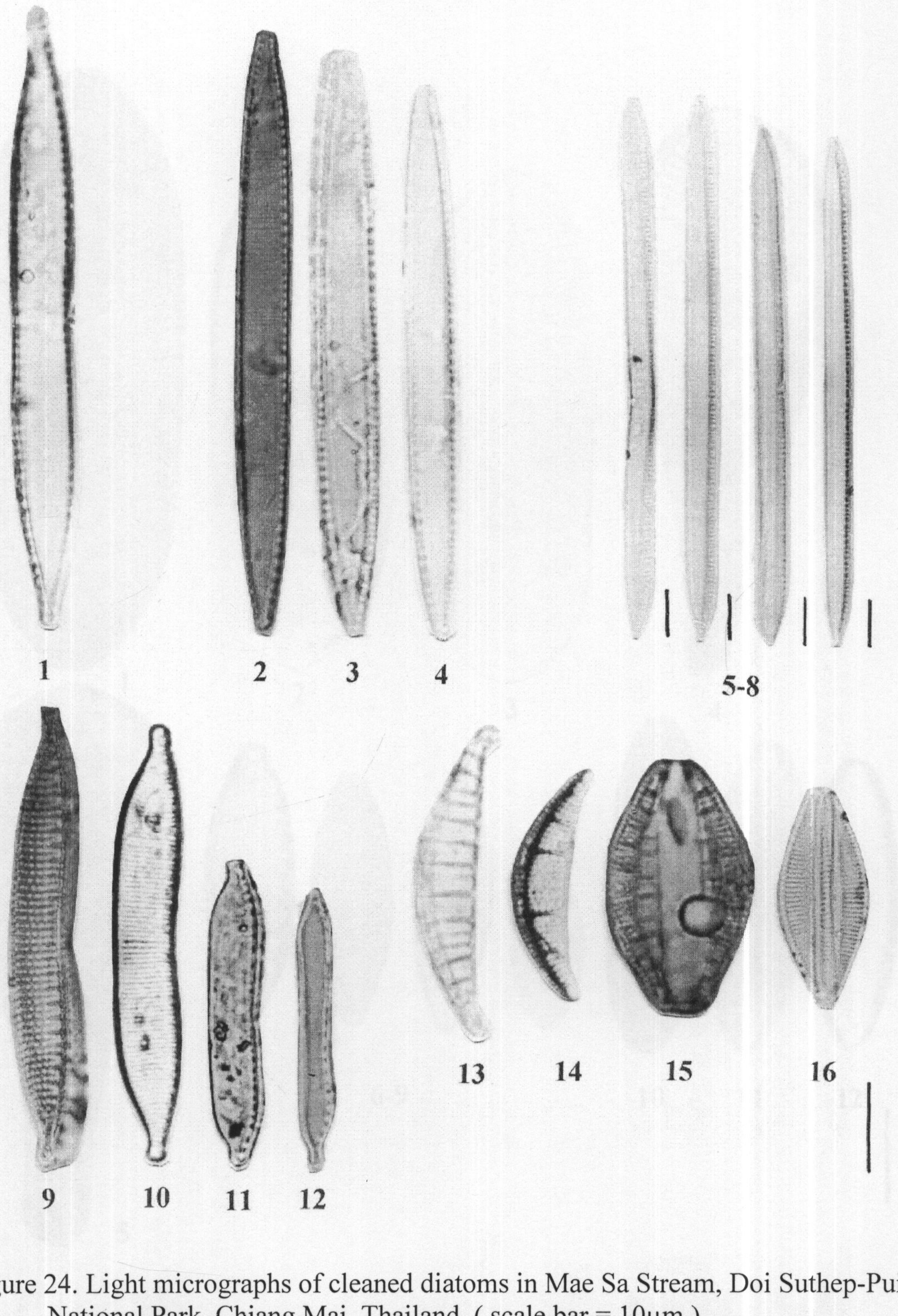


Figure 24. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)

1- *Nitzschia capitellata* Hustedt, 2-4- *N. sublinearis* Hustedt, 5-8- *Nitzschia* spp., 9- *Hantzschia distinctepunctata* (Hustedt) Hustedt, 10-11- *H. amphioxys* (Ehrenberg) Grunow, 10-12- *Hantzschia* sp., 13- *Rhopalodia rupestris* (W. Smith) Krammer, 14-15- *R. gibberula* (Ehrenberg) O. Müller, 16- *Rhopalodia* sp.

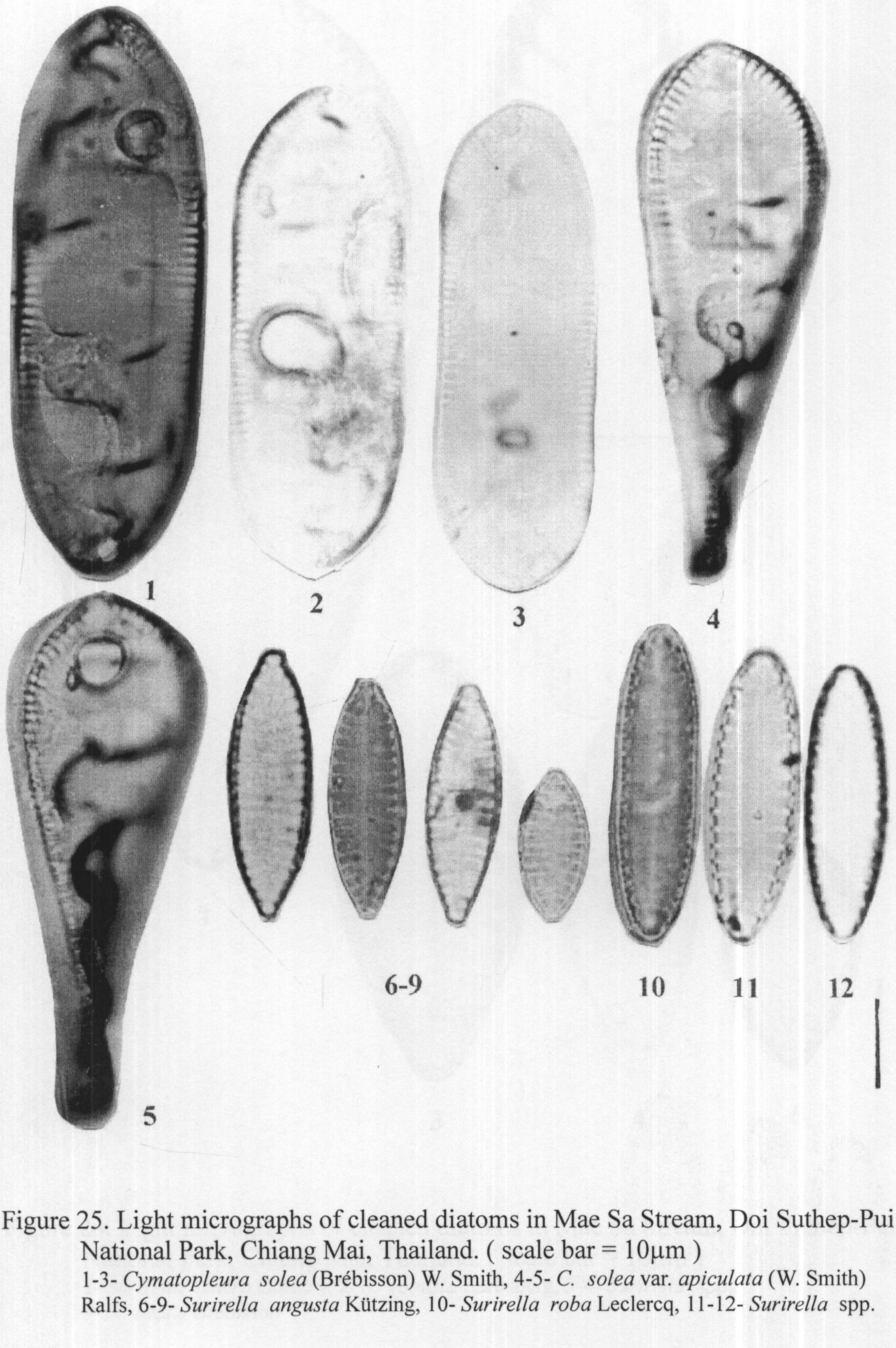


Figure 25. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1-3- *Cymatopleura solea* (Brébisson) W. Smith, 4-5- *C. solea* var. *apiculata* (W. Smith) Ralfs, 6-9- *Surirella angusta* Kützing, 10- *Surirella roba* Leclercq, 11-12- *Surirella* spp.

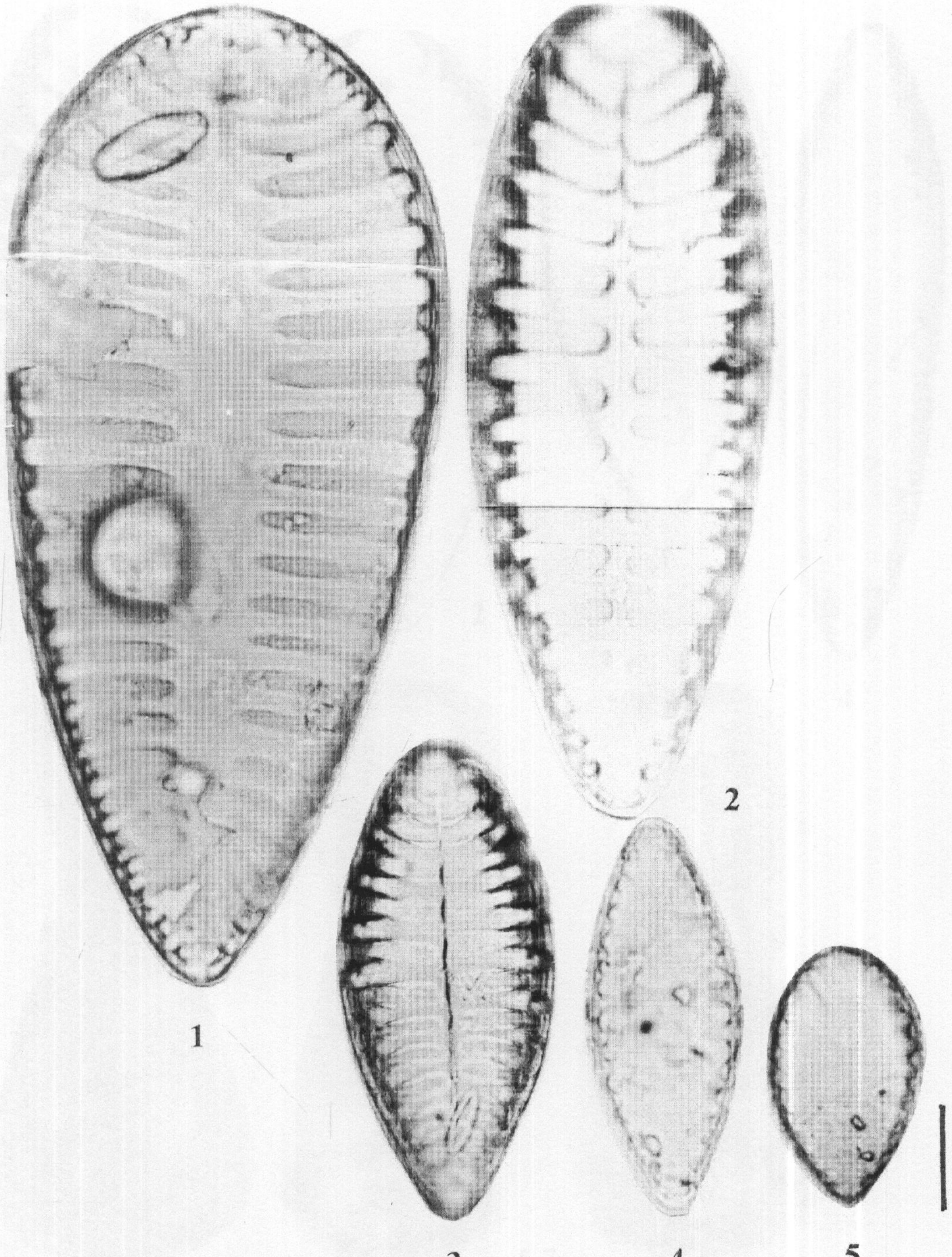


Figure 26. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10μm)
1- *Surirella tenera* Grunow, 2- *S. robusta* Ehrenberg, 3-4- *Surirella* spp., 5- *S. ovalis* Brébisson

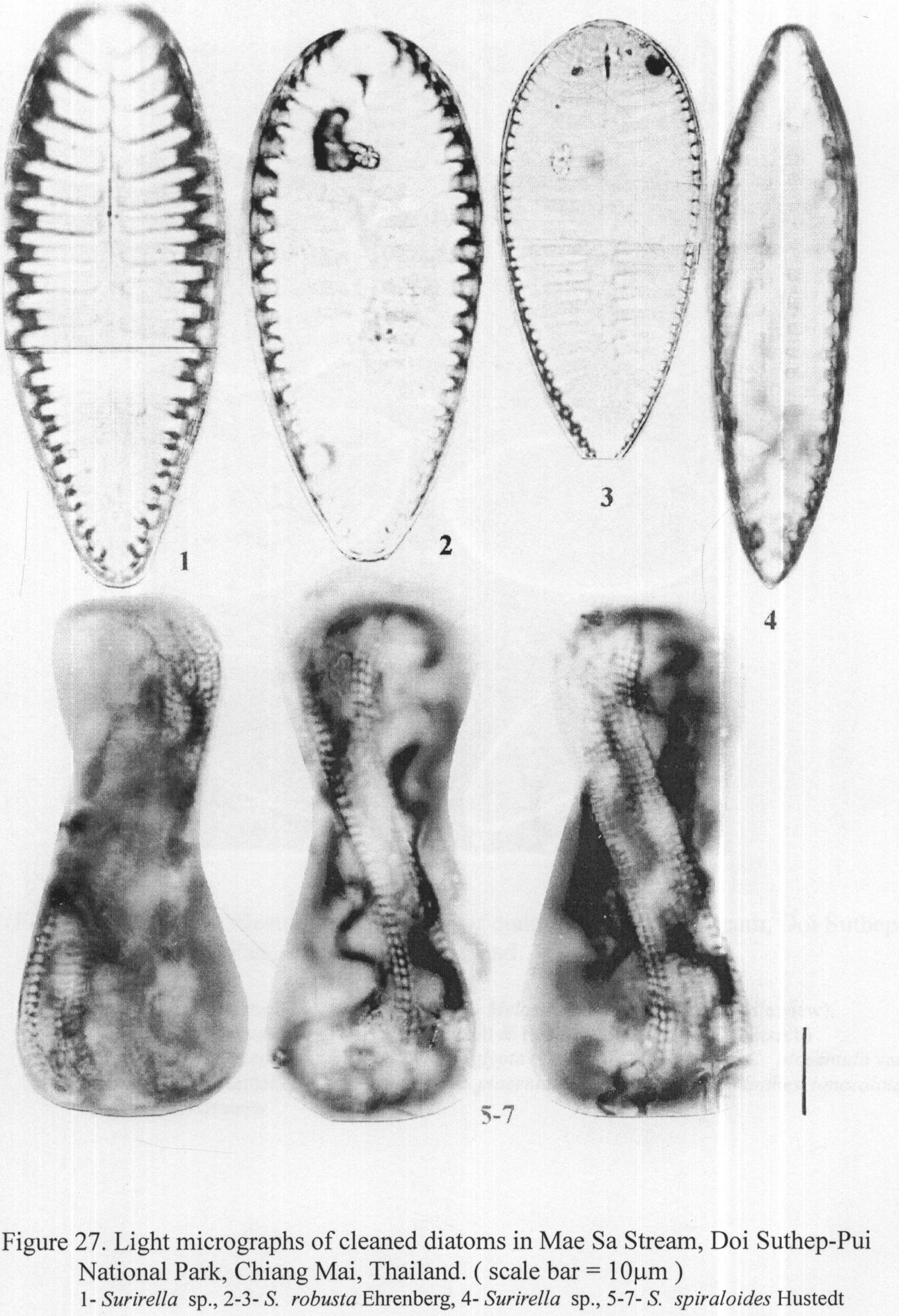


Figure 27. Light micrographs of cleaned diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scale bar = 10µm)

1- *Surirella* sp., 2-3- *S. robusta* Ehrenberg, 4- *Surirella* sp., 5-7- *S. spiraloides* Hustedt

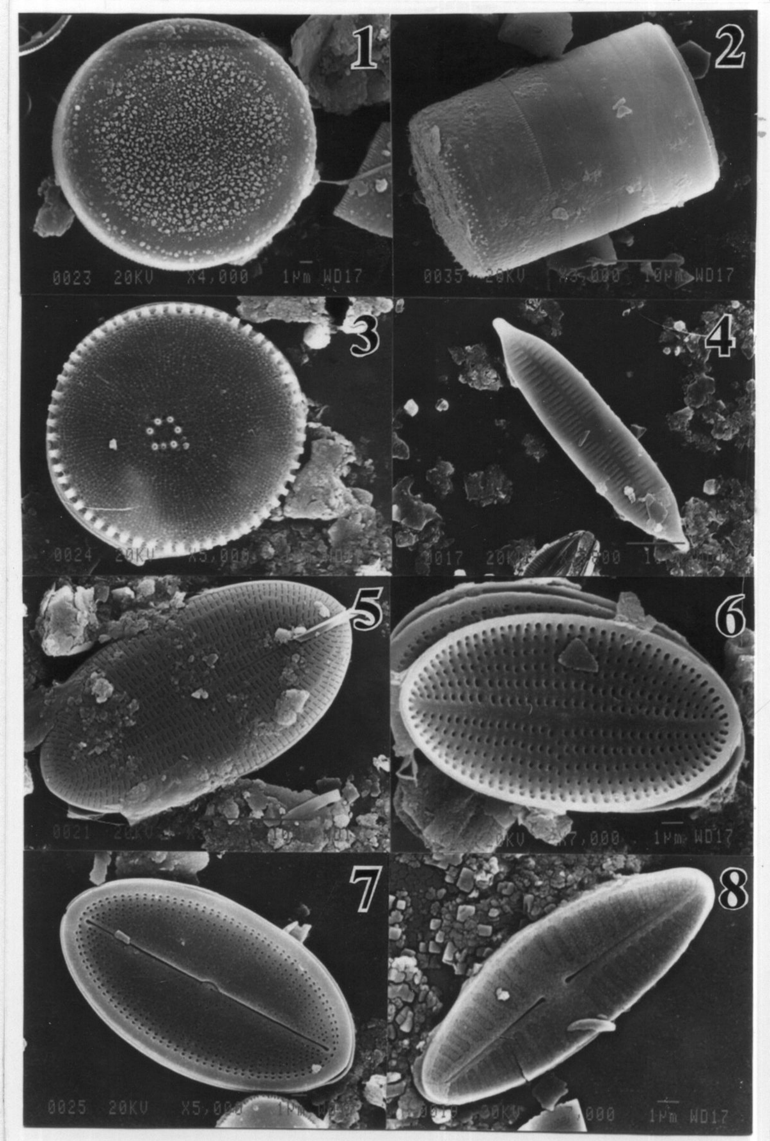


Figure 28. Scanning Electron Micrographs of diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

1- *Melosira varians* Agardh (valve view), 2- *Melosira varians* Agardh (girdle view), 3- *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle, 4- *Synedra ulna* (Nitzsch) Ehrenberg, 5- *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow, 6- *C. placentula* var. *pseudolineata* Geitler, 7- *C. placentula* var. *placentula* Ehrenberg, 8- *Achnanthes lanceolata* (Brébisson) Grunow

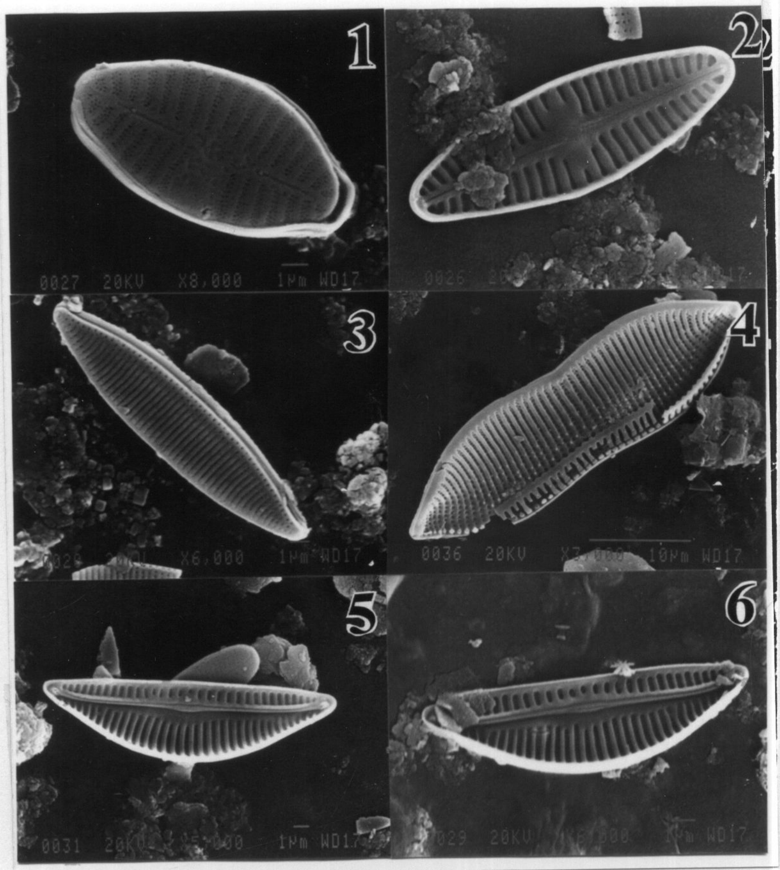


Figure 29. Scanning Electron Micrographs of diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

1-2- *Achnanthes lanceolata* (Brébisson) Grunow, 3- *Nitzschia* sp., 4- *N. coarctata* Grunow, 5-6- *Cymbellopsis* cf. *lanceolata* Krammer

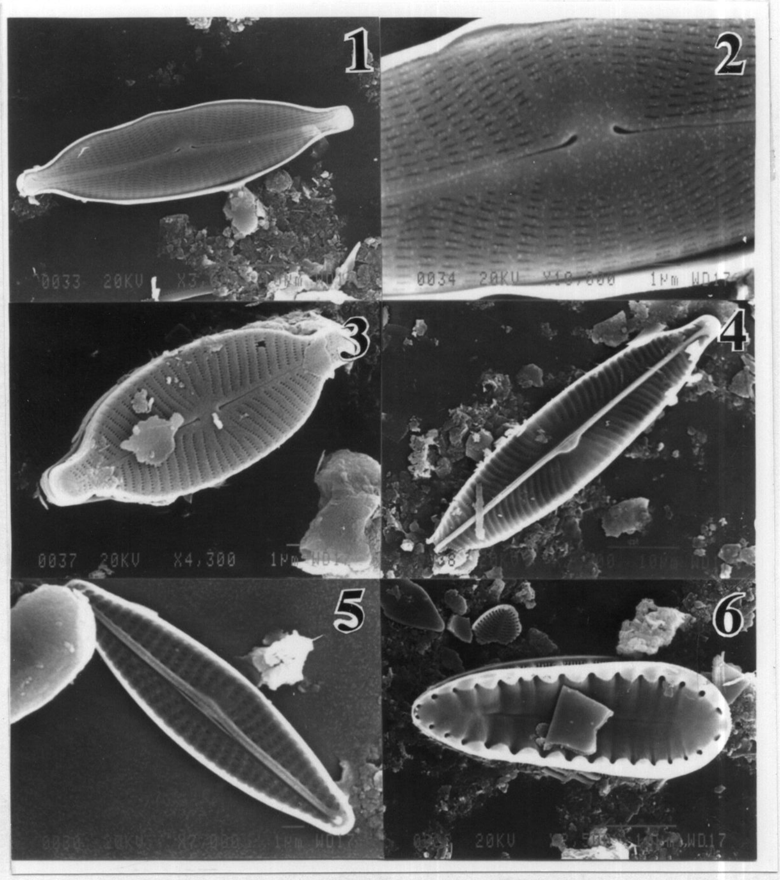


Figure 30. Scanning Electron Micrographs of diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

1-2- *Navicula* sp., 3- *N. elginensis* (Gregory) Ralfs var. *elginensis*, 4- *N. viridula* (Kützing) Ehrenberg var. *viridula*, 5- *Navicula* sp., 6- *Surirella* sp.

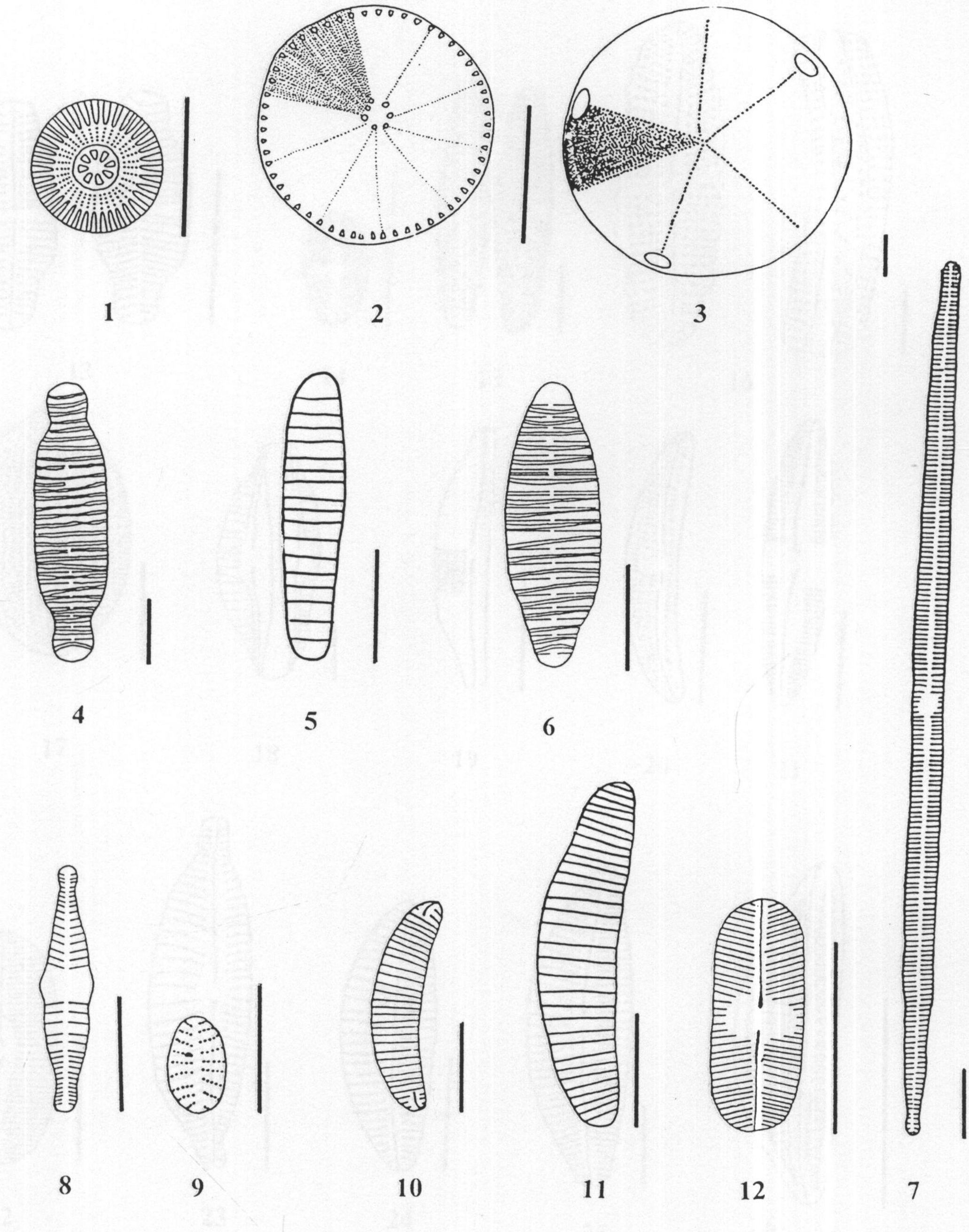


Figure 31. Hand-drawing of newly recorded diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scales = 10μm)

1- *Cyclotella stelligera* Cleve & Grunow, 2- *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle, 3- *Actinocyclus normanii* (Gregory) Hustedt, 4- *Diatoma ehrenbergii* Kützing, 5- *Diatoma moniliformis* Kützing, 6- *Diatoma vulgaris* Bory, 7- *Fragilaria biceps* (Kützing) Lange-Bertalot, 8- *Fragilaria bidens* Heiberg, 9- *Fragilaria elliptica* Schumann, 10- *Eunotia bilunaris* (Ehrenberg) Mills var. *bilunaris*, 11- *Eunotia minor* (Kützing) Grunow, 12- *Achnanthes chlidanos* Hohn & Hellermann

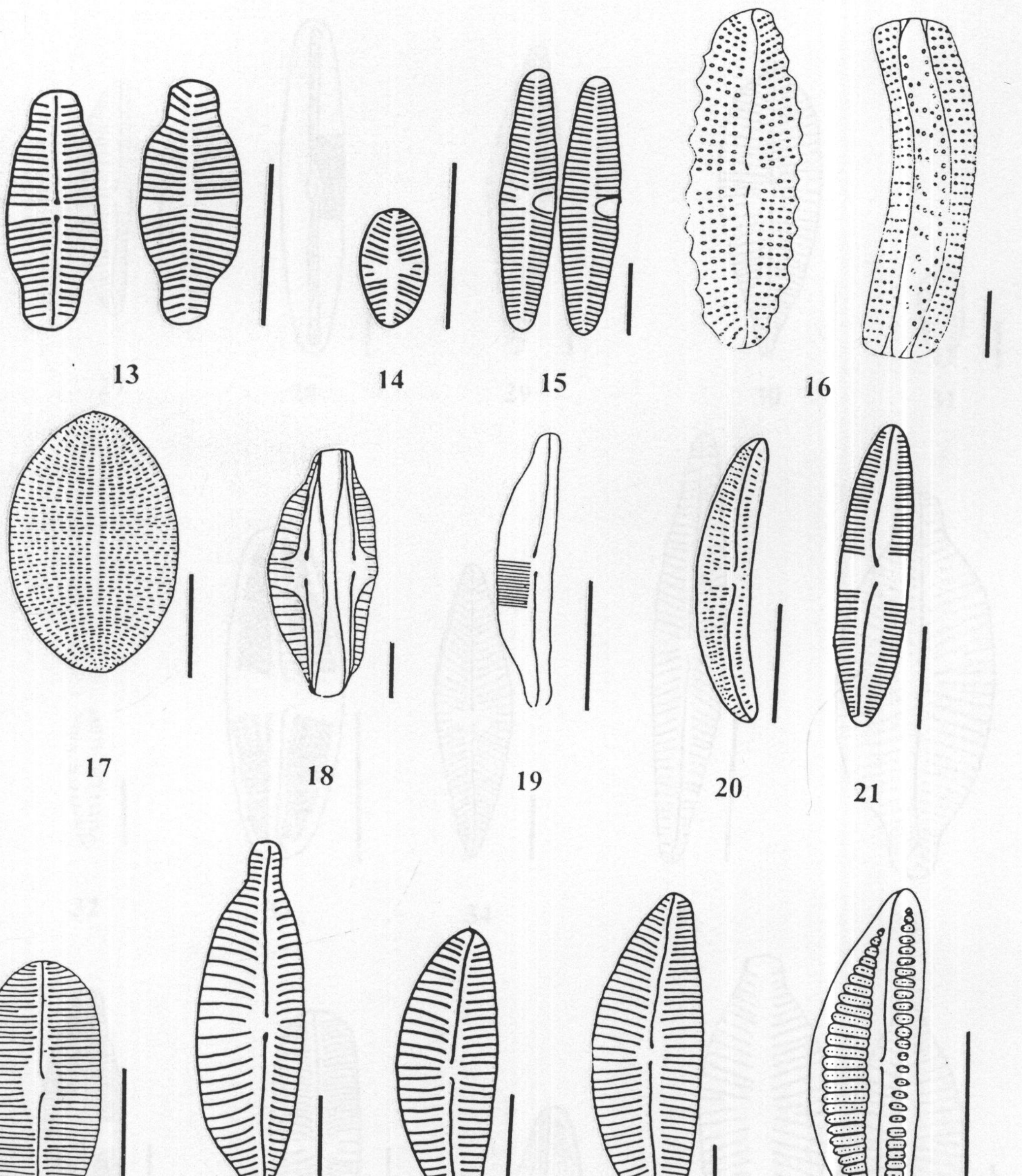


Figure 32. Hand-drawing of newly recorded diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scales = 10μm)

13- *Achnanthes exigua* Grunow var. *exigua*, 14- *Achnanthes helvetica* (Hustedt) Lange-Bertalot, 15- *Achnanthes lanceolata* var. *boyei* (Oestrup) Lange-Bertalot, 16- *Achnanthes undata* Meister, 17- *Cocconeis placentula* var. *pseudolineata* Geit, 18- *Amphora coffeaeformis* (Agardh) Kützing var. *coffeaeformis*, 19- *Amphora dusenii* Brun, 20- *Amphora libyca* Ehrenberg, 21- *Caloneis lauta* Carter & Bailey-Watts, 22- *Caloneis silicula* (Ehrenberg) Cleve, 23- *Cymbella amphicephala* Naegeli, 24- *Cymbella hustedtii* Krasske, 25- *Cymbella turgidula* Grunow, 26- *Cymbellopsis* cf. *lanceolata* Krammer

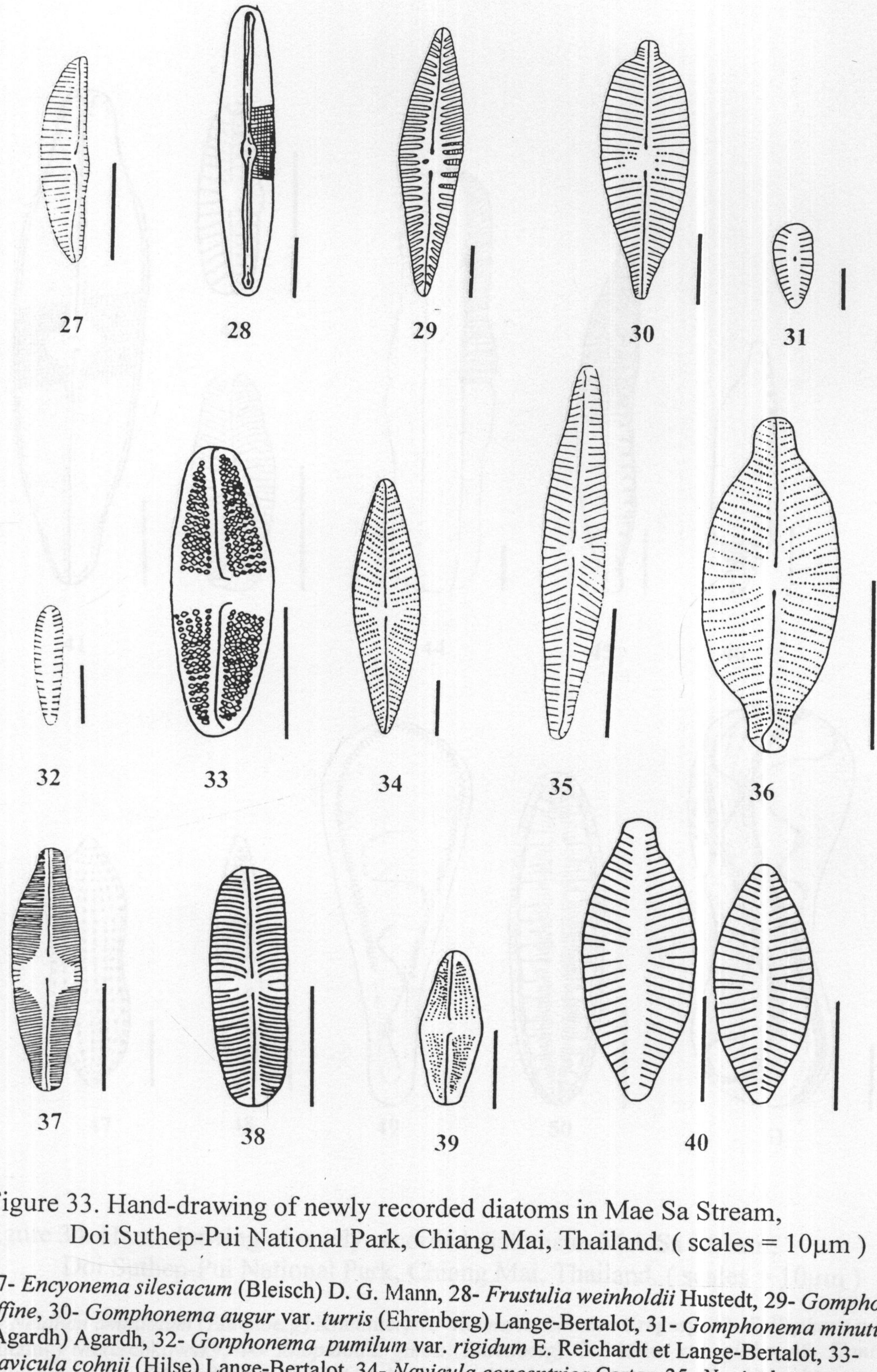


Figure 33. Hand-drawing of newly recorded diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scales = 10μm)

27- *Encyonema silesiacum* (Bleisch) D. G. Mann, 28- *Frustulia weinholdii* Hustedt, 29- *Gomphonema affine*, 30- *Gomphonema augur* var. *turris* (Ehrenberg) Lange-Bertalot, 31- *Gomphonema minutum* (Agardh) Agardh, 32- *Gonphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, 33- *Navicula cohnii* (Hilse) Lange-Bertalot, 34- *Navicula concentrica* Carter, 35- *Navicula cryptotenella* Lange-Bertalot, 36- *Navicula elginensis* (Gregory) Ralfs var. *elginensis*, 37- *Navicula jaagii* Meister, 38- *Navicula laevissima* Kützing var. *laevissima*, 39- *Navicula mutica* Kützing var. *mutica*, 40- *Navicula subplacentula* Hustedt

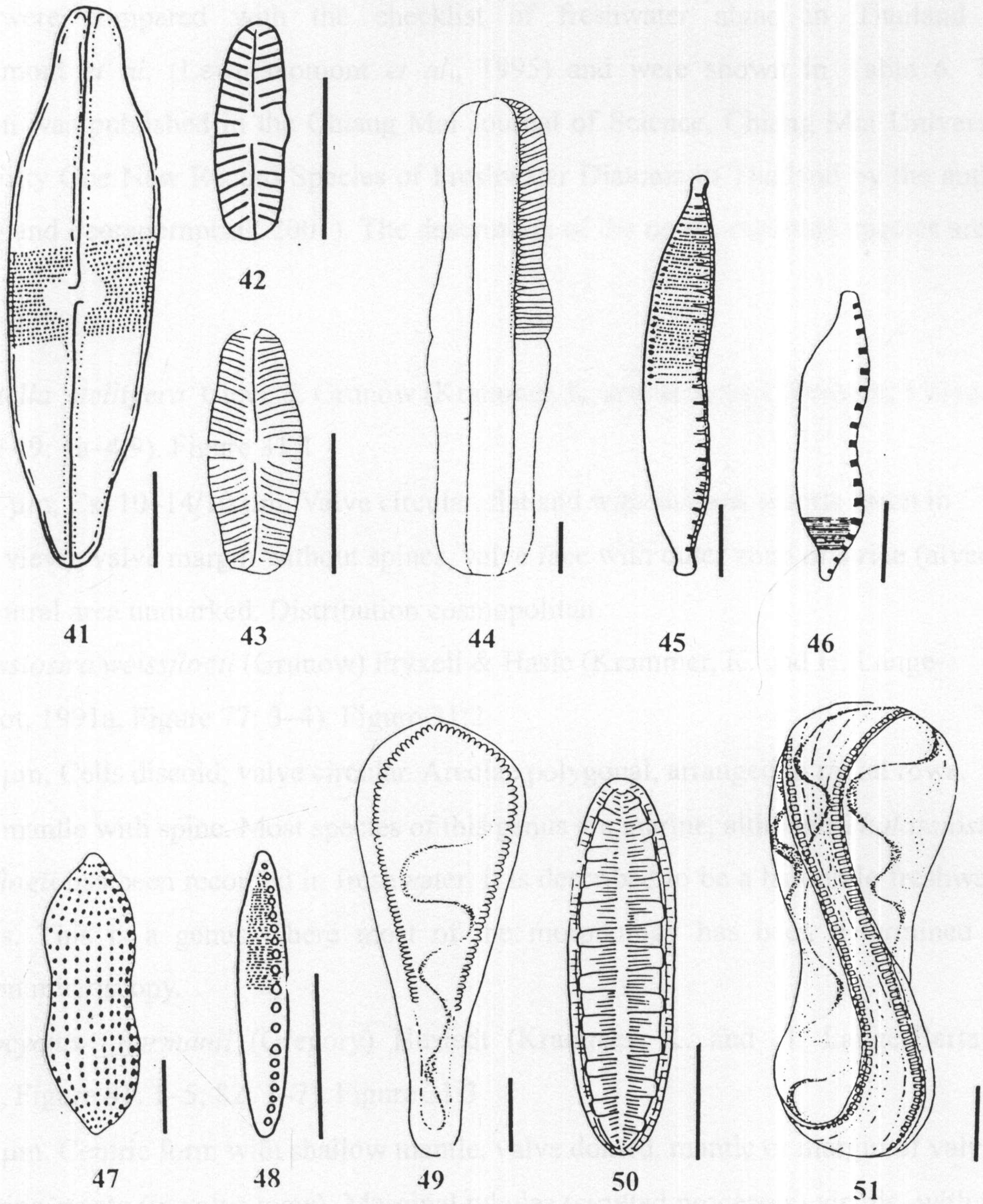


Figure 34. Hand-drawing of newly recorded diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (scales = 10μm)

41- *Neidium ampliatum* (Ehrenberg) Krammer, 42- *Reimeria sinuata* Gregory, 43- *Sellaphora pupula* (Kützing) Mereschkowsky, 44- *Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba*, 45- *Hantzschia distinctepunctata* (Hustedt) Hustedt, 46- *Nitzschia brevissima* Grunow, 47- *Nitzschia coarctata* Grunow, 48- *Nitzschia hantzschiana* Rabenhorse, 49- *Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs, 50- *Surirella roba* Leclercq, 51- *Surirella spiraloides* Hustedt

4.1.2 Newly Recorded species

Fifty one benthic diatom species were considered to be newly recorded in Thailand, and could be classified into 2 orders, 3 suborders, 9 families and 23 genera. The species of diatoms were compared with the checklist of freshwater algae in Thailand by Lewmanomont *et al.* (Lewmanomont *et al.*, 1995) and were shown in Table 6. The publication was published in the Chiang Mai Journal of Science, Chiang Mai University entitled: Fifty One New Record Species of Freshwater Diatoms in Thailand by the author (Pekthong and Peerapornpisal, 2001). The description of the newly recorded species are as follows.

1) *Cyclotella stelligera* Cleve & Grunow (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 49: 1a–4,9). Figure 31:1
   D: 9.3 µm, Cs: 10–14/10 µm. Valve circular, flat and with shallow mantle (seen in girdle view), valve margin without spines, valve face with outer zone of striae (alveoli) and central area unmarked. Distribution cosmopolitan.
2) *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 77: 3–4). Figure 31:2
   D: 17 µm, Cells discoid, valve circular. Areolae polygonal, arranged in radial rows. Valve mantle with spine. Most species of this genus are marine, although *Thalassiosira weissflogii* has been recorded in freshwater, it is described to be a halophile freshwater species. This is a genus where most of the morphology has been determined by electron microscopy.
3) *Actinocyclus normanii* (Gregory) Hustedt (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 81: 1–5; 82: 1–7). Figure 31:3
   D: 68 µm. Centric form with shallow mantle, valve domed, mantle or margin of valve appearing striate (in valve view). Marginal tubules (strutted processes) visible, with out spines. Small refractive area usually visible at or near the valve margin. Hexagonal areolae are equally spaced in straight rows of variable length. This is a freshwater species.

4) *Diatoma ehrenbergii* Kützing (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 97: 2). Figure 31:4

L: 52.3 µm, W: 8.1 µm, Cs: 9–10/10 µm. Cells elongate, rectangular in girdle view, valves narrowly linear with broadly rounded slightly capitate apices (truncated). Distribution cosmopolitan.

5) *Diatoma moniliformis* Kützing (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 96: 17). Figure 31:5

L: 26 µm, W: 5 µm, Cs: 8/10 µm . Valve isopolar, cells elongate, outline linear elliptic or linear without capitate ends.

6) *Diatoma vulgaris* Bory (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 93: 10). Figure 31:6

L: 28.2–72 µm, W: 7.9–12 µm, Cs: 7/10 µm . Valve elliptic lanceolate with capitate ends. Isopolar and isobilateral. Thickened transapical costae, striae fine. Axial area (pseudoraphe) present on both valves.

7) *Fragilaria biceps* (Kützing) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 121: 1–5). Figure 31:7

L: 125 µm, W: 4 µm, Str: 16/10 µm. Shape needle-like, valve linear, isopolar, with rostrate ends. Striae parallel and absent from the central area. Distribution cosmopolitan especially in oligotrophic habitat.

8) *Fragilaria bidens* Heiberg (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 111: 20–21). Figure 31:8

L: 20.9 µm, W: 3.5 µm, Str: 15/10 µm. Valve linear, isopolar, with rostrate ends. Central area a wide rectangular, obviously swollen on both sides. Axial area narrow Distribution cosmopolitan.

9) *Fragilaria elliptica* Schumann (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 130: 31–32). Figure 31:9

L: 3–10 µm, W: 3–6 µm, Str: 11–16/10 µm. Valve round to linear elliptic with small spine on margin. Distribution cosmopolitan in freshwater and brackish.

10) *Eunotia bilunaris* (Ehrenberg) Mills var. *bilunaris* (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 137: 9). Figure 31:10

L: 23 µm, W: 6 µm, Str: 15/10 µm. Valve arcuate or crecentic with almost straight ventral margin, convex dorsal margin and slightly protected apices. End broadly rounded. Shortened raphe present on each mantle. Striae transapical, punctate.

11) *Eunotia minor* (Kützing) Grunow (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 142: 8). Figure 31:11

L: 40 µm, W: 9.5 µm, Str: 7–9/10 µm . Valve crecentic with almost straight ventral margin, convex dorsal margin and slightly protected apices. End broadly rounded. Shortened raphe present on each mantle. Striae transapical, punctate.

12) *Achnanthes chlidanos* Hohn & Hellermann (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 12: 25–26). Figure 31:12

L: 18 µm, W: 6 µm, Str: 22/10 µm. Valve linear elliptic, isopolar. Central area an acute-angled sub-fascia. Striae fine.

13) *Achnanthes exigua* Grunow var. *exigua* (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 23: 3–7). Figure 32:13

L: 12.8–15 µm, W: 4.6–7 µm, Str: 17–24/10 µm. Valve broadly linear elliptic with distinct broadly rostrate apices. Central area a wide transverse fascia.

14) *Achnanthes helvetica* (Hustedt) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 10: 12–15). Figure 32:14

L: 7 µm, W: 7.3 µm, Str: 23/10 µm. Valve linear elliptic. Axial area linear. Central area an acute-angled fascia. Distribution cosmopolitan.

15) *Achnanthes lanceolata* var. *boyei* (Oestrup) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1993, Figure 41: 11–13). Figure 32:15

L: 20–22 µm, W: 8 µm, Str: 9–11 /10 µm. Valve linear lanceolate with horse-shoe shape thickening in one side of rapheless valve. Valve with raphe, central area an acute-angled sub fascia. Striae radiate throughout.

16) *Achnanthes undata* Meister (H. Lange-Bertalot, 1993, Figure 35: 8–10). Figure 32:16

L: 45–55 µm, W: 13–16 µm, Str: 9/10 µm. Pt: 10/10 µm. Valve lanceolate. Edge crenate, central area a narrow transverse fascia.

17) *Cocconeis placentula* var. *pseudolineata* Geitler (Krammer, K. and H. Lange-Bertalot, 1993, Figure 35: 4). Figure 32:17

L: 15 µm, W: 9 µm, Str: 22 /10 µm. Pt: 18/10 µm. Valve oval to elliptic lanceolate, isopolar and isobilateral. Apical axis stright, transapical axis bent (as seen in girdle view). Striae patterns radiate. Puncta coarse. Distribution cosmopolitan. Forms attached to plants or rock material.

18) *Amphora coffeaeformis* (Agardh) Kützing var. *coffeaeformis* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 151: 2). Figure 32:18

L: 40 µm, W: 15 µm, Str: 22/10 µm. in end and Str: 20/10 µm. in central of dorsal side. Valve semicircular or crecentic in valve view. In girdle view they are wider on the dorsal side than the ventral one. Isopolar and dorsiventral (bilateral). Ends capitate. Raphe threadlike, slightly curved, lying close to the ventral edge. Axial area narrow.

19) *Amphora dusenii* Brun (Krammer, K. and H. Lange-Bertalot, 1986, Figure 152: 7–8). Figure 32:19

L: 20 µm, W: 8 µm, Str: 22/10 µm. in central of dorsal side. Valve semi lanceolate, isopolar and dorsiventral. Ends rostrate. Raphe threadlike, slightly curved, lying close to the ventral edge. Axial area narrow.

20) *Amphora libyca* Ehrenberg (Krammer, K. and H. Lange-Bertalot, 1986, Figure 149: 4,7). Figure 32:20

L: 25–32.4 µm, W: 6 µm, Str: 12–15/10 µm. in central of dorsal side. Valve cresentic, isopolar and dorsiventral. Ends round. Raphe threadlike, slightly curved. Slightly finer striae interrupted at the centre on the dorsal side of the valve. Central area an acute-angled fascia. Distribution cosmopolitan.

21) Caloneis lauta Carter & Bailey-Watts (Krammer, K. and H. Lange-Bertalot, 1986, Figure 173: 2). Figure 32:21

L: 28.5 µm, W: 6.7 µm, Str: 20/10 µm. Valve lanceolate, isopolar and isobilateral. Ends rounded. Raphe straight, central and treadlike slit. Central area a wide transverse fascia. Striae fine and parallel throughout.

22) Caloneis silicula (Ehrenberg) Cleve (Krammer, K. and H. Lange-Bertalot, 1986, Figure 172: 7). Figure 32:22

L: 18 µm, W: 9 µm, Str: 20/10 µm. Valve linear elliptic, isopolar and isobilateral. Central area lanceolate. Striae fine and parallel throughout.

23) *Cymbella amphicephala* Naegeli (Krammer, K. and H. Lange-Bertalot, 1986, Figure 142: 7). Figure 32:23

L: 34.3 µm, W: 10 µm, Str: 10/10 µm in dorsal side and 16/10 µm in ventral side. Valve semilanceolate, isopolar and dorsiventral. Ends capitate.

24) Cymbella hustedtii Krasske (Krammer, K. and H. Lange-Bertalot, 1986, Figure 140: 15–17). Figure 32:24

L: 23.2 µm, W: 7.9 µm, Str: 12–14/10 µm in dorsal side and 14–15/10 µm in ventral side. Pt: 25/10 µm. Valve semi lanceolate, isopolar and dorsiventral, dorsal convex, ventral slightly convex. Distribution cosmopolitan. Present in oligotrophic habitat.

25) Cymbella turgidula Grunow (Krammer, K. and H. Lange-Bertalot, 1986, Figure 126: 4–7). Figure 32:25

L: 28–40 µm, W: 10.7–13 µm, Str: 7–13/10 µm. Pt: 22/10 µm. Valve dorsiventral, dorsal convex, ventral convex, elliptic lanceolate, ends cunate to rostrate.

26) *Cymbellopsis* cf. *lanceolata* Krammer (Krammer, K., 1997b, Figure 195: 10, 197: 9–13). Figure 32:26

L: 13–19 µm, W: 4–5 µm, Str: 14–19/10 µm. Valve semicircular, isopolar and dorsiventral, dorsal convex, with the outline raphe structure, near the ventral margin, straight and threadlike. Ends of the raphe curve to ventral side (opposite to *Cymbella*).

27) *Encyonema silesiacum* (Bleisch) D.G. Mann (Krammer, K., 1997a, Figure 4: 11–12, Round, F.E., R.M. Crawford and D.G. Mann, 1990, Page 490-491). Figure 33:27

L: 19–23 µm, W: 6 µm, Str: 14–18/10 µm in dorsal side and 15–19/10 µm in ventral side. Pt: 25/10 µm. Valve strongly dorsiventral. Raphe parallel to ventral margin. *Encyonema* are small group recognised by Krammer (1982) as a subgenus within *Cymbella,* were prefer to separated at the generic level. Live cells are easily identified because of the ventral plastid and dorsal nucleus. The whole cell interior and the orientation of the raphe system are opposite in *Encynema* and *Cymbella* relative to the dorsiventrality of the cell.

28) *Frustulia weinholdii* Hustedt (Krammer, K. and H. Lange-Bertalot, 1986, Figure 97: 12–14). Figure 33:28

L: 32–60 μm, W: 6.5–10 μm, Str: 30/10 μm. Shape narrow elliptic, isopolar and isobilateral. Ends rounded. Raphe central, straight and treadlike, set on a thickened ridge differentiated from the narrow axial area which is produced at the apices. Striae parallel and fine.

29) *Gomphonema affine* Kützing (Krammer, K. and H. Lange-Bertalot, 1986, Figure 161:1–3). Figure 33:29

L: 52 μm, W: 8 μm, Str: 12/10 μm. Valve heteropolar, clavate to rhombic but isobilateral. Raphe central, central area one-side with one stigma. Distribution in Trophic-subtrophic region.

30) *Gomphonema augur* var. *turris* (Ehrenberg) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 158: 6). Figure 33:30

L: 32 μm, W: 11 μm, Str: 13/10 μm. Valves markedly heteropolar, tapering evenly to the rather acute foot pole, broadening towards the head pole which often bears a bluntly rounded apical projection.

31) *Gomphonema minutum* (Agardh) Agardh (Krammer, K. and H. Lange-Bertalot, 1986, Figure 159: 5). Figure 33:31

L: 15–20 μm, W: 5–6 μm, Str: 10–15/10 μm. Valves narrowly heteropolar with bluntly rounded apices, foot pole only slightly narrower than head pole. Striae more widely spaced at centre of valve. Stigma one one-side.

32) *Gonphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot (Reichardt, E.,1997, Figure 1:7, 3:1–41, 4: 24–25). Figure 33:32

L: 21 μm, W: 4.2 μm, Str: 12/10 μm. Valve linear to linear lanceolate. Central area a wide transverse fascia with one stigma separated from the central nodule. Typically with broadly lanceolate axial area. Striae tranapical, slightly radiate.

33) *Navicula cohnii* (Hilse) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 63: 1). Figure 33:33

L: 22.6 μm, W: 7.8 μm, Str: 20/10 μm. Pt: 15/10 μm. Valve broad elliptic to linear elliptic. Central area an acute-angled fascia with central pore. Distribution cosmopolitan.

34) *Navicula concentrica* Carter (Krammer, K. and H. Lange-Bertalot, 1986, Figure 36: 10–12). Figure 33:34

L: 45 μm, W: 10 μm, Str: 9/10 μm. Valve lanceolate with sharp ends, isopolar, isobilateral. Axial area narrow. Striae radiate. Raphe line a little lateral.

35) *Navicula cryptotenella* Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 33: 9–11). Figure 33:35

L: 26.7–34.3 μm, W: 5.8–7 μm, Str: 14–15/10 μm. Valve lanceolate to rhombic lanceolate, tapering to acutely rounded apices which are only very slightly drawn out. Striae radiating in the central part, parallel at the poles. Distribution cosmopolitan.

36) *Navicula elginensis* (Gregory) Ralfs var. *elginensis* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 35:5). Figure 33:36

L: 20 μm, W: 8 μm, Str: 20/10 μm. Pt: 60/10 μm. Valve broad linear to broad elliptic. Ends stump. Striae radiate.

37) *Navicula jaagii* Meister (Krammer, K. and H. Lange-Bertalot, 1986, Figure 79: 18–21). Figure 33:37

L: 25 μm, W: 5 μm, Str: 32/10 μm. Valve broad linear to linear elliptic. Ends capitate to rounded. Axial area narrow linear, central area elliptic to rhombic. Striae fine.

38) *Navicula laevissima* Kützing var. *laevissima* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 67: 6–10). Figure 33:38

L: 20 μm, W: 6.7 μm, Str: 21/10 μm. Valve linear, isopolar, isobilateral. End broadly rounded. Axial area narrow, central area rhombic. Striae fine and curved around the central area.

39) *Navicula mutica* Kützing var. *mutica* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 61: 1). Figure 33:39

L: 19–20 μm, W: 7.3–7.8 μm, Str: 18–21/10 μm. Pt: 15/10 μm. Valve rhombic elliptic to broad elliptic. Axial area linear. Central area an acute-angled fascia. Striae radiate.

40) *Navicula subplacentula* Hustedt (Krammer, K. and H. Lange-Bertalot, 1986, Figure 50: 5–8). Figure 33:40

L: 23.8–25.9 µm, W: 9.6 µm, Str: 9–12/10 µm. Valve elliptic lanceolate. Ends stump. Axial area linear, central area elliptic. Striae radiate. Distribution cosmopolitan.

41) *Neidium ampliatum* (Ehrenberg) Krammer (Krammer, K. and H. Lange-Bertalot, 1986, Figure 105: 2). Figure 34:41

L: 127 µm, W: 24 µm, Pt: 16–24/10 µm. Valve broadly linear with bluntly cuneate to broadly rostrate apices more than one-third valve width. Striae fine parallel. Ends stump. Central area elliptic. Distribution cosmopolitan.

42) *Reimeria sinuata* (Gregory) Kociolek & Stoermer (Krammer, K. and H. Lange-Bertalot, 1986, Figure 148:10–17, Round, F.E., R.M. Crawford and D.G. Mann, 1990, Page 500-501). Figure 34:42

L: 15 µm, W: 5 µm, Str: 12/10 µm. Pt: 45/10 µm. Valve slightly dosiventral with a slight unilateral expansion. Dorsal convex, ventral slightly convex. Valve linear to linear lanceolate, subcapitate asymetrical about the apical axis. Striae distant biseriate, absent from the ventral swelling, opening internally between prominent ribs. Between the central raphe endings, or slightly to the dorsal side of them, is a single isolated pore (stigma), which is unoccluded both internally and externally. Distribution cosmopolitan, freshwater, associated with stone surfaces particularly in rivers.

43) *Sellaphora pupula* (Kützing) Mereschkowsky (Krammer, K. and H. Lange-Bertalot, 1986, Figure 68: 1–21). Figure 34:43

L: 27 µm, W: 8 µm, Str: 20–22/10 µm. Valve linear elliptic to lanceolate, usually with bluntly rounded or capitate poles. Valve face flat, curveing fairly gently into shallow or moderately deep mantles; often grooved near the raphe externally. Striae uniseriate, containing small round poroids occluded near their internal apertures by hymenes. Raphe system central, straight.

44) *Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 111: 1–13). Figure 34:44

L: 60–74 μm, W: 18–22 μm, Str: 9/10 μm. Valve linear with crescentic cunate ends. Isopolar and dorsiventral with dorsal edge slightly gibbous. Raphe system situated along the dorsal margin of the valve. External central raphe endings expanded, sometimes deflected slightly towards the ventral side, internal endings simple. Axial area very narrow, central area absent. Transapical costae present.

45) *Hantzschia distinctepunctata* (Hustedt) Hustedt (Krammer, K. and H. Lange-Bertalot, 1988, Figure 88: 8–10). Figure 34:45

L: 45 μm, W: 6 μm, Str: 12/10 μm. Valve slightly asymmetrical with respect to the apical plan, valves are either dorsiventral or slightly arc shaped. Striae fine and parallel. Raphe on ventral concave margin of valve supported by prominent fibulae. Distribution cosmopolitan.

46) *Nitzschia brevissima* Grunow (Krammer, K. and H. Lange-Bertalot, 1988, Figure 22: 1–6). Figure 34:46

L: 37.5 μm, W: 5 μm, Str: /10 μm, Fb: 10/10 μm. Valve broad linear, slightly sigmoid. Striae fine and paraellel along the transapical axis. Distribution cosmopolitan.

47) *Nitzschia coarctata* Grunow (Krammer, K. and H. Lange-Bertalot, 1988, Figure 38: 14–15). Figure 34:47

L: 50 μm, W: 12 μm, Str: 10/10 μm, Pt: 15/10 μm. Fb: 6/10 μm. Valve panduriform, isopolar, isobilateral with cunate ends. Striae coarse in central area and slightly curve in the ends. Distribution cosmopolitan.

48) *Nitzschia hantzschiana* Rabenhorse (Krammer, K. and H. Lange-Bertalot, 1988, Figure 73: 18). Figure 34:48

L: 17 μm, W: 3 μm, Str: 20/10 μm, Fb: 7/10 μm. Valve elliptic linear lanceolate, isopolar. Ends stump. Distribution cosmopolitan.

49) *Cymatopleura salea* var. *apiculata* (W. Smith) Ralfs (Krammer, K. and H. Lange-Bertalot, 1988, Figure 118:4 –8). Figure 34:49

L: 62–67.5 μm, W: 22.5–27.5 μm, Fb: 9/10 μm. Valve linear, often constricted about the central portion, isopolar and isobilateral. Ends apiculate. Valve surface undulate. Raphe system on peripheral wing (ala) developed from the valve margin and supported by ribs. Striae very finely punctate, the patterns sometime varying from apical to transapical in direction, corresponding to the undulations.

50) *Surirella roba* Leclercq (Krammer, K. and H. Lange-Bertalot, 1988, Figure 148:8). Figure 34:50

L: 37 μm, W: 9 μm, Fb: 50/100 μm. Valve linear lanceolate, isopolar. Ends stump.

51) *Surirella spiraloides* Hustedt (Huber-Pestalozzi, G.,1942, Figure 617). Figure 34:51

L: 60–62 μm, W: 25–27 μm, Fb: 15/100 μm. Valve spirally twisted, heteropolar. Raphe system peripheral on a wing (ala) extension of the valve margin, supported by rib-like undulations. Striae fine, difficult to resolve.

4.1.3 Diversity Index

Shannon's diversity index, evenness and number of presented diatoms in each sampling site are shown in Table 7. Sampling site 2 had a high value of diversity index which ranged from 2.523 - 3.520 and also had a number in maximum of species which was investigated. Sampling site 3 had a low value of diversity index which ranged from 1.508 - 3.212. There is no diatom present in the sample from sampling site 5 in month 6 of the sampling periods (September 1998). The average number of species from sampling sites one to five are 32 species, 38 species, 29 species, 32 species and 28 species respectively.

Diversity indices were developed by theoretical ecologists who were interested in such questions as the relationship between stability and diversity in ecosystems. There are several different diversity indices which have been used in water pollution studies (Abel, 1989). Generally, polluted sites contain fewer species than communities from comparable unpolluted waters.

Table 7. Shannon's diversity index, Evenness and number of diatom species in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

Sampling Sites	Diversity Index	Evenness	Number of species
S1M1	2.449	0.752	26
S1M2	2.516	0.772	26
S1M3	2.622	0.779	29
S1M4	0.837	0.260	25
S1M5	1.841	0.514	36
S1M6	3.106	0.811	46
S1M7	2.574	0.810	24
S1M8	2.558	0.854	20
S1M9	2.044	0.682	20
S1M10	2.800	0.840	28
S1M11	2.459	0.681	37
S1M12	2.942	0.803	39
S1M13	3.365	0.812	63
S1M14	1.729	0.452	46
S1M15	2.940	0.803	39
S1M16	1.768	0.564	23
S1M17	2.255	0.766	19
S1M18	2.719	0.759	36
S2M1	2.929	0.879	28
S2M2	3.095	0.929	28
S2M3	2.523	0.721	33
S2M4	2.760	0.764	37
S2M5	3.344	0.834	55
S2M6	2.999	0.824	38
S2M7	2.823	0.866	26
S2M8	3.151	0.909	32
S2M9	3.038	0.893	30
S2M10	3.276	0.929	34
S2M11	3.129	0.832	43
S2M12	3.039	0.794	46
S2M13	3.520	0.837	67
S2M14	3.193	0.804	53
S2M15	2.915	0.785	41
S2M16	2.726	0.818	28
S2M17	3.109	0.933	28
S2M18	3.376	0.887	45
S3M1	2.363	0.776	21
S3M2	2.448	0.713	31
S3M3	2.739	0.874	23
S3M4	2.570	0.927	16
S3M5	2.759	0.789	33
S3M6	2.661	0.748	35
S3M7	1.508	0.544	16
S3M8	2.429	0.825	19
S3M9	2.712	0.797	30

Table 7. Continued

Sampling Sites	Index values	Evenness	Number of species
S3M10	2.578	0.791	26
S3M11	2.434	0.709	31
S3M12	3.212	0.849	44
S3M13	2.732	0.731	42
S3M14	3.190	0.833	46
S3M15	3.012	0.796	44
S3M16	2.707	0.841	25
S3M17	1.924	0.836	10
S3M18	3.099	0.852	38
S4M1	2.569	0.831	22
S4M2	2.974	0.913	26
S4M3	2.913	0.894	26
S4M4	2.171	0.766	17
S4M5	3.547	0.921	47
S4M6	2.696	0.721	42
S4M7	2.408	0.748	25
S4M8	2.946	0.858	31
S4M9	1.897	0.576	27
S4M10	2.200	0.692	24
S4M11	3.156	0.829	45
S4M12	3.130	0.827	44
S4M13	3.456	0.859	56
S4M14	3.235	0.896	37
S4M15	2.848	0.772	40
S4M16	2.230	0.693	25
S4M17	1.906	0.980	7
S4M18	3.224	0.907	35
S5M1	3.019	0.871	32
S5M2	1.743	0.582	20
S5M3	2.489	0.805	22
S5M4	2.443	0.741	27
S5M5	2.115	0.801	14
S5M6*	****	****	0
S5M7	2.293	0.779	19
S5M8	2.692	0.859	23
S5M9	1.464	0.455	25
S5M10	1.859	0.547	30
S5M11	3.413	0.925	40
S5M12	2.837	0.769	40
S5M13	3.132	0.801	50
S5M14	3.377	0.863	50
S5M15	2.804	0.732	46
S5M16	1.571	0.567	16
S5M17	2.626	0.927	17
S5M18	2.567	0.722	35

* No diatoms presented in this sampling site

4.2 Diatoms distribution

Species distribution of epilithic and epipelic diatoms were shown in Tables 8 and 9. The total number of presented species were given at the end of the table and were shown in Figure 35. From the figure, it is show that sampling site 2 had the a highest number of presented species either epilithic diatom or epipelic diatom (153 species and 56 species respectively). Sampling site 3 had the lowest present species of epipelic diatoms (34 species). The lowest number of presented species of epilithic diatom is present in site 1 (127 species).

4.3 Cell counting

A total of 14,880 epilithic diatom cells were counted and identified. The number of each species counted during 18 months (April 1998 – September 1999) are shown in Table 10. The highest amount of epilithic diatoms which have the number of relative abundance more than 1% are *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot (7.76%), *Nitzschia palea* (Kützing) W. Smith (7.22%), *Achnanthes lanceolata* (Bré bisson) Grunow (5.59%), *Bacillaria paradoxa* Gmelin (5.04%), *Cocconeis placentula* Ehrenberg (4.29%), *Gyrosigma scalproides* (Rabenhorst) Cleve (3.65%), *G. parvulum* Kü tzing (3.33%), *A. oblongella* Oestrup (2.88%), *Navicula schroeterii* Meister (2.86%), *Navicula* sp.5 (2.67%), *N. viridula* (Kützing) *Ehrenberg* var. *viridula* (2.65%), *A. exigua* Grunow var. *exigua* (2.21%), *G. clevei* Fricke (2.15%), *Stauroneis anceps* Ehrenberg (2.02%), *Melosira varians* Agardh (1.94%), *Amphora libyca* Ehrenberg (1.78%), *N. viridula* var. *rostellata* (Kützing) Cleve (1.73%), *N. cryptotenella* Lange-Bertalot (1.73%), *Achnanthes* sp.1 (1.73%), *Sellaphora pupula* (Kützing) Mereschkowsky (1.47%), *Synedra ulna* var. *aequalis* (Kützing) Hustedt (1.42%), *Encyonema silesiacum* (Bleisch) D. G. Mann (1.30%), *Surirella roba* Leclercq (1.22%), *Nitzschia* sp.5 (1.06%), *Navicula* sp.7 (1.06%), *N. medioconvexa* Hustedt (1.06%) and *Navicula* sp.1 (1.00%) respectively. A summation of each species presented are given at the end of the table.

Table 8 Species distribution of epilithic diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

	Species	Sampling site				
		Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
1	*Achnanthes brevipes* var. *intermedia* (Kützing) Cleve	+				
2	*Achnanthes crenulata* Grunow	+	+	+	+	+
3	*Achnanthes exigua* Grunow var. *exigua*	+	+	+	+	+
4	*Achnanthes helvetica* (Hustedt) Lange-Bertalot		+			
5	*Achnanthes inflata* (Kützing) Grunow	+				+
6	*Achnanthes lanceolata* (Brébisson) Grunow	+	+	+	+	+
7	*Achnanthes minutissima* Kützing	+	+	+		+
8	*Achnanthes oblongella* Oestrup	+	+	+	+	+
9	*Achnanthes pseudoswazi* Carter		+	+		
10	*Achnanthes pusilla* (Grunow) De Toni			+		
11	*Achnanthes undata* Meister	+	+	+	+	+
12	*Achnanthes* sp.1	+	+	+	+	+
13	*Achnanthes* sp.2	+	+	+	+	
14	*Achnanthes* sp.3	+	+	+	+	+
15	*Achnanthes* sp.4	+	+	+	+	+
16	*Achnanthes* sp.5			+	+	
17	*Achnanthes* sp.6	+	+	+	+	+
18	*Achnanthes* sp.7	+	+	+	+	+
19	*Achnanthes* sp.8	+	+	+	+	+
20	*Achnanthes* sp.9	+	+	+	+	+
21	*Achnanthes* sp.10		+	+		+
22	*Achnanthes* sp.11					+
23	*Achnanthes* sp.12		+	+		
24	*Amphora aequalis* Krammer	+			+	+
25	*Amphora dusenii* Brun		+		+	+
26	*Amphora libyca* Ehrenberg	+	+	+	+	+
27	*Amphora ovalis* (Kützing) Kützing				+	
28	*Amphora pediculus* (Kützing) Grunow				+	+
29	*Amphora* sp.1		+			
30	*Amphora* sp.2			+		
31	*Amphora* sp.3					+
32	*Amphora* sp.4		+	+		
33	*Amphora* sp.5				+	
34	*Amphora* sp.6			+		+
35	*Aulacoseira glanulata* Ehrenberg		+	+		
36	*Bacillaria paradoxa* Gmelin	+	+	+	+	+
37	*Caloneis bacillum* (Grunow) Cleve			+		+
38	*Caloneis lauta* Carter & Bailey-Watts	+	+	+	+	
39	*Caloneis silicula* (Ehrenberg) Cleve			+	+	
40	*Caloneis* sp.1	+				
41	*Caloneis* sp.2					+
42	*Cocconeis placentula* Ehrenberg	+	+	+	+	+
43	*Craticula* sp.1		+		+	
44	*Cyclotella meneghiniana* Kützing		+		+	+
45	*Cyclotella stelligera* Cleve & Grunow		+	+	+	+
46	*Cyclotella* sp.1	+				
47	*Cyclotella* sp.2	+	+	+	+	+
48	*Cymatopleura solea* (Brébisson) W. Smith			+	+	+
49	*Cymbella affinis* Kützing			+	+	
50	*Cymbella amphicephala* Naegeli	+	+			

Table 8. Continued

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
51	*Cymbella hustedtii* Krasske			+	+	+
52	*Cymbella minuta* Hilse			+		
53	*Cymbella naviculiformis* Auerswald	+	+			
54	*Cymbella tumida* (Brébisson) Van Heurck	+		+	+	+
55	*Cymbella turgidula* Grunow	+		+	+	+
56	*Cymbella* sp.1				+	
57	*Cymbella* sp.2	+		+	+	+
58	*Cymbella* sp.3	+		+		
59	*Diploneis elliptica* (Kützing) Cleve	+	+		+	
60	*Diploneis oblongella* (Naegeli) Cleve-Euler	+	+	+		+
61	*Diploneis ovalis* (Hilse) Cleve	+			+	
62	*Encyonema silesiacum* (Bleisch) D. G. Mann	+	+	+	+	+
63	*Encyonema* sp.1			+	+	+
64	*Encyonema* sp.2	+	+	+		
65	*Epithemia* sp.1	+				
66	*Eunotia bilunaris* (Ehrenberg) Mills	+	+			
67	*Eunotia minor* (Kützing) Rabenhorst	+	+		+	
68	*Eunotia soleirolii* (Kützing) Rabenhorst	+	+		+	+
69	*Eunotia* sp.1	+	+			
70	*Eunotia* sp.2		+			
71	*Fragilaria biceps* (Kützing) Lange-Bertalot	+	+		+	+
72	*Fragilaria bidens* Heiberg				+	
73	*Fragilaria elliptica* Schumann		+			
74	*Fragilaria lanceolata* (Kützing) Reichardt			+	+	+
75	*Fragilaria ulna* (Nitzsch) Lange-Bertalot	+	+	+	+	+
76	*Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot	+	+	+	+	+
77	*Fragilaria* sp.1			+		
78	*Fragilaria* sp.2		+	+	+	+
79	*Fragilaria* sp.3		+	+		
80	*Frustulia rhomboides* (Ehrenberg) De Toni	+		+		
81	*Frustulia weinholdii* Hustedt	+	+	+	+	+
82	*Frustulia* sp.1	+	+	+		
83	*Frustulia* sp.2	+	+			
84	*Frustulia* sp.3	+	+			
85	*Frustulia* sp.4		+			
86	*Gomphonema augur* Ehrenberg	+		+	+	
87	*Gomphonema clevei* Fricke	+	+	+		
88	*Gomphonema gracile* Ehrenberg	+	+	+	+	+
89	*Gomphonema lingulatiforme* Lange-Bertalot & Reichardt	+				
90	*Gomphonema minutum* (Agardh) Agardh		+			
91	*Gomphonema parvulum* Kützing	+	+	+	+	+
92	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	+	+	+	+	+
93	*Gomphonema* sp.1	+	+	+	+	+
94	*Gomphonema* sp.2		+			
95	*Gomphonema* sp.3				+	
96	*Gomphonema* sp.4	+	+		+	+
97	*Gomphonema* sp.5	+				
98	*Gomphonema* sp.6			+	+	
99	*Gyrosigma scalproides* (Rabenhorst) Cleve	+	+	+	+	+
100	*Gyrosigma spencerii* (Quekeitt) Griffith & Henfrey		+	+	+	+

Table 8. Continued

	Species	Sampling site				
		Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
101	*Hantzschia amphioxys* (Ehrenberg) W. Smith	+	+	+	+	+
102	*Hantzschia distinctepunctata* (Hustedt) Hustedt				+	+
103	*Melosira varians* Agardh	+	+	+	+	+
104	*Navicula bacillum* Ehrenbergh		+	+	+	+
105	*Navicula clementis* Grunow	+	+			
106	*Navicula cohnii* (Hilse) Lange-Bertalot	+	+		+	
107	*Navicula cryptotenella* Lange-Bertalot	+	+	+	+	+
108	*Navicula elginensis* (Gregory) Ralfs var. elginensis	+	+	+	+	+
109	*Navicula goeppertiana* var. *dapaliformis* (Hustedt) Lange-Bertalot					+
110	*Navicula insociabilis* Krasske		+	+		
111	*Navicula leptostriata* Jørgensen	+	+	+	+	+
112	*Navicula medioconvexa* Hustedt	+	+	+	+	
113	*Navicula mobiliensis* Boyer			+		
114	*Navicula mutica* Kützing	+	+	+	+	+
115	*Navicula radiosa* Kützing		+			
116	*Navicula schroeterii* Meister	+	+	+	+	+
117	*Navicula trivialis* Lange-Bertalot		+			
118	*Navicula viridula* var. *germainii* (Wallace) Lange-Bertalot	+	+	+	+	+
119	*Navicula viridula* var. *rostellata* (Kützing) Cleve	+	+	+	+	+
120	*Navicula viridula* (Kützing) *Ehrenberg* var. *viridula*	+	+	+	+	+
121	*Navicula* sp.1	+	+	+	+	+
122	*Navicula* sp.2	+	+	+	+	+
123	*Navicula* sp.3		+	+	+	+
124	*Navicula* sp.4	+	+	+	+	+
125	*Navicula* sp.5	+	+	+	+	+
126	*Navicula* sp.6	+	+	+	+	+
127	*Navicula* sp.7	+	+	+	+	+
128	*Navicula* sp.8			+	+	
129	*Navicula* sp.9	+	+	+	+	+
130	*Navicula* sp.10	+	+	+	+	+
131	*Navicula* sp.11	+	+			
132	*Navicula* sp.12	+	+	+		
133	*Navicula* sp.13	+	+	+	+	+
134	*Navicula* sp.14	+		+		
135	*Navicula* sp.15		+	+	+	+
136	*Navicula* sp.16	+	+		+	+
137	*Navicula* sp.17	+	+	+	+	+
138	*Navicula* sp.18	+		+		
139	*Navicula* sp.19		+		+	+
140	*Navicula* sp.20		+			
141	*Navicula* sp.21			+		+
142	*Neidium affine* (Ehrenberg) Pfitzer	+	+		+	+
143	*Neidium ampliatum* (Ehrenberg) Krammer	+	+		+	+
144	*Neidium binodis* (Ehrenberg) Hustedt		+			
145	*Neidium iridis* (Ehrenberg) Cleve	+				
146	*Neidium septentrionale* Cleve-Euler		+			
147	*Neidium* sp.1		+			
148	*Neidium* sp.2		+	+	+	+
149	*Neidium* sp.3	+	+	+		

Table 8. Continued

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
150	*Neidium* sp.4	+	+	+		
151	*Nitzschia acula* Hantzsch				+	
152	*Nitzschia bremensis* Hustedt				+	+
153	*Nitzschia coacrtata* Grunow				+	+
154	*Nitzschia dissipata* (Kützing) Grunow		+	+	+	+
155	*Nitzschia dubia* W.Smith		+			+
156	*Nitzschia fonticola* Grunow	+	+	+	+	+
157	*Nitzschia fonticola* var. *palagica* Hustedt				+	
158	*Nitzschia geitleri* Hustedt				+	+
159	*Nitzschia levidensis* (W. Smith) Grunow var. *levidensis*		+	+	+	+
160	*Nitzschia palea* Kützing	+	+	+	+	+
161	*Nitzschia* sp.1	+				
162	*Nitzschia* sp.2	+	+	+	+	+
163	*Nitzschia* sp.3	+	+	+	+	+
164	*Nitzschia* sp.4	+	+	+	+	+
165	*Nitzschia* sp.5	+	+	+	+	+
166	*Nitzschia* sp.6				+	+
167	*Nitzschia* sp.7					+
168	*Nitzschia* sp.8	+	+			+
169	*Nitzschia* sp.9					+
170	*Nitzschia* sp.10					+
171	*Nitzschia* sp.11			+		
172	*Nitzschia* sp.12				+	+
173	*Nitzschia* sp.13	+	+		+	+
174	*Pinnularia acrosphaeria* W. Smith		+		+	
175	*Pinnularia appendiculata* (Agardh) Cleve					+
176	*Pinnularia borealis* var. *scalaris* (Ehrenberg) Rabenhorst	+	+	+	+	+
177	*Pinnularia mesolepta* (Ehrenberg) W. Smith	+	+		+	+
178	*Pinnularia platycephala* (Ehrenberg) Cleve	+	+			
179	*Pinnularia schoenfelderii* Krammer	+	+	+	+	+
180	*Pinnularia subgibba* Krammer	+	+	+		+
181	*Pinnularia subinterupta* Krammer & Schroeter		+			+
182	*Pinnularia viridis* (Nitzsch) Ehrenberg	+	+			+
183	*Pinnularia* sp.1	+	+			+
184	*Pinnularia* sp.2	+			+	+
185	*Pinnularia* sp.3			+		+
186	*Pinnularia* sp.4	+	+			
187	*Pinnularia* sp.5		+		+	+
188	*Pinnularia* sp.6	+	+			
189	*Pinnularia* sp.7		+			
190	*Pinnularia* sp.8		+			
191	*Pinnularia* sp.9	+	+		+	+
192	*Pinnularia* sp.10	+		+		
193	*Pinnularia* sp.11				+	
194	*Reimeria sinuata* Gregory		+	+	+	
195	*Rhopalodia acuminata* Krammer		+			
196	*Rhopalodia brebissonii* Krammer				+	
197	*Rhopalodia gibba* (Ehrenberg) O.Müller var. *gibba*		+		+	+
198	*Rhopalodia gibba* var. *parallela* (Grunow) Fryxell & Hasle				+	
199	*Rhopalodia gibberula* (Ehrenberg) O. Müller	+	+	+	+	

Table 8. Continued

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
200	*Rhopalodia rupestris* (W. Smith) Krammer		+	+		
201	*Rhopalodia* sp.1		+	+	+	+
202	*Rhopalodia* sp.2		+			
203	*Rhopalodia* sp.3	+			+	
204	*Rhopalodia* sp.4				+	
205	*Sellaphora pupula* (Kützing) Mereschkowsky	+	+	+	+	+
206	*Sellaphora* sp.1		+			
207	*Stauroneis anceps* Ehrenberg	+	+	+	+	
208	*Stauroneis smithii* Gronow	+	+	+	+	+
209	*Surirella angusta* Kützing	+	+	+	+	+
210	*Surirella bifrons* Ehrenberg		+	+		+
211	*Surirella biseriata* Brébisson	+		+	+	+
212	*Surirella elegans* Ehrenberg		+			
213	*Surirella ovalis* Brébisson				+	+
214	*Surirella roba* Keclercq	+	+	+	+	+
215	*Surirella robusta* Ehrenberg		+		+	
216	*Surirella tenera* Gregory	+	+	+		+
217	*Surirella* sp.1	+		+		+
218	*Surirella* sp.2	+		+	+	+
219	*Surirella* sp.3			+		+
220	*Surirella* sp.4	+		+	+	+
221	*Surirella* sp.5		+	+		+
222	*Surirella* sp.6		+			
223	*Surirella* sp.7				+	+
224	*Surirella* sp.8		+			+
225	*Surirella* sp.9					+
226	*Synedra lanceolata* Kützing	+	+	+	+	+
227	*Synedra ulna* (Nitzsch) Ehrenberg	+	+	+		
228	*Synedra ulna* var. *aequalis* (Kützing) Hustedt	+	+	+	+	+
	Sumation of presented species	127	153	129	135	133

Table 9. Species distribution of epipelic diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
1	*Achnanthes crenulata* Grunow	+		+		
2	*Achnanthes exigua* Grunow var. *exigua*	+	+		+	
3	*Achnanthes lanceolata* (Brébisson) Grunow	+			+	+
4	*Achnanthes oblongella* Oestrup	+				+
5	*Achnanthes pusilla* (Grunow) De Toni	+				
6	*Achnanthes* sp.5			+		
7	*Achnanthes* sp.7				+	
8	*Actinocyclus normanii* (Gregory) Hustedt			+		
9	*Amphora dusenii* Brun					+
10	*Amphora* sp.3		+		+	
11	*Amphora* sp.4			+		
12	*Amphora* sp.5				+	+
13	*Amphora* sp.6				+	+
14	*Bacillaria paradoxa* Gmelin	+	+		+	+
15	*Caloneis* sp.3		+			
16	*Cocconeis placentula* Ehrenberg		+	+	+	+
17	*Craticula* sp.1		+		+	
18	*Cyclotella meneghiniana* Kützing				+	+
19	*Cyclotella* sp.2		+			+
20	*Cymatopleura solea* (Brébisson) W. Smith				+	
21	*Cymbella affinis* Kützing				+	
22	*Cymbella naviculiformis* Auerswald	+	+			
23	*Cymbella tumida* (Brébisson) Van Heurck			+	+	+
24	*Cymbella turgidula* Grunow			+	+	+
25	*Encyonema silesiacum* (Bleisch) D. G. Mann				+	
26	*Encyonema* sp.2	+				
27	*Encyonema* sp.4			+		
28	*Eunotia minor* (Kützing) Rabenhorst	+	+			
29	*Eunotia soleirolii* (Kützing) Rabenhorst		+			
30	*Eunotia* sp.1		+			
31	*Eunotia* sp.2		+			
32	*Eunotia* sp.3					+
33	*Fragilaria biceps* (Kützing) Lange-Bertalot	+				
34	*Fragilaria ulna* (Nitzsch) Lange-Bertalot			+	+	
35	*Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot	+	+			
36	*Fragilaria* sp.2			+		
37	*Frustulia weinholdii* Hustedt	+	+			+
38	*Frustulia* sp.3	+				
39	*Gomphonema gracile* Ehrenberg	+	+			
40	*Gomphonema parvulum* Kützing	+	+	+	+	+
41	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	+			+	
42	*Gomphonema* sp.1			+		
43	*Gomphonema* sp.4	+	+			
44	*Gyrosigma scalproides* (Rabenhorst) Cleve		+	+	+	+
45	*Gyrosigma spencerii* (Quekeitt) Griffith & Henfrey		+		+	+
46	*Hantzschia amphioxys* (Ehrenberg) W. Smith	+	+	+	+	
47	*Melosira varians* Agardh	+	+	+	+	+
48	*Navicula bacillum* Ehrenbergh		+		+	
49	*Navicula cryptotenella* Lange-Bertalot			+	+	
50	*Navicula elginensis* (Gregory) Ralfs var. elginensis		+		+	

Table 9. Continued

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
51	*Navicula medioconvexa* Hustedt			+	+	
52	*Navicula mutica* Kützing	+	+		+	
53	*Navicula schroeterii* Meister	+	+	+		
54	*Navicula trivialis* Lange-Bertalot	+	+			
55	*Navicula viridula* var. *germainii* (Wallace) Lange-Bertalot	+	+	+	+	+
56	*Navicula viridula* (Kützing) *Ehrenberg* var. *viridula*	+	+	+	+	
57	*Navicula* sp.1	+				
58	*Navicula* sp.2	+				
59	*Navicula* sp.3		+	+		
60	*Navicula* sp.4					+
61	*Navicula* sp.5			+		+
62	*Navicula* sp.6	+	+		+	+
63	*Navicula* sp.7				+	
64	*Navicula* sp.11	+	+	+		
65	*Navicula* sp.12			+		
66	*Navicula* sp.13		+			+
67	*Navicula* sp.14		+			
68	*Navicula* sp.16	+	+			
69	*Navicula* sp.19			+		
70	*Neidium ampliatum* (Ehrenberg) Krammer	+				+
71	*Neidium binodis* (Ehrenberg) Hustedt		+	+		
72	*Neidium* sp.4		+			
73	*Neidium* sp.5		+			
74	*Neidium* sp.6				+	+
75	*Nitzschia dissipata* (Kützing) Grunow		+	+		+
76	*Nitzschia geitleri* Hustedt				+	+
77	*Nitzschia levidensis* (W. Smith) Grunow var. *levidensis*		+			
78	*Nitzschia* sp.3	+	+	+	+	+
79	*Nitzschia* sp.4	+			+	
80	*Nitzschia* sp.5	+	+			
81	*Nitzschia* sp.6		+			+
82	*Nitzschia* sp.8	+				
83	*Nitzschia* sp.9					+
84	*Nitzschia* sp.10					+
85	*Pinnularia borealis* var. *scalaris* (Ehrenberg) Rabenhorst	+				
86	*Pinnularia viridis* (Nitzsch) Ehrenberg	+			+	
87	*Pinnularia* sp.3		+			
88	*Pinnularia* sp.4	+	+			+
89	*Pinnularia* sp.5		+			
90	*Pinnularia* sp.6	+				
91	*Pinnularia* sp.8		+			
92	*Pinnularia* sp.9	+				
93	*Rhopalodia gibba* (Ehrenberg) O.Müller var. *gibba*		+			+
94	*Rhopalodia rupestris* (W. Smith) Krammer		+			
95	*Rhopalodia* sp.1		+			
96	*Sellaphora pupula* (Kützing) Mereschkowsky	+	+			
97	*Stauroneis anceps* Ehrenberg		+	+	+	
98	*Stauroneis smithii* Gronow		+		+	+
99	*Surirella angusta* Kützing					+
100	*Surirella biseriata* Brébisson				+	

Table 9. Continued

	Species	Sampling site				
		Site 1	Site 2	Site 3	Site 4	Site 5
101	*Surirella tenera* Gregory			+		
102	*Surirella* sp.1		+			+
103	*Surirella* sp.4	+				+
104	*Surirella* sp.5			+		
105	*Surirella* sp.6				+	
106	*Surirella* sp.8				+	+
107	*Surirella* sp.9					+
108	*Synedra lanceolata* Kützing		+	+	+	+
109	*Synedra ulna* (Nitzsch) Ehrenberg		+	+	+	+
110	*Synedra ulna* var. *aequalis* (Kützing) Hustedt		+	+	+	
	Sumation of presented species	41	56	34	44	40

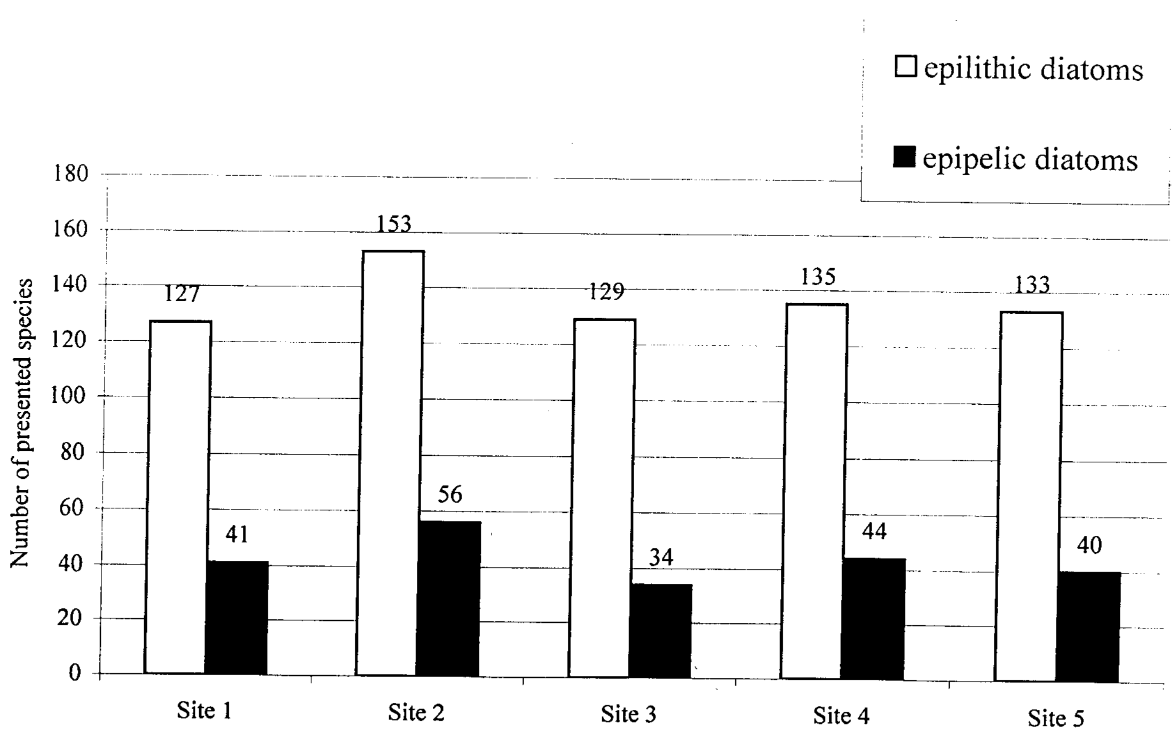


Figure 35. Number of presented species of epilithic diatoms and epipelic diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

Table 10. Cell count of benthic diatoms in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

		Achbre	Achcre	Achexi	Achhel	Achinf	Achlan	Achmin	Achobl	Achpus	Achpse	Achund	Achsp1	Achsp2	Achsp3	Achsp4	Achsp5	Achsp6
Site 1	Month 1	0	1	0	0	0	11	3	6	0	0	0	0	0	0	0	0	0
	Month 2	0	4	2	0	0	9	0	10	0	0	0	0	0	0	0	0	0
	Month 3	0	10	1	0	1	5	1	3	0	0	0	0	0	0	0	0	0
	Month 4	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
	Month 5	0	3	5	0	0	10	0	1	0	0	3	1	1	1	2	0	0
	Month 6	1	3	7	0	7	18	0	29	0	0	1	17	0	8	3	0	0
	Month 7	0	11	8	0	0	20	0	37	0	0	0	0	0	0	0	0	0
	Month 8	0	4	1	0	0	26	0	10	0	0	0	0	0	0	0	0	0
	Month 9	0	1	6	0	0	46	0	46	0	0	0	0	0	0	0	0	0
	Month 10	0	2	6	0	0	17	0	6	0	0	0	0	0	0	0	0	0
	Month 11	0	0	1	0	1	11	0	12	0	0	2	0	0	0	0	0	0
	Month 12	0	0	8	0	0	12	0	5	0	0	3	4	0	1	0	0	0
	Month 13	0	1	24	0	0	5	0	1	0	0	2	7	0	0	2	0	0
	Month 14	0	4	2	0	2	7	0	6	0	0	3	0	1	1	1	0	6
	Month 15	0	1	6	0	0	31	0	30	0	0	0	9	0	1	1	0	2
	Month 16	0	2	5	0	0	7	0	2	0	0	0	0	0	0	0	0	0
	Month 17	0	1	10	0	0	16	1	5	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	1	4	0	5	0	0	5	0	0	0	0	0	0
Site 2	Month 1	0	0	10	0	0	9	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	3	0	0	10	0	0	0	0	0	1	0	0	0	0	0
	Month 4	0	0	2	0	0	1	1	0	0	0	0	2	0	0	0	0	2
	Month 5	0	0	25	0	0	19	10	0	0	0	0	19	0	0	4	0	0
	Month 6	0	0	40	0	0	15	0	0	0	0	0	19	0	0	0	0	1
	Month 7	0	0	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	2	8	0	0	5	0	4	0	0	0	0	0	0	0	0	0
	Month 9	0	0	7	0	0	9	0	4	0	0	0	0	0	0	0	0	0
	Month 10	0	0	6	0	0	5	0	0	0	2	0	0	0	0	0	0	0
	Month 11	0	0	13	0	0	12	0	0	0	1	0	0	0	0	0	0	0
	Month 12	0	0	6	0	0	17	2	0	0	0	1	10	0	2	21	0	0
	Month 13	0	1	11	0	0	45	0	1	0	0	3	20	1	4	3	0	4
	Month 14	0	0	9	0	0	2	0	0	0	0	0	0	0	1	2	0	0
	Month 15	0	0	17	0	0	7	0	1	0	0	0	8	0	0	1	0	1
	Month 16	0	0	19	0	0	20	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	3	0	0	6	0	1	0	0	0	0	0	0	0	0	0
	Month 18	0	0	3	1	0	1	0	1	0	0	0	2	0	1	9	0	1
Site 3	Month 1	0	0	0	0	0	8	0	0	0	0	0	5	0	0	0	0	0
	Month 2	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 5	0	0	0	0	0	7	2	0	0	0	0	24	0	2	0	0	4
	Month 6	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
	Month 11	0	0	1	0	0	5	0	0	0	0	1	0	0	0	0	0	0
	Month 12	0	0	0	0	0	2	0	0	0	0	1	5	0	13	0	0	0
	Month 13	0	0	0	0	0	6	0	0	0	0	0	6	0	1	6	4	0
	Month 14	0	0	2	0	0	1	0	1	6	0	0	22	1	0	0	0	6
	Month 15	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0
	Month 16	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Site 4	Month 1	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	2	2	0	0	5	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	Month 5	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	0
	Month 6	0	0	3	0	0	30	0	0	0	0	0	9	0	0	0	0	1
	Month 7	0	0	2	0	0	12	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	1	1	0	0	7	0	1	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0
	Month 10	0	0	1	0	0	6	0	1	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0
	Month 12	0	0	6	0	0	9	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	8	0	0	13	0	7	0	0	0	12	0	3	0	0	12
	Month 14	0	0	2	0	0	6	0	0	0	0	0	1	0	0	0	0	3
	Month 15	0	0	6	0	0	47	0	4	0	0	0	13	0	0	2	0	1
	Month 16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	1	0	0	9	0	0	0	0	0	1	0	1	0	1	0
Site 5	Month 1	0	0	2	0	0	14	0	7	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	13	0	74	0	0	0	0	0	0	0	0	0
	Month 3	0	0	2	0	0	25	0	1	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	40	0	4	0	0	1	19	0	0	1	0	0
	Month 5	0	0	1	0	0	7	0	0	0	0	0	5	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	2	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	1	0	0	16	0	4	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	5	0	0	0	0	0	0	0	0	1	0	5
	Month 12	0	0	1	0	1	30	0	31	0	0	0	1	0	1	0	0	0
	Month 13	0	0	2	0	0	33	7	50	0	0	0	7	0	0	0	0	3
	Month 14	0	0	0	0	0	12	0	12	0	0	1	1	0	0	0	0	0
	Month 15	0	0	1	0	0	4	0	0	0	0	0	1	0	0	0	0	1
	Month 16	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0
	Sumation	1	60	329	1	14	883	28	428	6	9	33	257	5	42	60	6	54

Table 10. Continued

		Achsp7	Achsp8	Achsp9	Achsp10	Achsp11	Achsp12	Ampaeq	Ampdus	Amplib	Ampova	Ampped	Ampsp1	Ampsp2	Ampsp3	Ampsp4	Ampsp5	Ampsp6	Aulgra	Bacpar
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	Month 13	1	1	1	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	1
	Month 14	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	7	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	10	0	0	1	0	0	0	0	0	0	2
	Month 3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	4	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
	Month 5	0	1	9	1	0	2	0	0	16	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	2	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
	Month 11	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	28
	Month 12	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	38
	Month 13	3	1	3	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	2
	Month 14	1	0	2	0	0	0	0	1	2	0	0	0	0	0	0	0	0	1	0
	Month 15	0	0	2	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Site 3	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
	Month 3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	2	15	2	0	1	0	0	3	0	0	0	0	0	2	0	0	0	0
	Month 6	0	0	2	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
	Month 11	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	12
	Month 12	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	6
	Month 13	5	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	Month 14	3	0	1	1	0	0	0	0	9	0	0	0	0	0	0	0	1	0	1
	Month 15	0	1	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Month 16	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3
Site 4	Month 1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	10
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Month 3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	8
	Month 4	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	3
	Month 5	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	1
	Month 7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
	Month 8	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	8
	Month 9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	83
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	Month 11	0	0	0	0	0	0	1	0	9	0	1	0	0	0	0	0	0	0	36
	Month 12	0	0	0	0	0	0	1	0	13	0	0	0	0	0	0	0	0	0	11
	Month 13	5	0	4	0	0	0	0	5	19	1	1	0	0	0	0	5	0	0	32
	Month 14	0	3	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	0	2
	Month 15	1	1	3	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	8
	Month 16	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	9
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	3
Site 5	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
	Month 9	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	155
	Month 10	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	89
	Month 11	1	4	1	0	0	0	0	0	6	0	0	0	0	1	0	1	0	0	5
	Month 12	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	16
	Month 13	7	0	0	0	1	0	1	6	4	0	1	0	0	0	0	0	0	0	23
	Month 14	0	0	0	1	0	0	2	0	3	0	0	0	0	0	0	0	1	0	29
	Month 15	0	0	3	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 18	0	1	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
	Sumation	43	21	74	11	1	3	6	23	265	1	5	1	1	2	3	6	4	4	750

Table 10. Continued

		Calbac	Callau	Calsil	Calsp1	Calsp2	Calsp3	Calsp4	Cocpla	Crasp1	Cycmen	Cycste	Cycsp1	Cycsp2	Cymsap	Cymsol	Cymafl	Cymamp	Cymhus	Cymmin	Cymnav	Cymtum
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 17	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
Site 2	Month 1	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	6	0	1	0	0	1	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 11	0	0	0	0	0	0	0	7	0	0	1	0	1	0	0	0	1	0	0	0	0
	Month 12	0	0	0	0	0	0	0	15	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	0	0	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	9	0	1	1	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	0	0	0	12	0	0	0	0	1	0	0	0	0	0	0	0	0
Site 3	Month 1	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	1	0	1
	Month 2	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	3	0	0	6
	Month 3	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	1	0	2	0	0	3
	Month 4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	2
	Month 5	0	0	0	0	0	0	0	31	0	0	0	0	3	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	12	0	10	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
	Month 8	0	4	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0
	Month 9	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 10	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	11
	Month 11	0	0	0	0	0	0	0	63	0	0	2	0	2	0	0	0	0	0	0	0	0
	Month 12	0	1	0	0	0	0	0	55	0	0	3	0	0	8	0	0	0	0	0	0	7
	Month 13	0	0	0	0	0	0	0	69	0	0	0	0	0	0	4	0	0	0	0	0	2
	Month 14	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	3
	Month 15	0	0	0	0	0	0	0	9	0	1	0	0	0	0	4	0	0	0	0	0	2
	Month 16	1	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	3
	Month 17	1	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6
Site 4	Month 1	0	0	1	0	0	0	0	31	0	4	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	3	0	8	0	0	0	0	2	0	0	0	0	0	1
	Month 3	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	8	0	0	0	0	0	0	1	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	3	1	0	0	0	1	0	2	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	4	0	0	4	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	1	0	0	2	0	0	0	1	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	13	0	0	0	0	1	0	0	1	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	8	0	0	0	0	0	0	1	0	0	0	0	0	0
	Month 13	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	1	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	1	0	0	1
	Month 16	0	0	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 5	Month 1	0	0	0	0	0	0	0	5	0	1	0	0	0	0	1	0	0	0	0	0	2
	Month 2	0	0	0	0	0	0	0	17	0	0	1	0	0	0	0	0	0	1	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0
	Month 5	0	0	0	0	0	0	0	12	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	6	0	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	1	0	0	0
	Month 11	0	0	0	0	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	35	0	1	0	0	0	0	0	0	0	0	0	0	1
	Month 13	0	0	0	0	1	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	24	0	0	0	0	0	0	3	0	0	0	0	0	2
	Month 15	0	0	0	0	0	0	0	3	0	0	0	0	1	0	1	0	0	1	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
	Month 17	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0
	Sumation	8	11	3	2	1	1	2	639	2	36	20	1	17	8	25	16	6	33	1	2	61

Table 10. Continued

		Cymtur	Cymsp1	Cymsp2	Cymsp3	Dipell	Dipobl	Dipova	Encsi	Encsp1	Encsp2	Encsp3	Encsp4	Encsp5	Episp1	Eunbi	Eunmi	Eunsol	Eunsp1	Eunsp2	Eunsp3	Frabic
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	Month 2	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1
	Month 3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	6
	Month 4	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 5	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	1	2	0	0	0	0
	Month 6	0	0	0	0	1	0	0	2	0	1	0	0	0	0	1	3	0	0	0	0	0
	Month 7	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	5	0	0	0	0	3
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	3
	Month 11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	1	0	0	0
	Month 13	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
	Month 14	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	2
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	1	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	4	6	1	0	0	0
	Month 4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Month 6	0	0	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3
	Month 9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	5
	Month 11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0
	Month 12	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	1	0	0
	Month 13	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	3	8	0	0	0	0
	Month 14	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
	Month 18	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Site 3	Month 1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	13	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	6	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	6	0	4	0	0	0	0	2	0	7	0	0	0	0	0	0	0	0	0	0	0
	Month 13	3	0	0	0	0	0	0	1	0	13	1	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 15	5	0	0	1	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 16	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 4	Month 1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	1	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	2	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 8	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	3	0	0	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	8	0	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	3	1	0	0	0	0	0	4	2	0	0	0	0	0	0	1	0	0	0	0	0
	Month 12	5	0	0	0	0	0	0	1	2	0	1	0	0	0	0	2	1	0	0	0	0
	Month 13	1	0	0	0	1	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 5	Month 1	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
	Month 3	9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	2	0	23	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 8	2	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	1	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	6	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 13	1	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 14	10	0	0	0	0	2	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 16	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sumation	131	1	7	3	7	12	2	193	12	25	5	1	1	1	7	53	24	2	4	1	36

Table 10. Continued

		Frabid	Fraell	Fralan	Frauln	Frauac	Frasp1	Frasp2	Frasp3	Frurho	Fruwei	Frusp1	Frusp2	Frusp3	Frusp4	Gomaug	Gomcle	Gomgra	Gomlin	Gommin	Gompar	Gompun
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	44	0	0	0	0	0
	Month 2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	10	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	9	2
	Month 4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	258
	Month 5	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	4	0	10	227
	Month 6	0	0	0	0	4	0	0	0	1	3	1	1	0	0	0	0	0	0	0	29	63
	Month 7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0	0	1	0
	Month 8	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	7	0	0	0	0	3
	Month 9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	21	0	2	0	1	0
	Month 10	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	5	0	0	0	3	1
	Month 11	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	109	0	0	0	1	29
	Month 12	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	49
	Month 13	0	0	0	2	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	3
	Month 14	0	0	0	0	4	0	0	0	0	0	1	0	2	0	0	0	0	1	0	5	245
	Month 15	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	27
	Month 16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	94	0	0	0	3	2
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	20
	Month 18	0	0	0	0	29	0	0	0	0	2	1	0	0	0	0	1	0	0	0	4	4
Site 2	Month 1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
	Month 2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	4	3
	Month 3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	9	2
	Month 4	0	0	0	0	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	5	2
	Month 5	0	0	0	0	0	0	0	0	0	1	3	0	0	1	0	0	0	0	0	8	8
	Month 6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	12	1
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
	Month 9	0	0	0	4	0	0	0	0	0	5	0	0	0	0	0	0	0	0	1	10	0
	Month 10	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	1
	Month 11	0	0	0	0	2	0	14	0	0	0	1	0	0	0	0	0	0	0	0	8	1
	Month 12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	3
	Month 13	0	1	0	0	2	0	0	2	0	3	0	0	0	0	0	0	0	0	0	7	6
	Month 14	0	0	0	0	0	0	0	0	0	0	9	1	1	3	0	0	0	0	0	7	0
	Month 15	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	16	5
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
	Month 17	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	3
	Month 18	0	0	0	0	1	0	0	0	0	3	2	1	0	0	0	0	0	0	0	4	4
Site 3	Month 1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	4
	Month 3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
	Month 6	0	0	0	0	7	0	0	0	2	1	0	0	0	0	1	0	0	0	0	1	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 8	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	4
	Month 13	0	0	0	0	3	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	1
	Month 14	0	0	0	0	1	0	4	0	0	1	1	0	0	0	0	0	0	0	0	1	0
	Month 15	0	0	0	0	1	0	2	3	0	1	0	0	0	0	0	0	0	0	0	6	1
	Month 16	0	0	6	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	3
	Month 17	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 18	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	10
Site 4	Month 1	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3
	Month 2	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
	Month 3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	1
	Month 4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Month 5	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	3	1
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	11	1
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	7	4
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	15
	Month 13	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	5	18
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	4
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	35
	Month 16	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4
	Month 17	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1
Site 5	Month 1	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0
	Month 2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	2
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	4
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
	Month 9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3
	Month 13	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	3	4
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	7	0
	Month 16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0
	Month 17	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 18	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	7	0
	Sumation	1	1	21	48	83	1	25	6	3	68	20	4	4	4	7	320	9	8	1	496	1154

Table 10. Continued

		Gomsp1	Gomsp2	Gomsp3	Gomsp4	Gomsp5	Gomsp6	Gomsp7	Gomsp8	Gyrsca	Gyrspe	Hanamp	Handis	Melvar	Navbac	Navcle	Navcoh	Navcry	Navelg	Navgda	Navins
Site 1	Month 1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
	Month 2	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	1	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	1	0	0	0
	Month 5	10	0	0	1	0	0	0	6	1	0	1	0	16	0	0	0	0	0	0	0
	Month 6	21	0	0	0	0	0	0	8	1	0	0	0	15	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	3	0	0	0
	Month 9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
	Month 11	3	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
	Month 12	5	0	0	0	0	0	0	0	0	0	2	0	6	0	0	0	0	0	0	0
	Month 13	1	0	0	0	0	0	0	0	3	0	2	0	1	0	0	0	3	0	0	0
	Month 14	2	0	0	0	0	0	0	0	3	0	3	0	2	0	0	0	0	1	0	0
	Month 15	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 18	1	0	0	0	0	0	0	0	3	0	1	0	18	0	0	0	0	0	0	0
Site 2	Month 1	0	1	0	0	0	0	0	0	3	0	1	0	1	0	0	0	0	14	0	0
	Month 2	0	0	0	0	0	0	0	0	4	0	4	0	0	0	0	0	2	2	0	6
	Month 3	0	0	0	0	0	0	0	0	5	0	3	0	0	0	0	0	0	1	0	0
	Month 4	2	1	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	4
	Month 5	7	0	0	0	0	0	0	0	0	0	5	0	1	1	0	0	3	0	0	3
	Month 6	10	0	0	0	0	0	0	0	7	0	0	0	7	0	0	0	0	0	0	0
	Month 7	1	0	0	0	0	0	0	0	13	0	0	0	0	0	3	0	0	10	0	1
	Month 8	0	0	0	0	0	0	0	0	0	0	2	0	3	0	7	0	3	0	0	1
	Month 9	0	0	0	3	0	0	0	0	2	0	0	0	2	0	0	0	0	8	0	0
	Month 10	0	0	0	0	0	0	0	0	1	0	1	0	4	0	0	0	0	5	0	0
	Month 11	0	0	0	0	0	0	0	0	2	0	2	0	0	0	2	0	0	4	0	0
	Month 12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	5	0	0
	Month 13	7	0	0	0	0	0	0	0	5	1	1	0	0	0	0	0	0	8	0	0
	Month 14	0	0	0	0	0	0	0	0	14	0	6	0	0	2	0	0	1	5	0	0
	Month 15	2	0	0	0	0	0	0	0	6	0	2	0	0	0	0	0	0	1	0	1
	Month 16	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	5	0	0
	Month 17	0	0	0	0	0	0	0	0	3	0	1	0	0	0	1	0	3	1	0	1
	Month 18	2	0	0	0	0	0	0	0	14	0	0	0	1	1	0	0	0	1	0	0
Site 3	Month 1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	33	0	0	0
	Month 2	0	0	0	0	0	0	0	0	1	0	1	0	2	1	0	0	9	0	0	0
	Month 3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	6	0	0	0
	Month 4	0	0	0	0	0	0	0	0	6	0	0	0	3	0	0	0	2	0	0	0
	Month 5	1	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0
	Month 6	1	0	0	0	0	0	0	0	46	0	1	0	63	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	85	0	0	0	2	0	0	0	8	0	0	0
	Month 8	0	0	0	0	0	0	0	0	7	0	0	0	28	0	0	0	12	0	0	0
	Month 9	0	0	0	0	0	0	0	0	7	1	0	0	6	4	0	0	38	0	0	0
	Month 10	0	0	0	0	0	0	0	0	2	0	0	0	4	6	0	0	54	0	0	1
	Month 11	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	3	0	0	0	8	6	0	0	0	0	0	0
	Month 13	3	0	0	0	0	0	0	0	3	0	0	0	0	2	0	0	11	0	0	0
	Month 14	2	0	0	0	0	0	0	0	2	0	3	0	1	0	0	0	4	1	0	0
	Month 15	0	0	0	0	0	0	0	0	14	1	0	0	27	0	0	0	12	0	0	0
	Month 16	0	0	0	0	0	0	0	0	6	0	0	0	2	0	0	0	4	0	0	1
	Month 17	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	17	1	0	0
	Month 18	0	0	0	0	0	0	0	0	23	0	0	0	13	0	0	0	3	0	0	0
Site 4	Month 1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6	0	0
	Month 2	0	0	0	0	0	0	0	0	7	3	1	0	2	0	0	0	1	0	0	0
	Month 3	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	3	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	1	0	0	3	1	3	0	2	0	0	0	0	1	0	0
	Month 6	2	0	0	0	0	0	0	0	8	0	3	0	0	1	0	0	0	0	0	0
	Month 7	0	0	0	0	0	1	0	0	36	2	0	0	1	2	0	1	2	0	0	0
	Month 8	0	0	0	0	0	0	0	0	6	0	1	0	1	0	0	0	5	0	0	0
	Month 9	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	3	0	0
	Month 10	0	0	0	0	0	0	0	0	2	2	0	0	0	4	0	0	0	0	0	0
	Month 11	2	0	0	2	0	0	0	0	1	0	0	0	1	4	0	0	0	1	0	0
	Month 12	18	0	0	1	0	0	1	0	3	1	1	1	0	4	0	0	0	2	0	0
	Month 13	10	0	0	0	0	0	0	0	6	0	0	0	0	1	0	0	0	1	0	0
	Month 14	8	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
	Month 15	3	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	4	1	0	0
	Month 16	1	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0
	Month 18	0	0	0	0	0	0	0	0	3	0	2	0	1	0	0	0	0	0	0	0
Site 5	Month 1	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	1	0	0
	Month 2	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	3	0	0	0
	Month 3	1	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0
	Month 4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	1	0	0	0	0	0	0	0	19	0	4	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	13	1	0	0	1	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
	Month 11	2	0	0	0	0	0	0	0	6	0	4	0	0	0	0	0	0	0	0	0
	Month 12	1	0	0	0	0	0	0	0	7	0	0	0	12	0	0	0	0	2	0	0
	Month 13	1	0	0	0	0	0	0	0	8	0	0	1	1	0	0	0	0	1	0	0
	Month 14	0	0	0	0	0	0	0	0	7	2	4	0	5	1	0	0	4	4	0	0
	Month 15	0	0	0	0	0	0	0	0	51	1	0	6	5	0	0	0	1	2	0	0
	Month 16	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
	Month 17	0	0	0	0	0	0	0	0	6	0	1	0	1	0	0	0	0	1	0	0
	Month 18	0	0	0	0	0	0	0	0	9	0	3	0	0	0	0	0	1	1	0	0
	Sumation	139	2	1	12	32	3	1	14	543	20	97	8	289	42	14	4	258	107	1	19

Table 10. Continued

		Navlep	Navmed	Navmob	Navmut	Navrad	Navsch	Navtri	Navvge	Navvli	Navvro	Navvvi	Navsp1	Navsp2	Navsp3	Navsp4	Navsp5	Navsp6	Navsp7	Navsp8	Navsp9
Site 1	Month 1	0	1	0	0	0	5	0	0	0	2	7	4	0	0	0	0	0	0	0	0
	Month 2	0	0	0	1	0	1	0	0	0	0	1	2	0	0	1	0	0	0	0	0
	Month 3	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	2	0	3	0	0	0	1	0	0	1	0	3	0	1	0	0	0
	Month 5	0	0	0	0	0	1	0	0	0	12	0	0	0	0	4	0	0	0	0	0
	Month 6	0	4	0	0	0	7	0	0	0	10	0	0	0	0	8	0	0	5	0	0
	Month 7	0	9	0	0	0	2	0	0	0	0	6	0	0	0	3	0	0	0	0	0
	Month 8	4	13	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
	Month 9	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	21	7	0	1	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	4	0	0	0	2	0	0	0	10	0	0	3	0	2	0	0	0
	Month 12	0	0	0	2	0	4	0	0	0	0	4	6	1	0	1	0	1	0	0	1
	Month 13	0	0	0	4	0	8	0	0	0	47	10	2	1	0	4	7	1	7	0	0
	Month 14	0	0	0	0	0	2	0	1	0	2	0	1	0	0	0	2	0	0	0	0
	Month 15	0	7	0	0	0	0	0	0	0	7	0	0	1	0	3	1	1	8	0	0
	Month 16	0	0	0	0	0	1	0	0	0	4	3	0	0	0	0	0	0	0	0	1
	Month 17	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	4
	Month 18	0	0	0	3	0	4	0	0	0	0	16	29	1	0	0	0	0	0	0	0
Site 2	Month 1	0	0	0	3	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	3	0	3	0	0	0	8	1	0	0	0	0	3	0	0	0	0
	Month 3	0	0	0	1	0	1	2	0	0	0	1	1	0	0	0	1	0	4	0	0
	Month 4	0	0	0	3	0	0	0	0	1	5	0	0	3	0	2	3	4	5	0	0
	Month 5	0	0	0	4	0	7	0	1	0	3	1	5	3	1	5	11	6	31	0	3
	Month 6	0	0	0	4	0	8	0	0	0	27	0	3	0	0	0	1	4	6	0	3
	Month 7	0	0	0	0	0	0	0	0	0	0	7	0	0	0	3	0	0	0	0	0
	Month 8	1	4	0	2	1	3	0	1	0	0	13	0	0	1	0	0	2	0	0	0
	Month 9	0	0	0	0	0	3	0	0	0	0	7	0	0	0	0	10	0	0	0	0
	Month 10	0	1	0	1	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	1	0	0	0	9	0	0	0	0	0	0	0	0	3	1	0	0
	Month 12	0	0	0	1	0	9	0	0	0	0	3	2	1	1	9	1	3	1	0	1
	Month 13	0	13	0	0	0	5	0	0	0	6	0	0	1	0	5	8	0	4	0	0
	Month 14	0	0	0	1	0	1	0	0	0	12	5	3	6	0	3	8	6	13	0	3
	Month 15	0	0	0	3	0	3	0	0	0	10	0	0	3	1	0	7	0	9	0	0
	Month 16	0	3	0	0	0	3	0	0	0	0	5	0	0	0	1	1	0	0	0	0
	Month 17	0	1	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5
	Month 18	0	0	0	3	0	4	0	4	0	0	3	6	0	0	1	12	0	2	0	0
Site 3	Month 1	0	0	0	2	0	4	0	0	0	0	8	0	6	2	0	0	0	0	0	0
	Month 2	0	60	1	0	0	7	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	Month 3	0	4	0	0	0	8	0	0	0	0	2	0	0	0	0	8	0	0	0	0
	Month 4	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	6	0	0	0	0
	Month 5	0	0	0	0	0	4	0	0	0	0	2	5	1	0	0	23	1	3	0	0
	Month 6	0	2	0	2	0	0	0	0	0	0	0	0	0	7	4	29	0	2	3	0
	Month 7	0	0	0	1	0	2	0	0	0	0	1	0	0	15	0	0	0	0	0	0
	Month 8	0	3	0	0	0	5	0	0	0	0	1	0	0	0	0	5	0	10	0	0
	Month 9	2	0	0	0	0	7	0	0	0	0	1	0	0	1	7	0	0	0	1	3
	Month 10	8	0	1	3	0	7	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	4	0	0	10	1	2	2	0	5	0	0	0	0
	Month 12	0	0	0	0	0	24	0	2	0	0	13	12	6	0	0	14	0	1	0	7
	Month 13	0	19	0	0	0	1	0	1	0	2	0	0	0	2	1	51	0	4	0	1
	Month 14	0	0	0	1	0	7	0	0	0	3	0	1	3	5	0	15	1	3	0	2
	Month 15	0	1	0	1	0	15	0	0	0	3	2	0	1	45	0	37	0	1	1	0
	Month 16	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	21	0	0	0	0
	Month 17	0	0	0	0	0	14	0	0	0	0	0	0	0	15	0	0	0	0	0	0
	Month 18	0	0	0	4	0	21	0	2	0	0	0	5	11	3	0	21	0	6	3	3
Site 4	Month 1	0	3	0	0	0	4	0	0	0	0	5	0	0	6	1	1	0	0	0	0
	Month 2	0	0	0	0	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	6	0	0	0	0	6	6	0	1	0	0	0	0	0	0
	Month 4	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	Month 5	0	0	0	1	0	0	0	0	0	4	0	1	1	0	0	4	2	3	0	2
	Month 6	0	0	0	1	0	15	0	1	0	39	1	6	2	1	1	8	1	2	3	1
	Month 7	0	0	0	0	0	2	0	0	0	0	7	0	0	0	0	0	0	0	0	0
	Month 8	1	0	0	16	0	4	0	0	0	0	16	0	0	0	1	1	0	4	1	0
	Month 9	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	1	0
	Month 10	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	2	0	8	0	5	0	0	1	0	4	1	1	1	0	0	0	0
	Month 12	0	0	0	0	0	0	0	1	0	0	15	0	8	2	5	2	3	0	0	0
	Month 13	0	0	0	0	0	10	0	0	0	0	4	1	2	0	7	24	12	5	0	0
	Month 14	0	0	0	0	0	0	0	0	3	1	1	1	2	1	0	0	0	1	0	1
	Month 15	0	0	0	0	0	6	0	3	0	3	0	3	0	3	3	4	0	0	0	1
	Month 16	0	0	0	1	0	53	0	0	0	0	3	0	0	1	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
	Month 18	0	0	0	7	0	0	0	3	0	4	0	8	0	0	3	0	1	0	0	1
Site 5	Month 1	0	0	0	0	0	1	0	3	0	0	17	0	1	0	0	1	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	3	0	12	0	0	0	0	19	17	0	0	0	0	2	0	0	0
	Month 4	0	0	0	0	0	28	0	0	2	8	0	0	1	0	0	6	0	0	0	0
	Month 5	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	3	0	0	0	0	8	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	3	0	0	0	0	13	0	0	0	0	0	0	0	0	0
	Month 9	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Month 11	0	0	0	10	0	0	0	0	1	0	1	2	3	2	1	2	0	5	0	1
	Month 12	0	0	0	0	0	2	0	1	0	0	13	0	0	5	0	3	0	2	0	0
	Month 13	0	0	0	0	0	8	0	0	0	2	2	0	3	1	1	13	0	0	0	0
	Month 14	0	0	0	0	0	3	0	0	0	9	5	1	0	0	0	4	1	1	0	0
	Month 15	0	0	0	0	0	0	0	17	4	14	78	0	0	3	0	6	3	1	0	0
	Month 16	0	0	0	0	0	3	0	0	0	8	0	0	0	2	0	0	0	0	0	0
	Month 17	0	0	0	3	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
	Month 18	0	0	0	0	0	14	0	2	0	0	8	5	0	3	0	4	1	3	0	2
	Sumation	43	157	2	109	1	426	2	64	11	258	394	149	80	135	96	397	62	157	13	47

Table 10. Continued

		Navsp10	Navsp11	Navsp12	Navsp13	Navsp14	Navsp15	Navsp16	Navsp17	Navsp18	Navsp19	Navsp20	Navsp21	Neiafl	Neiamp	Neibin	Neiiri	Neisep	Neisp1	Neisp2
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	1	1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	10	1	0	6	0	1	0	0	0	4	3	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	13	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 4	0	0	0	4	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0
	Month 5	2	3	0	1	0	0	2	2	0	0	0	0	0	1	1	0	1	0	0
	Month 6	0	0	0	6	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	1	0	26	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 12	0	0	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 13	2	1	0	1	0	0	2	0	0	1	1	0	0	1	0	0	0	0	0
	Month 14	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0
	Month 15	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0
Site 3	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 12	1	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	1	0	0	5	0	0	0	3	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	1	0	7	1	0	0	0	0	0	0	0	0	0	0
Site 4	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	1	0	0	1	5	0	1	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	1
	Month 13	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	1	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Site 5	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 11	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Month 13	0	0	0	0	0	0	1	5	0	1	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	Month 15	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Sumation	19	6	42	53	4	7	30	55	3	7	1	4	9	20	1	1	1	2	5

Table 10. Continued

		Neisp3	Neisp4	Neisp5	Neisp6	Nitacu	Nitbre	Nitcoa	Nitdis	Nitdub	Nitfon	Nitfpa	Nitgei	Nitlev	Nitpal	Nitumb	Nitsp1	Nitsp2	Nitsp3	Nitsp4	Nitsp5	Nitsp6	Nitsp7	Nitsp8
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	1	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	3	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0
	Month 10	1	0	0	0	0	0	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0
	Month 11	1	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	5	0	5	0	0	0	5
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	6	0	25	1	0	0	0
	Month 13	2	0	0	0	0	0	0	0	0	0	0	0	0	65	0	0	21	1	21	1	0	0	3
	Month 14	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	4	0	1	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	2	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	8	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	53	0	0	0	0	0	0	0	0	0
	Month 5	0	1	0	2	0	0	0	0	1	0	0	0	0	46	0	0	0	1	0	2	0	0	3
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	38	1	0	3	0	0	0	0	0	3
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	2
	Month 9	0	0	0	0	0	0	0	1	0	0	0	0	0	12	0	0	0	0	0	0	0	0	1
	Month 10	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	50	0	0	0
	Month 13	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	1	3	0	0	1
	Month 14	0	4	0	0	0	0	0	0	0	0	0	0	0	67	0	0	0	1	3	1	0	0	6
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0	1	0	0	24	0	0	3
	Month 16	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	1	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0	2	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	1
Site 3	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
	Month 3	0	0	0	0	0	0	0	1	0	1	0	0	1	10	0	0	0	0	1	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	6	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	7	0	0	0	0	0	17	0	0	1	0	1	0	0	0	0
	Month 10	0	1	0	0	0	0	0	2	0	0	0	0	0	6	0	0	2	0	1	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0	0	0
	Month 12	6	1	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1	2	1	0	0	0	0
	Month 13	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	2	0	2	0	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	1	31	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	1	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	1	1	1	0	0	0
Site 4	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	1	0	0	0	0	0	0	0	1	8	0	0	0	1	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	1	10	0	3	0	0	1	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	81	0	0	0	2	1	2	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	1	0	0	0	0	0	0	1	0	15	0	0	2	0	0	0	0	0	0
	Month 9	0	0	0	0	0	1	1	3	0	0	0	0	1	1	0	0	0	5	0	0	0	0	0
	Month 10	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
	Month 11	0	0	0	0	0	0	0	1	0	0	0	0	1	4	0	0	1	2	2	1	3	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0
	Month 13	0	0	0	0	0	0	0	2	0	0	0	1	0	15	0	0	1	0	1	3	0	0	0
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	1	2	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	3	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	2	0	0	0
Site 5	Month 1	0	0	0	0	0	0	0	7	0	1	0	4	0	0	0	0	0	1	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	Month 3	0	0	0	0	0	0	0	1	0	0	0	0	0	16	0	0	0	2	1	0	0	1	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	2	0	2	0	0	1
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	1	3	0	0	0	1	2	17	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	1	0	1	0	0	0	0	2	6	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	7	1	0	0	2	0	1	0	0	0	0	2	1	0	0	1	0	0
	Month 11	0	0	0	1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	2	1	0	0	1
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	2	51	0	0	0	2	2	1	0	0	0
	Month 13	0	0	5	0	0	0	0	4	0	0	0	1	4	26	0	0	0	0	0	4	0	0	0
	Month 14	0	0	0	0	0	0	0	0	1	0	0	0	2	10	0	0	0	0	1	0	3	0	0
	Month 15	0	0	0	1	0	0	0	0	0	0	0	2	2	14	0	0	0	0	2	0	0	0	1
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	1	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0	0	5	2	3	0	0	0
	Sumation	13	8	5	4	2	10	5	45	2	12	1	22	21	1075	1	3	85	39	97	158	9	1	32

Table 10. Continued

		Nitsp9	Nitsp10	Nitsp11	Nitsp12	Nitsp13	Pinacr	Pinapp	Pinbor	Pinmes	Pinpla	Pinsch	Pinsub	Pinsui	Pinvir	Pinsp1	Pinsp2	Pinsp3	Pinsp4	Pinsp5	Pinsp6	Pinsp7	Pinsp8
Site 1	Month 1	0	0	0	0	0	0	0	0	7	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	1	0	0	0	6	0	0	0	0	0	0	0	0	0	0	1	0	0
	Month 7	0	0	0	0	0	0	0	0	17	0	0	0	0	2	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	1	0	1	7	0	1	1	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	0	0	0	0	0	8	4	3	6	0	3	0	0	0	0	0	1	0	0
	Month 14	0	0	0	0	0	0	0	1	0	0	0	3	0	3	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	7	0	0	5	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	18	0	5	0	0	0	0	0	0	0	0	1	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0
	Month 7	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	0	0	1	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	1	2	0	2	0	0	0	0	0	2	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	3	0
	Month 13	0	0	0	0	0	0	0	1	0	1	3	0	0	1	0	0	0	0	0	0	2	0
	Month 14	0	0	0	0	1	0	0	0	2	0	21	0	0	3	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Month 16	0	0	0	0	0	1	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Site 3	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 4	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 14	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Site 5	Month 1	0	0	0	0	0	0	1	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 10	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Month 12	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Month 13	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Month 14	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sumation	4	3	2	2	7	3	1	5	97	5	58	34	8	31	8	9	4	4	6	5	6	1

Table 10. Continued

Site	Month	Pinsp9	Pinsp10	Pinsp11	Pinsp12	Reisin	Rhoacu	Rhobre	Rhogg	Rhogpa	Rhogib	Rhorup	Rhosor	Rhosp1	Rhosp2	Rhosp3	Rhosp4	Selpup	Selsp1	Staanc	Stasmi	Surang
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	1	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	2	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1	1
	Month 4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	4	1	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	12	2	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	2	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	1	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	4	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	11	1	2
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	3	3
	Month 12	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	3	0	0	1	1
	Month 13	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	18	0	0	7	0
	Month 14	0	0	0	0	0	0	0	0	0	6	0	0	0	0	1	0	3	0	2	0	0
	Month 15	2	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	6	0	48	3	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	5	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0
Site 2	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	5
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	1
	Month 3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0
	Month 4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
	Month 6	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	4	0
	Month 8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	9	0	0	4	0
	Month 9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0	1	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	1	1	0
	Month 11	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	0	1	3	0
	Month 12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	1	0	2
	Month 13	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	2	0	6	4	0
	Month 14	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	5	0	3	2	3
	Month 15	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	3	0	1
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	2	0	1
	Month 18	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0
Site 3	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	Month 2	0	0	0	0	1	0	0	0	0	7	1	0	2	0	0	0	1	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	0
	Month 6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	1
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	15	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	1
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
	Month 11	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
	Month 14	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	11	1	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0
Site 4	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
	Month 4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 5	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	Month 12	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	3	0	0	2	0
	Month 13	0	0	0	0	0	0	0	3	1	14	0	0	0	0	1	1	0	0	2	1	2
	Month 14	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Site 5	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	1
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 4	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	1	0
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	3	0	0	0	0
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Month 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Month 14	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	2	1
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Month 18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sumation	12	2	1	2	11	5	1	5	1	54	2	1	37	1	3	1	219	1	301	60	33

Table 10. Continued

		Surbi	Surbis	Surele	Surova	Surrob	Surrou	Surten	Sursp1	Sursp2	Sursp3	Sursp4	Sursp5	Sursp6	Sursp7	Sursp8	Sursp9	Synlan	Synuln	Synuae		total nummber
Site 1	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		116
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		98
	Month 3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		91
	Month 4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		301
	Month 5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0		365
	Month 6	0	0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0		373
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		149
	Month 8	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0		121
	Month 9	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0		155
	Month 10	0	1	0	0	23	0	1	0	0	0	0	0	0	0	0	0	0	0	0		181
	Month 11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		260
	Month 12	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1		213
	Month 13	0	0	0	0	3	0	2	0	1	0	0	0	0	0	0	0	0	0	0		382
	Month 14	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		355
	Month 15	0	0	0	0	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0		257
	Month 16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		152
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		72
	Month 18	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	0	2	0	0		269
Site 2	Month 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4		84
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		85
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	58		139
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		137
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		311
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		256
	Month 7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1		82
	Month 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		107
	Month 9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1		112
	Month 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0		77
	Month 11	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	11		189
	Month 12	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5		256
	Month 13	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	2		295
	Month 14	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		263
	Month 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1		234
	Month 16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1		97
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		63
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		131
Site 3	Month 1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	1	0		108
	Month 2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3		141
	Month 3	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3		87
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		35
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0		196
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	2		261
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		141
	Month 8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0		112
	Month 9	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		149
	Month 10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		162
	Month 11	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2		148
	Month 12	0	0	0	0	4	0	0	4	0	0	1	2	0	0	0	0	2	0	0		271
	Month 13	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		254
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		189
	Month 15	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8		276
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1		96
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		74
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3		192
Site 4	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		116
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		73
	Month 3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13		78
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		53
	Month 5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0		91
	Month 6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	1		273
	Month 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		101
	Month 8	0	13	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		129
	Month 9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		144
	Month 10	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2		147
	Month 11	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3		148
	Month 12	0	0	0	1	3	0	0	0	1	0	0	0	0	0	0	0	0	0	45		222
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		299
	Month 14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1		91
	Month 15	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3		231
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		116
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		8
	Month 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1		89
Site 5	Month 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		116
	Month 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		137
	Month 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6		175
	Month 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0		216
	Month 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0		36
	Month 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
	Month 7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1		104
	Month 8	2	4	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	0	0		119
	Month 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3		228
	Month 10	0	2	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1		144
	Month 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		106
	Month 12	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4		267
	Month 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2		277
	Month 14	0	0	0	0	3	0	0	0	1	0	1	0	0	1	1	0	2	0	0		208
	Month 15	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	2	1	0	3		281
	Month 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		137
	Month 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		29
	Month 18	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	4		171
	Sumation	4	31	1	10	181	6	14	13	8	2	6	4	1	2	2	2	40	11	211		
																				Total Countin		14880

4.4 Physico-chemical properties of the Mae Sa Stream

The overall results from the physico-chemical properties of water quality in the Mae Sa stream during the research period were shown in figures of area plots and average bar graphs with standard deviation. Raw data of the water quality is given in Table 11. The results of the physico-chemical measurements done in the 5 sampling sites are summarized in details and shown in Table 12. The water qualities of each site were compared by one-way ANOVA with Least-significant difference (LSD) method.

4.4.1 Substrate investigation

There are many kinds of measurement possible to characterize the structure of the stream sites. In this study, the stream depth, width and percentage distribution of organic and inorganic components (gravel, boulder, sand and silt) were measured at each site during an 18 month period (April 1998 – September 1999). The results of the investigation were shown in Figures 36 – 53. Benthic algae in running water must be firmly anchored living on solid surfaces, or able to regain their position if they live on soft substrata. All, or almost all, of the diatoms which occur in river silts are motile, and such epipelic genera include *Nitzschia, Navicula, Caloneis, Gyrosigma, Surirella* and *Cymatopleura* (Round, 1964 cited by Hyne, 1970). Epilithic and epiphytic genera are either firmly attached with jelly or stalked as are many diatoms; e.g. *Cymbella, Achnanthes* and *Gomphonema.* These imply that the type of substrates are important to diatom distribution (Hyne, 1970).

4.4.2 Velocity

Water velocity depends on river morphology; depth, width, slope and water discharge. Velocity affects directly to soil erosion and affects indirectly to dissolved oxygen and total dissolved solid.

The area plots of velocity are shown in Figure 54. Average values of all sampling sites are shown in Figure 55. The average current velocity at the deeper study sites (Sites 3 and 4) was significantly higher than the shallow sites (Sites 1 and 2). The current velocity during the research period ranges between 0 and 0.613 $m.l^{-1}$.

Table 12. Average values of water quality variables in five sampling sites of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand (min = minimum value, max = maximum value, ave = average value).

		Site 1			Site 2			Site 3			Site 4			Site 5		
		min	max	ave	min	max	ave	min	max	ave	min	max	ave	min	max	ave
Alkalinity	(mg/L)	19.5	43.8	34.07a±6.69	50	138.8	90.26b±26.43	92.5	181	143.88d±26.54	42	172.5	131.88d±33.22	27.5	154.5	111.61c±29.15
Turbidity	(NTU)	1.3	7.5	3.59±1.89	2.7	24.5	8.83±6.61	7.9	5100	334.3±1189.85	3.5	220	55.46±69.98	4	254	62.61±83.04
Velocity	(m/s)	0.01	0.3	0.133a±0.08	0	0.273	0.196ab±0.07	0.14	0.56	0.329c±0.11	0	0.527	0.232b±0.16	0	0.613	0.204ab± 0.14
DO	(mg/L)	4.8	8	7.08±0.85	5.2	7.5	6.65±0.68	5.2	8	7.35±0.74	5.6	8.8	6.92±0.96	6.2	7.8	6.94±0.56
BOD5	(mg/L)	0.3	3.4	1.23a±1.07	0.2	3.8	1.28a±0.92	0.4	6.7	2.27b±1.79	0.4	2.4	1.24a±0.65	0.4	3	1.03a±0.64
Conduct.	(mg/L)	35	116	68.11a±21.84	118	253	188.4b±36.02	187	525	297.22d±70.15	186	415	274.28cd±55.74	103	594	245.98c±100.81
Temp.	°C	19	23	21.43a±1.27	20	23.5	22.15a±1.12	22.5	28.7	25.33b±1.63	23	33.1	27.68c±2.32	24	31.5	27.72c±2.02
pH		6.45	7.65	6.99a±0.30	6.8	7.55	7.18a±0.21	7.16	8.95	8.23c±0.43	7.1	8.28	7.49b±0.30	6.99	8.11	7.45b±0.29
TDS	(mg/L)	18	58.2	32.4a±10.99	60	124	92.4b±18.01	101	246	150.5d±31.92	93	206	136.13cd±27.02	51.5	290	121.78c±49.16
NO_3^--N	(ug/L)	38	2426	492±654.19	80	7373	1350.72±2094.85	150	9635	1707.05±2612.39	95	3766	823.16±1086.62	41	3400	709.77±959.11
NO_2^--N	(ug/L)	2	11	4.02a±2.47	4	25	10.03b±5.36	3	22	10.49b±5.71	1	37	10.87b±9.30	2	47	11.87b±10.46
NH_4^+-N	(ug/L)	0	342	98.5±94.16	2.7	430	167.26±124.13	0	482	214.05±132.89	3.3	525	171.29±149.64	0	390	128.83±114.95
PO_4^{3-}-P	(ug/L)	10	1380	188.08±358.99	15	2040	358.93±578.67	22	1120	250.24±350.41	15	906	205.12±300.26	12	1100	206.13±306.05
Total P	(ug/L)	15	1750	272.73±493.43	18	2830	471.91±845.40	29	2150	344.62±577.19	19	2700	411.47±801.45	18	2490	381.19±691.45
Iron	(ug/L)	31	1190	173.61a±263.79	156	1250	394.83bc±280.36	26	1120	328.44ab±294.34	0	1520	547.88c±367.76	0	870	345.16ab±263.43

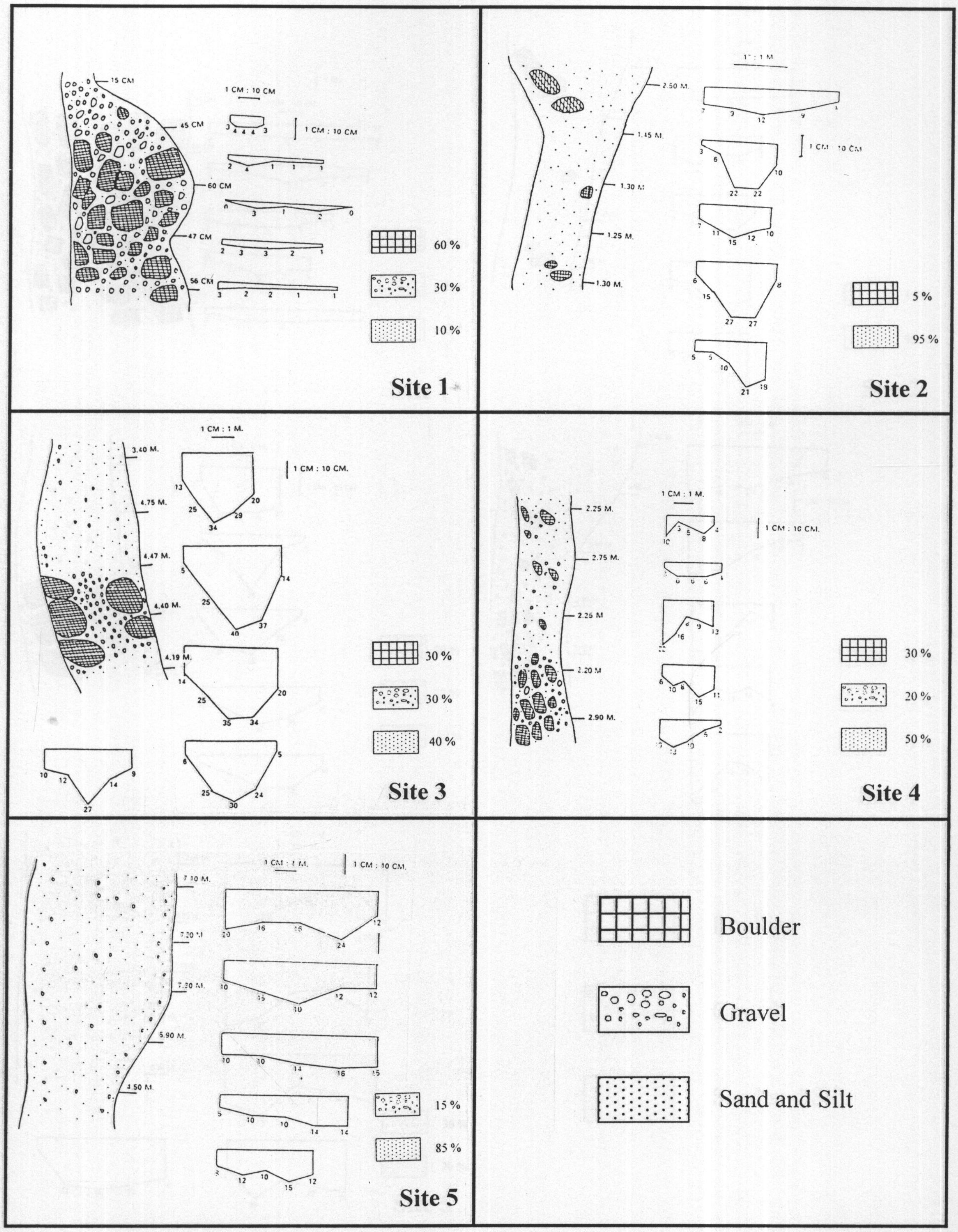


Figure 36. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park Chiang Mai, Thailand. (April 1998)

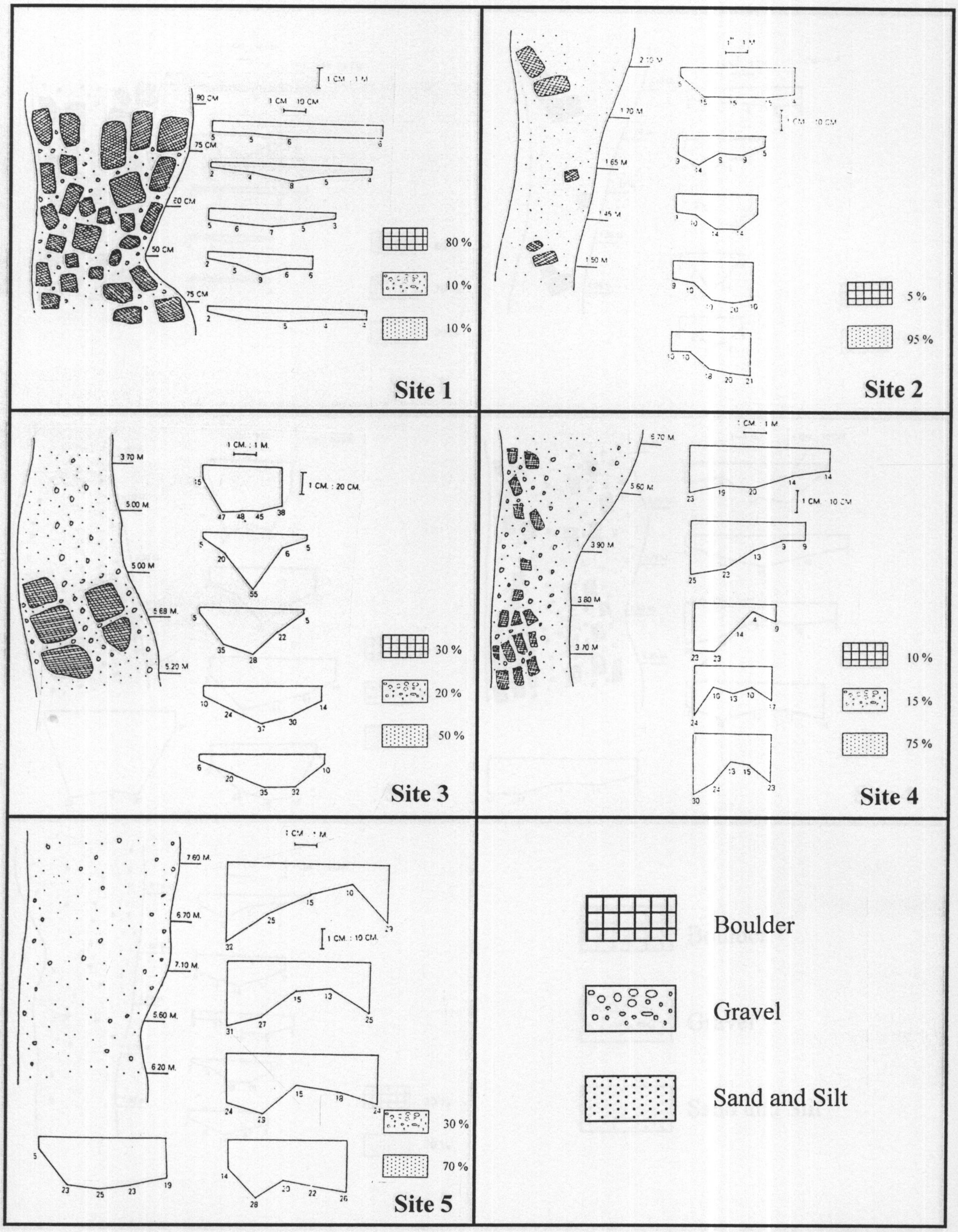


Figure 37. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (May 1998)

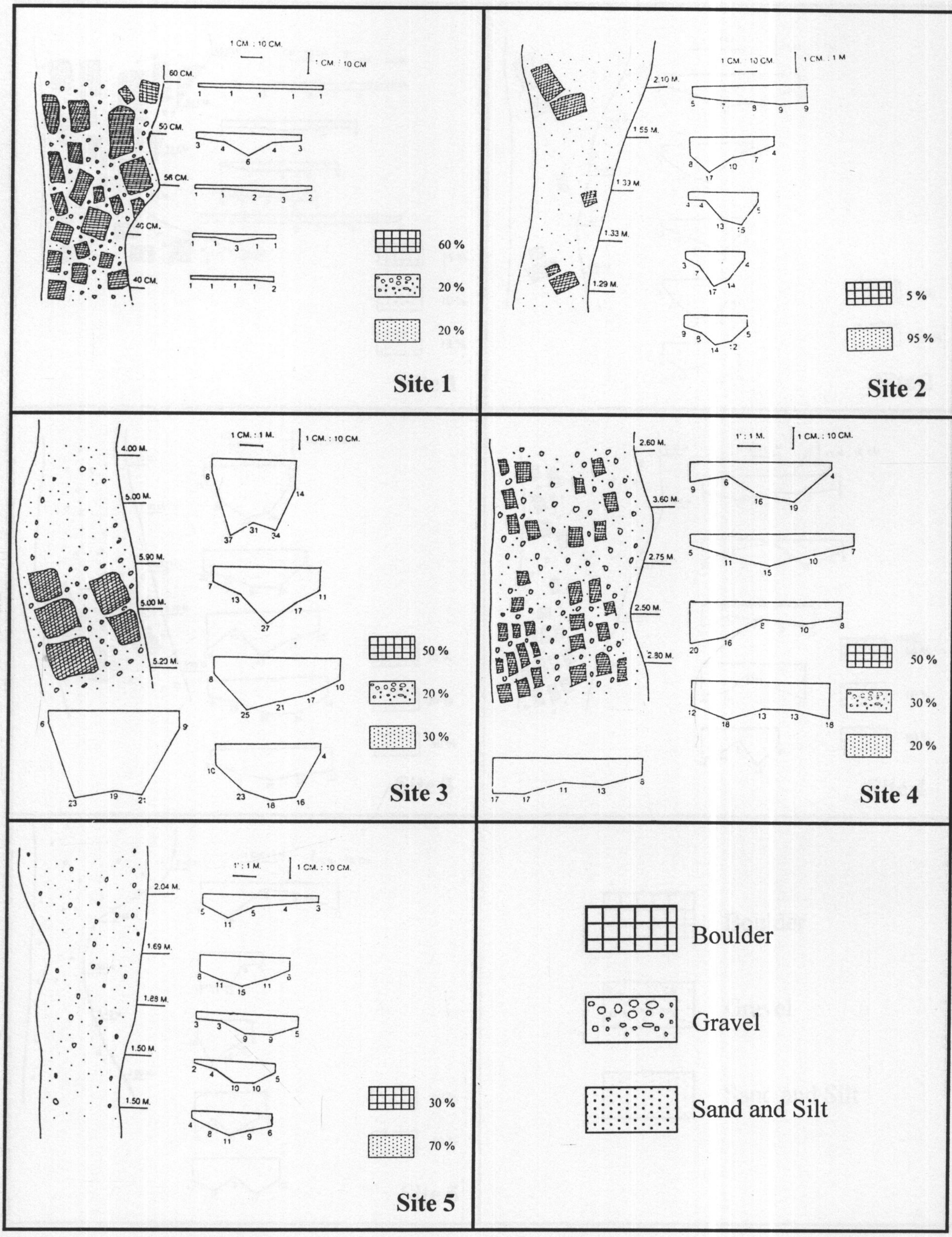


Figure 38. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (June 1998)

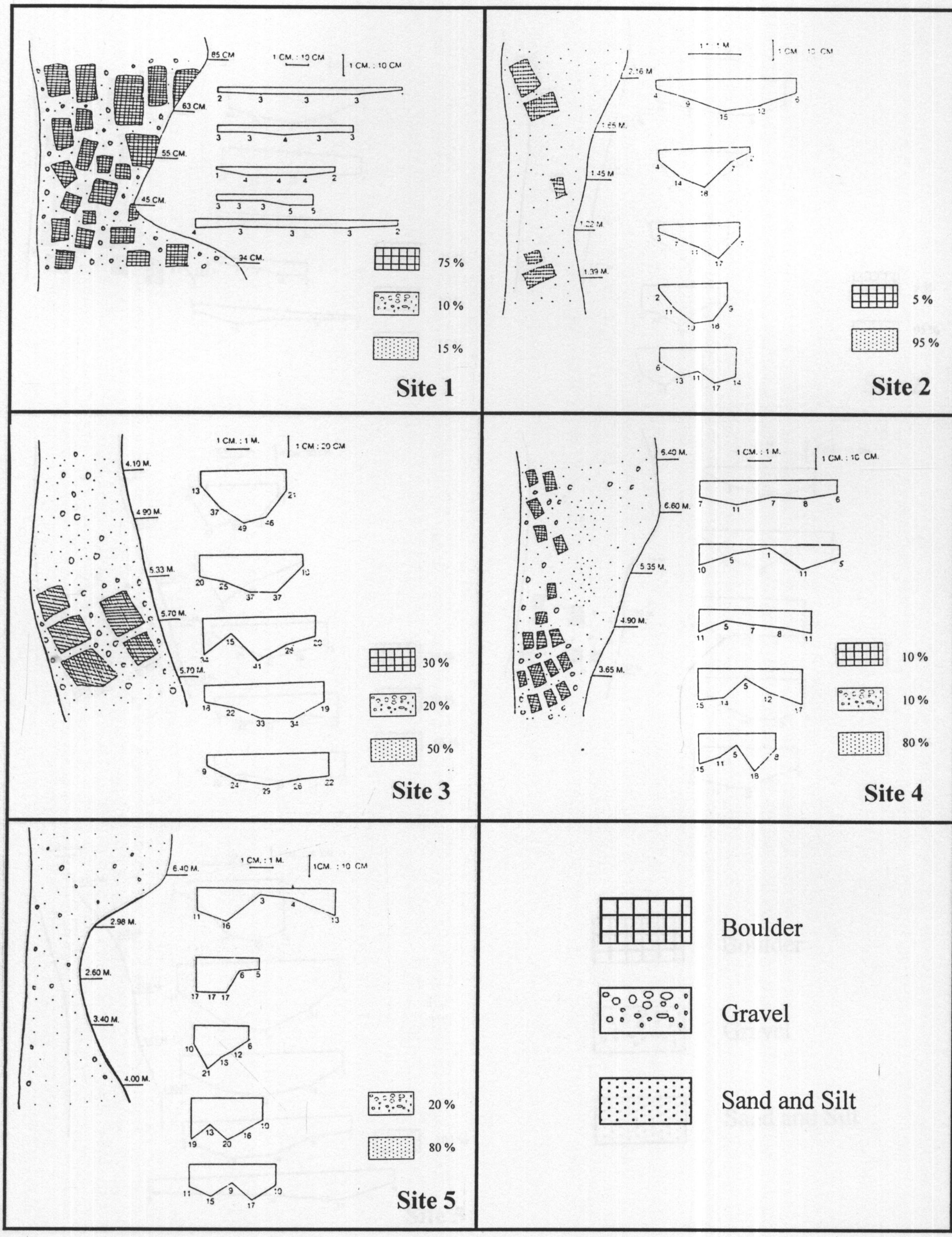


Figure 39. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (July 1998)

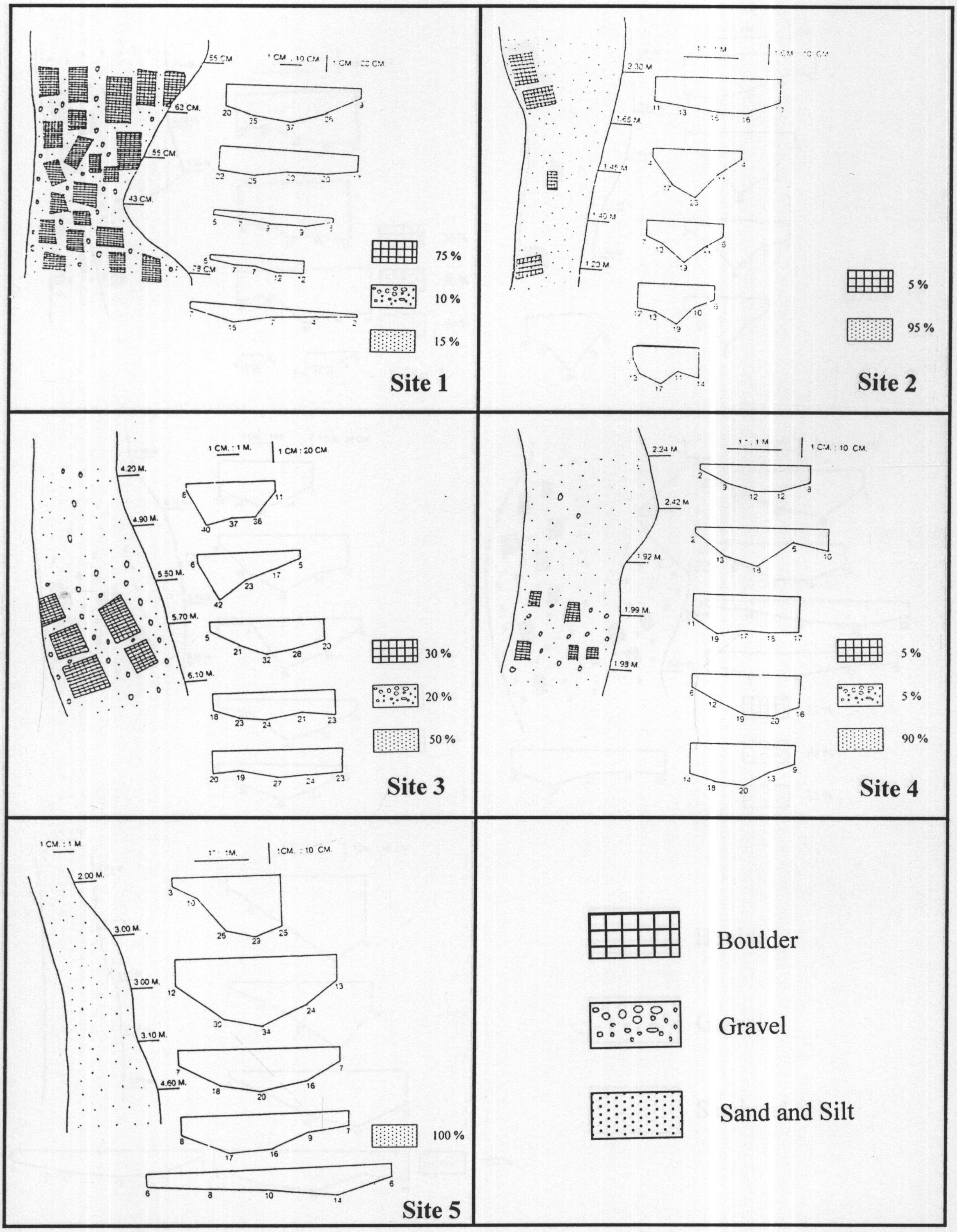


Figure 40. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (August 1998)

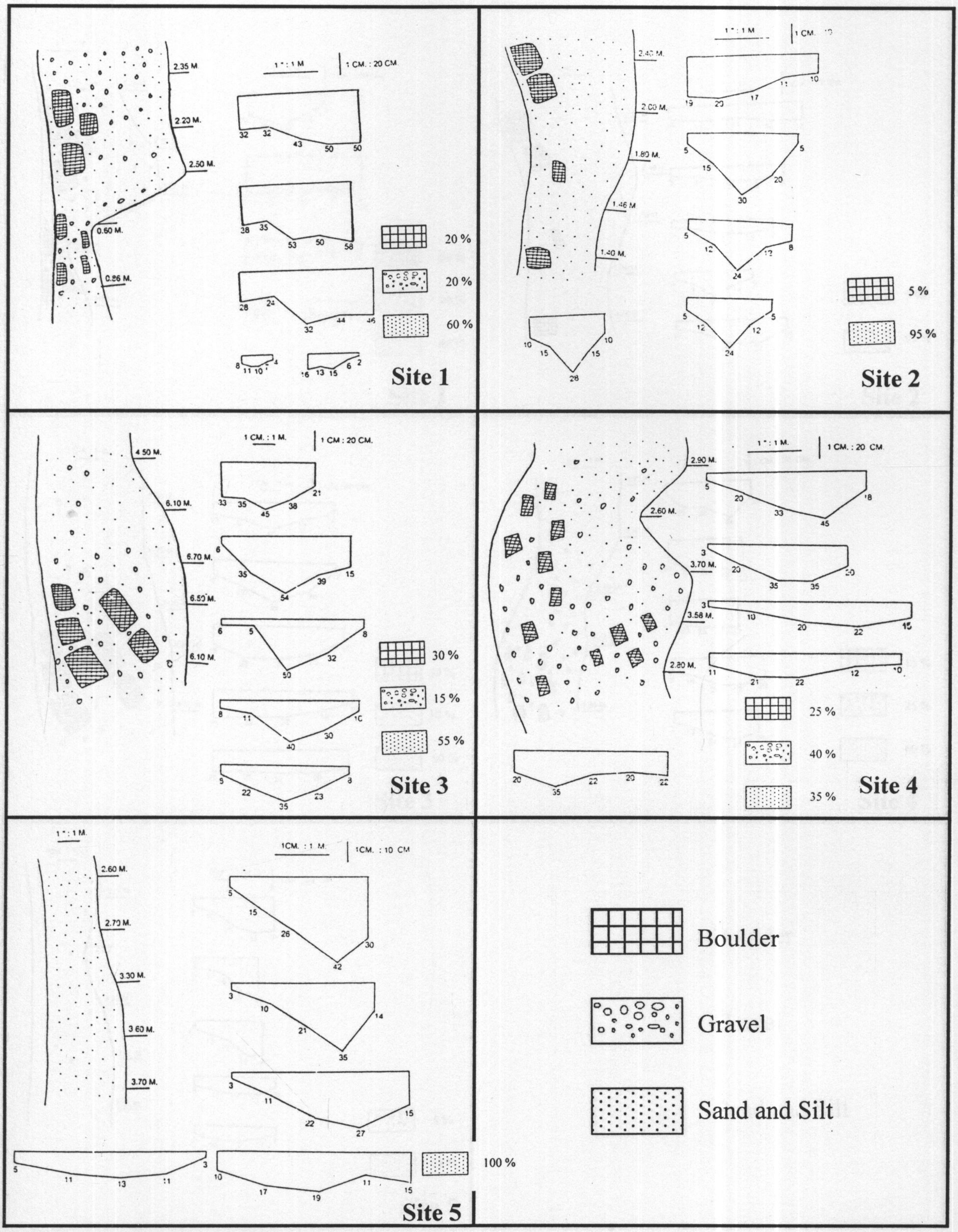


Figure 41. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (September 1998)

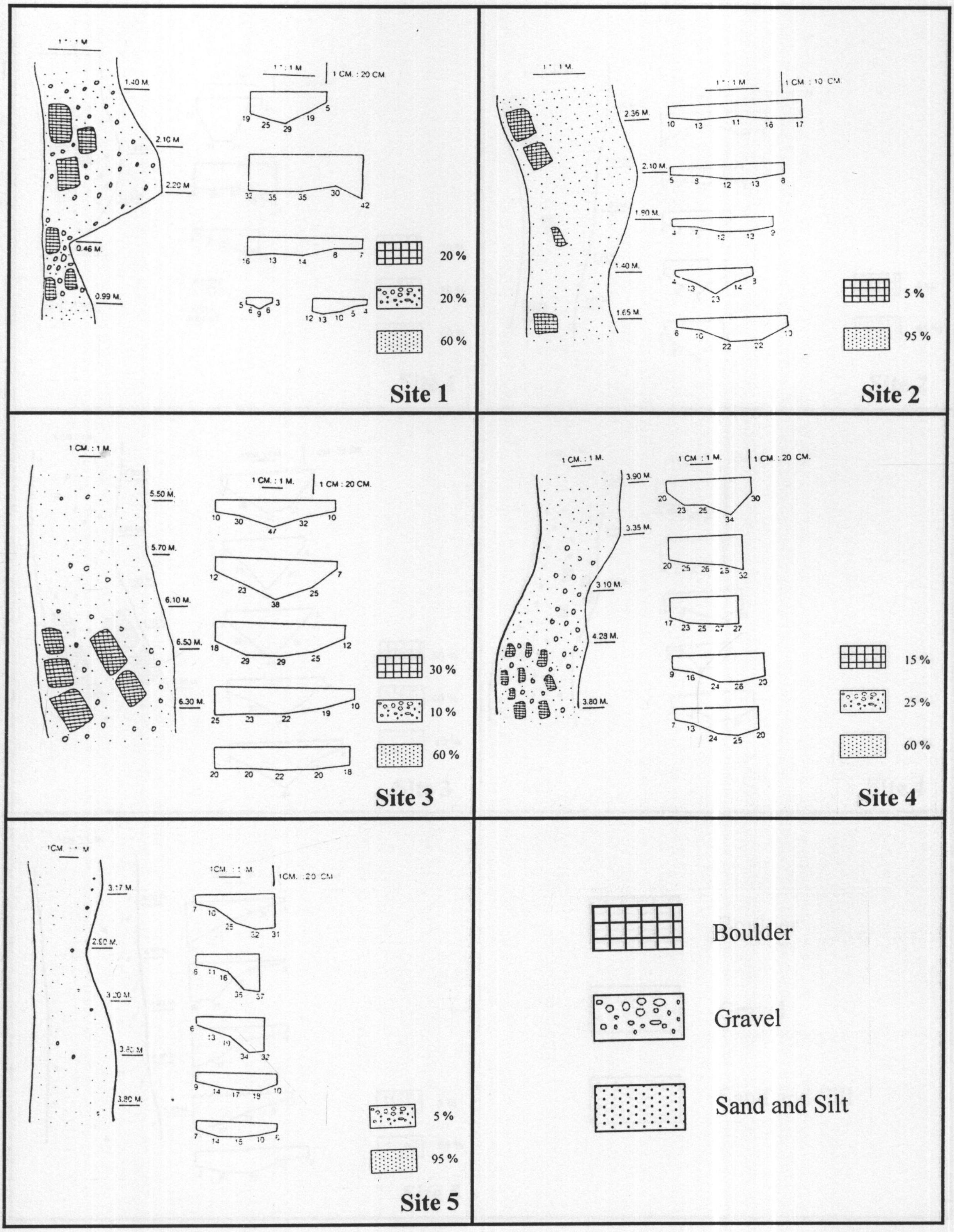


Figure 42. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (October 1998)

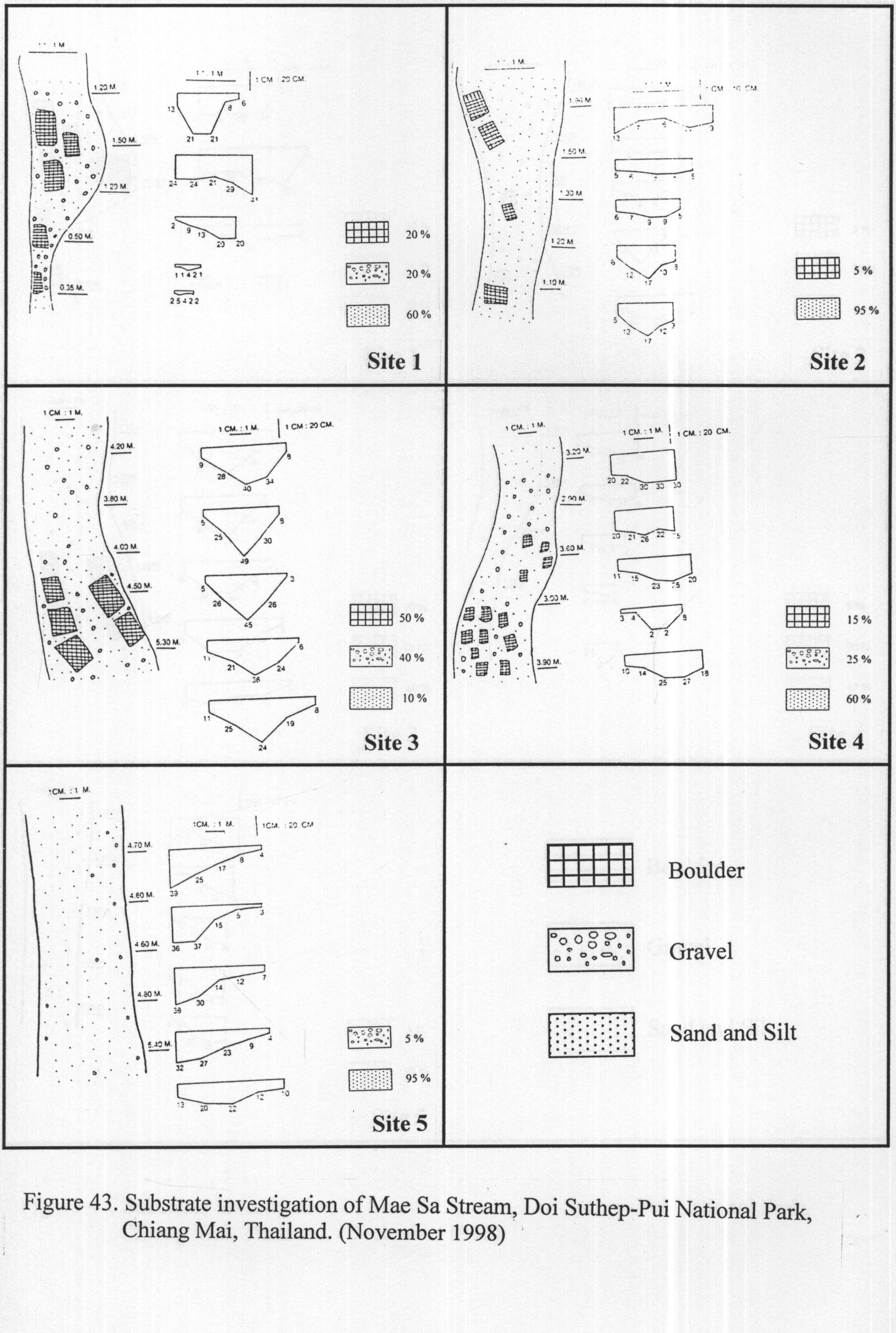


Figure 43. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (November 1998)

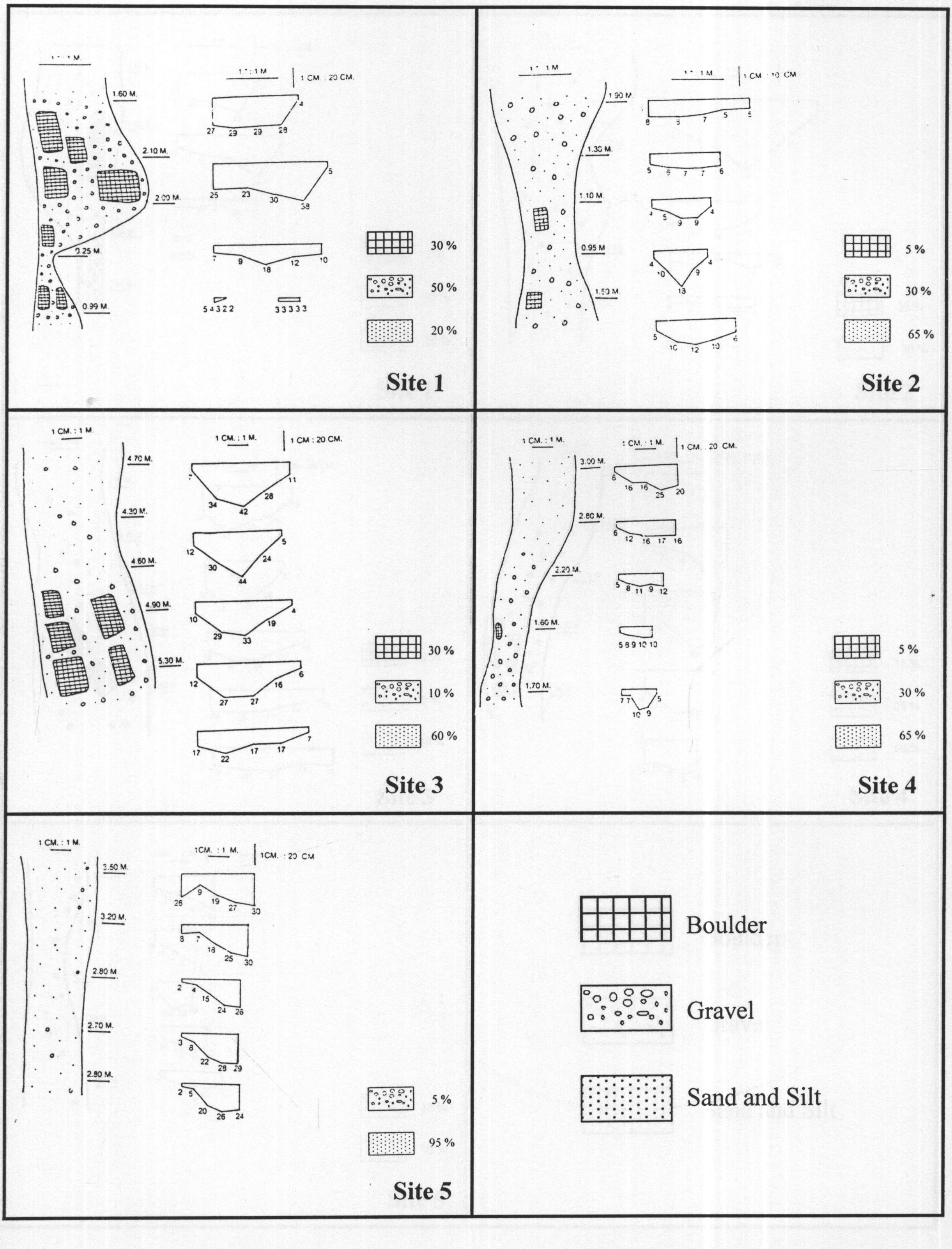


Figure 44. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (December 1998)

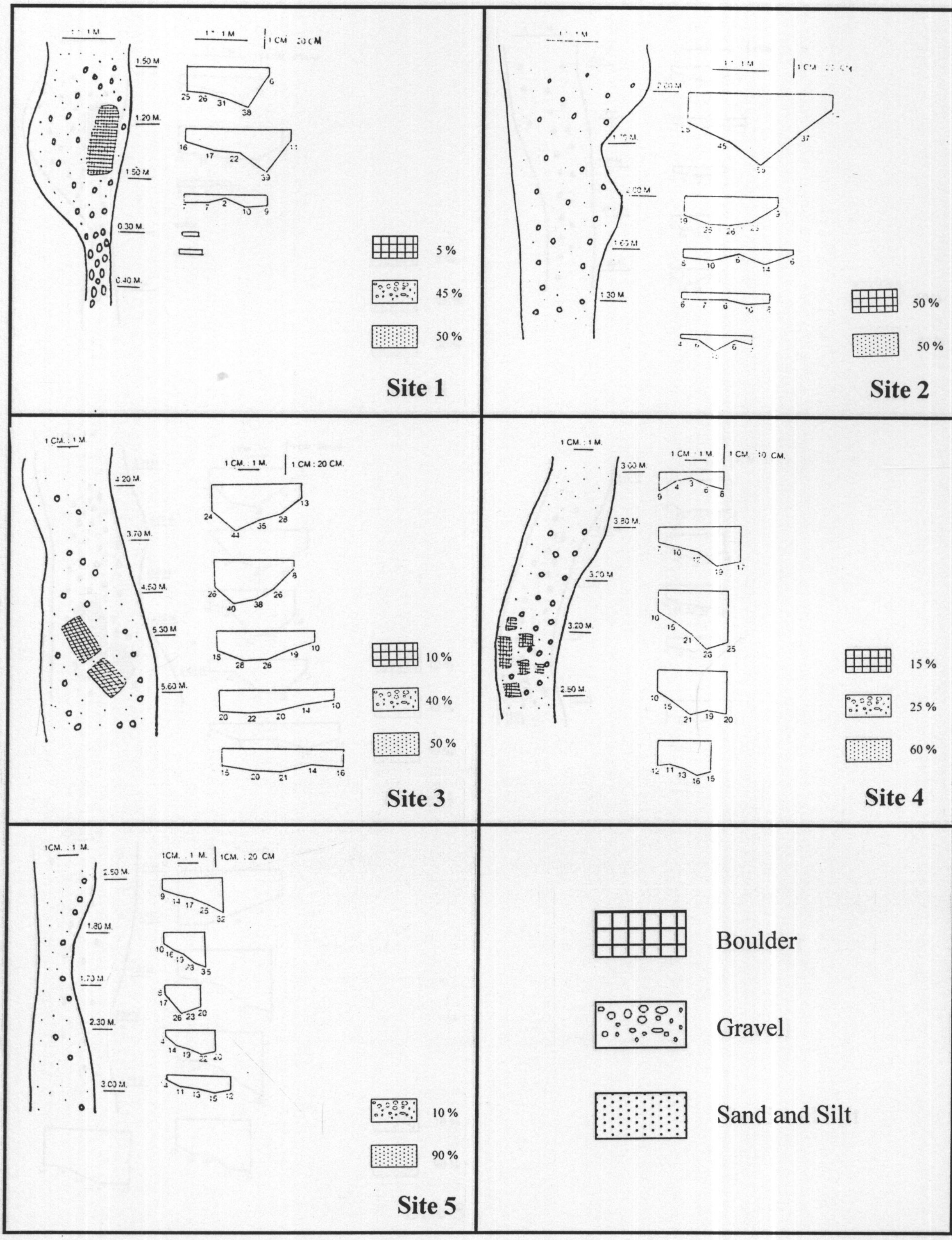


Figure 45. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (January 1999)

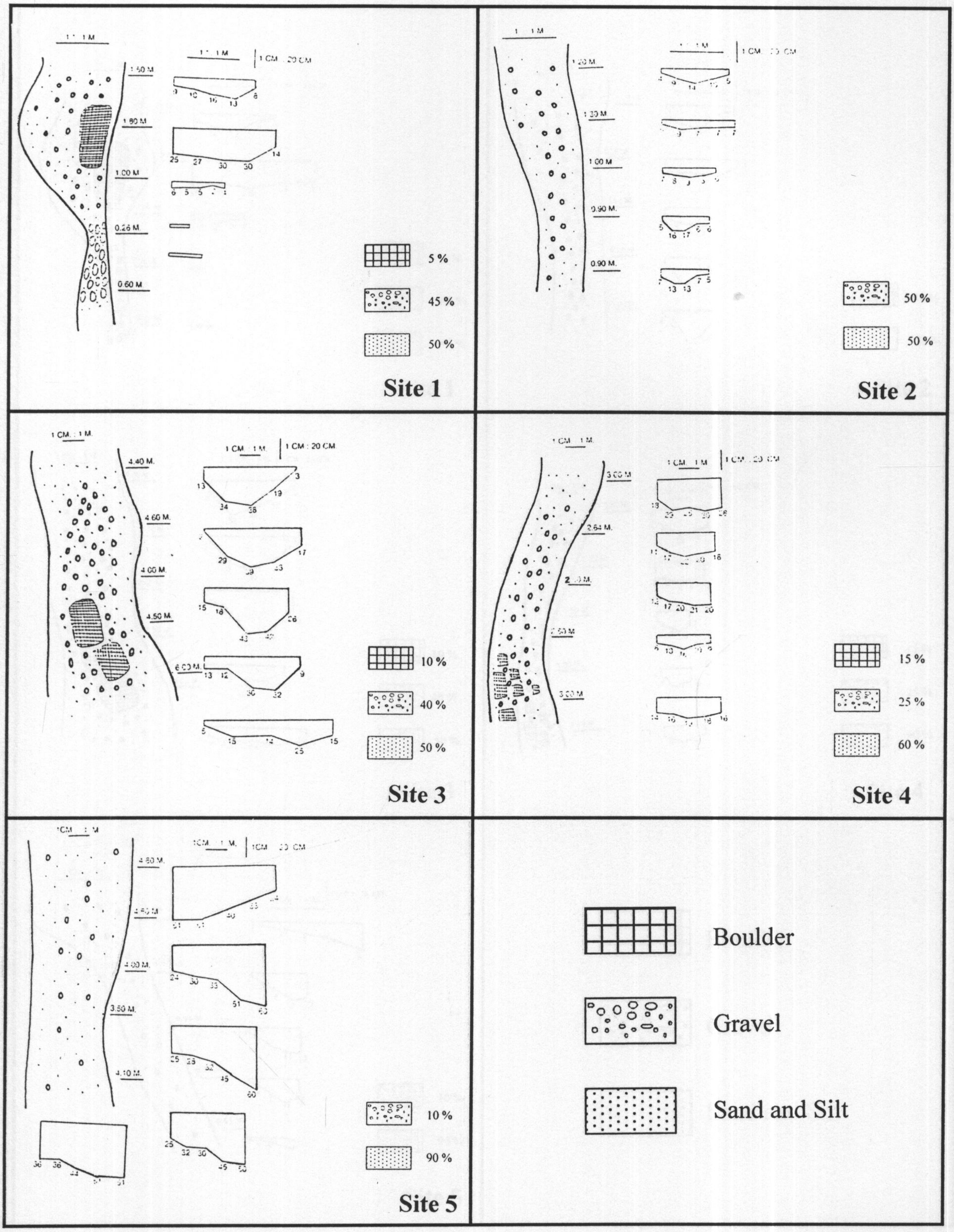


Figure 46. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (February 1999)

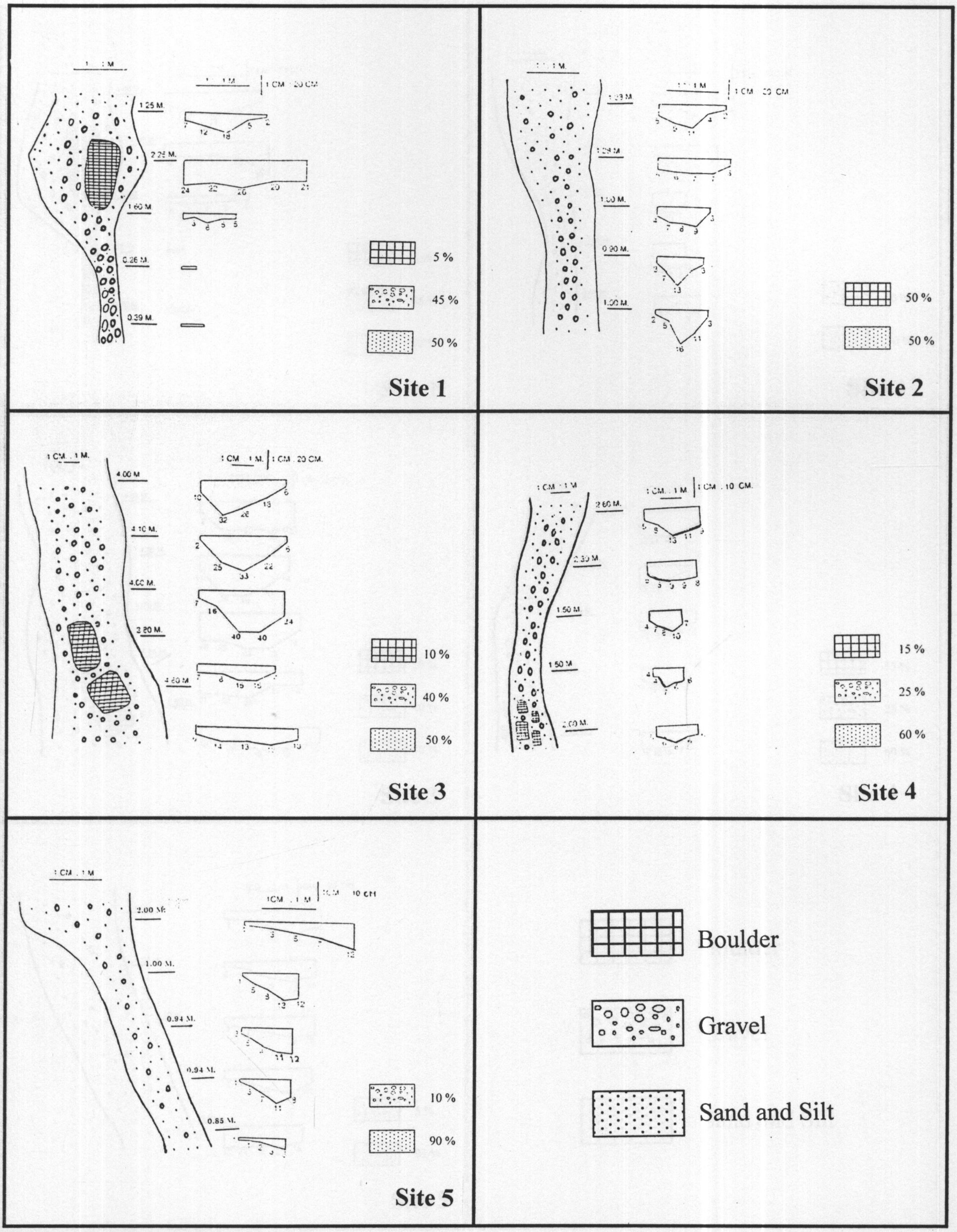


Figure 47. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (March 1999)

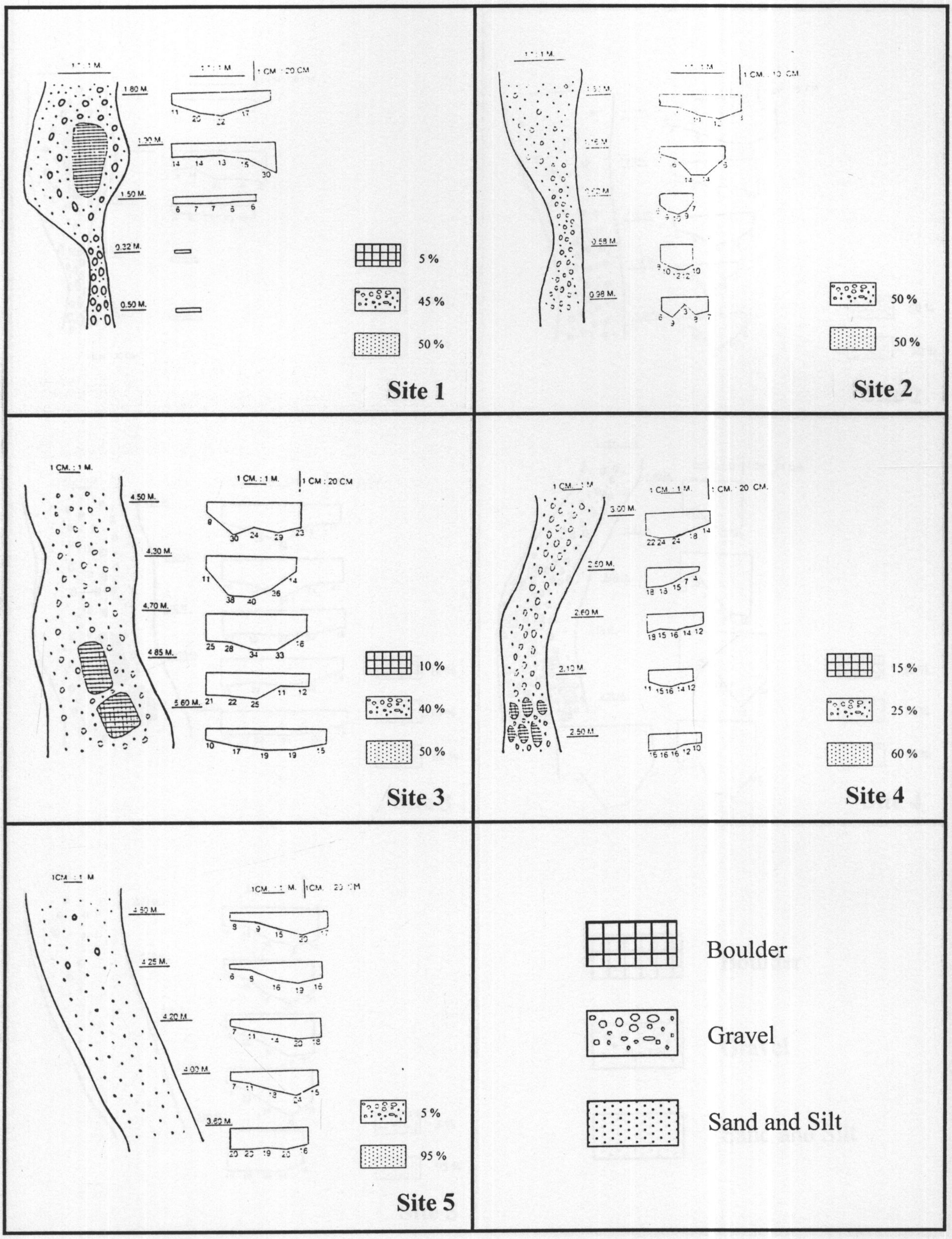


Figure 48. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (April 1999)

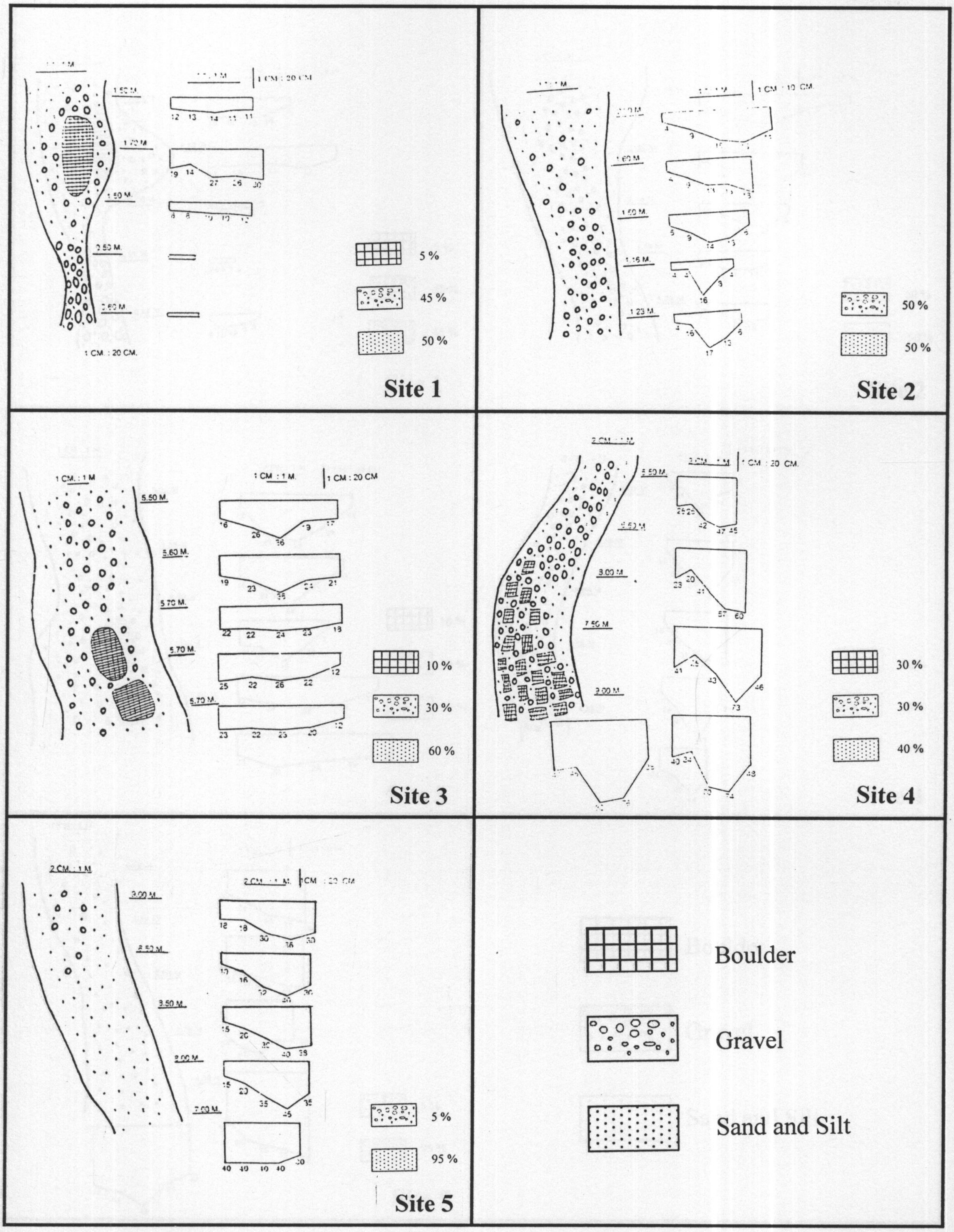


Figure 49. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (May 1999)

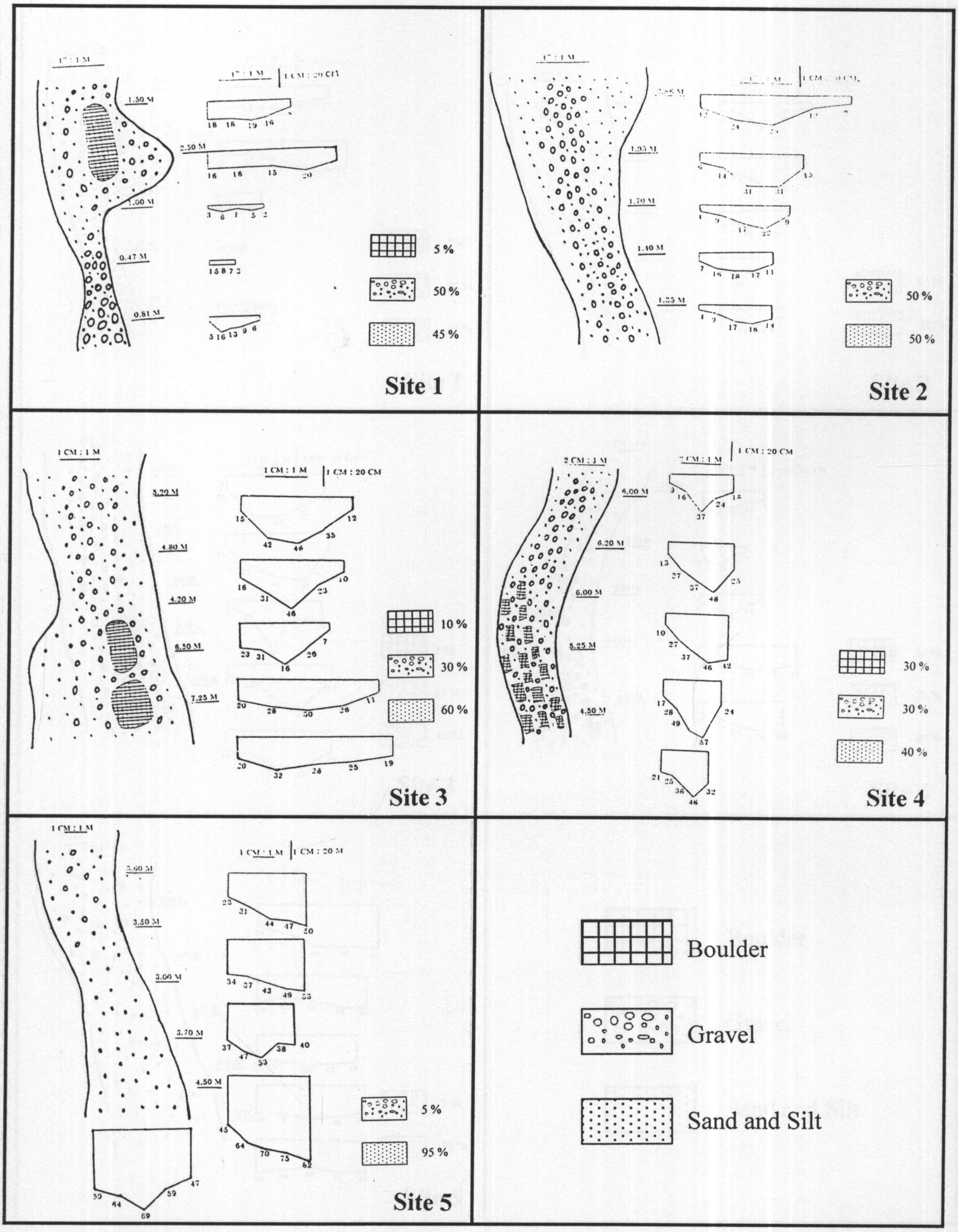


Figure 50. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (June 1999)

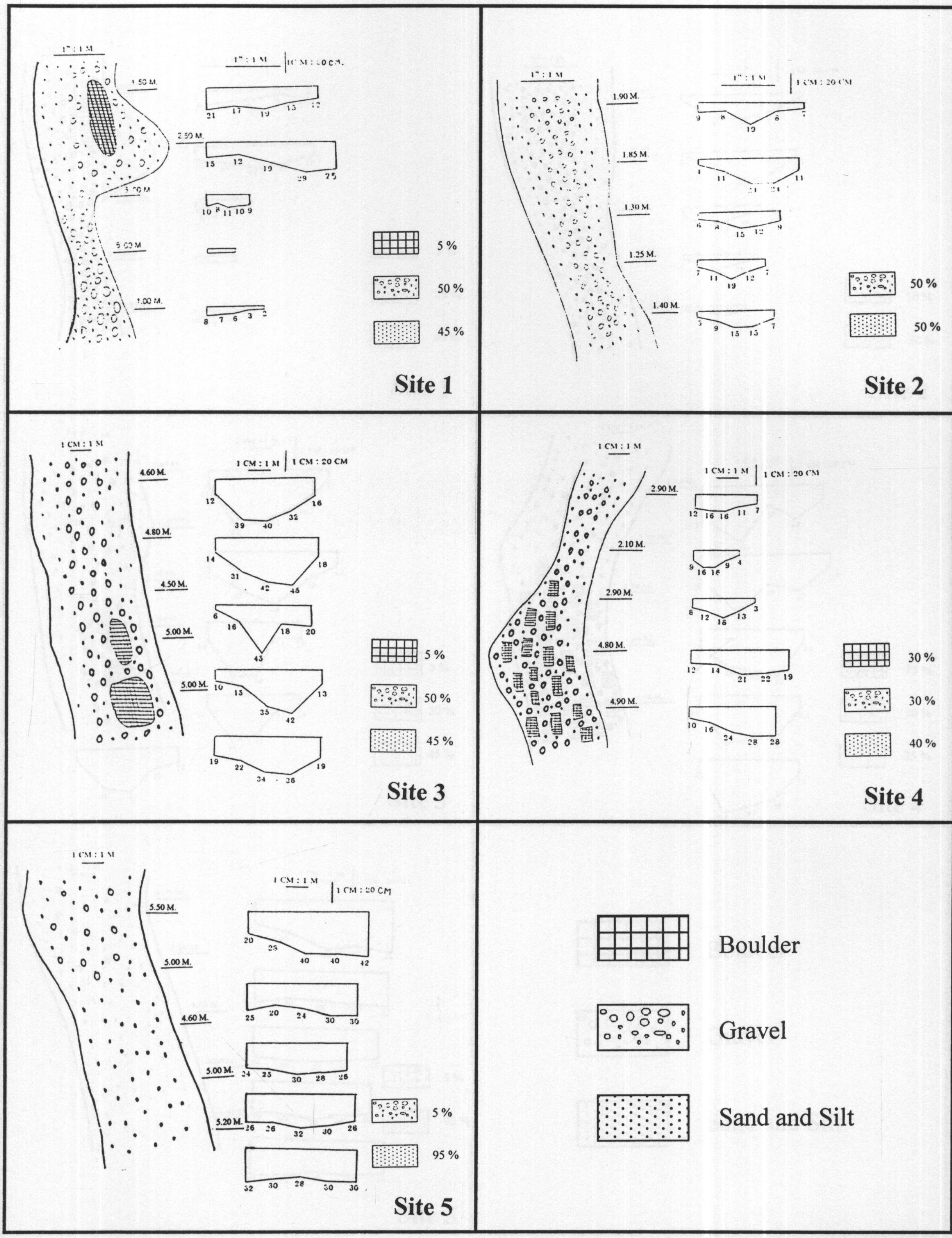


Figure 51. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (July 1999)

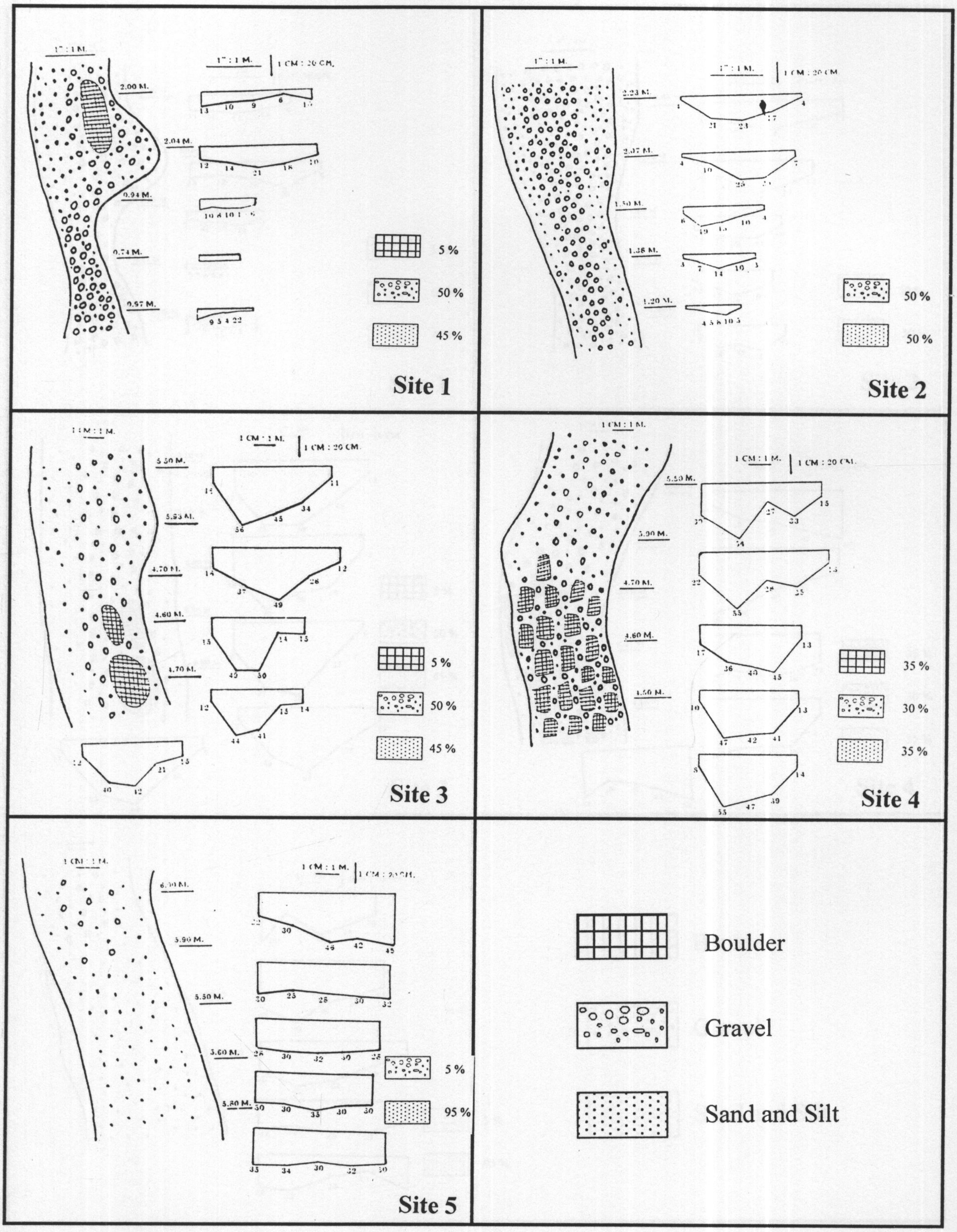


Figure 52. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (August 1999)

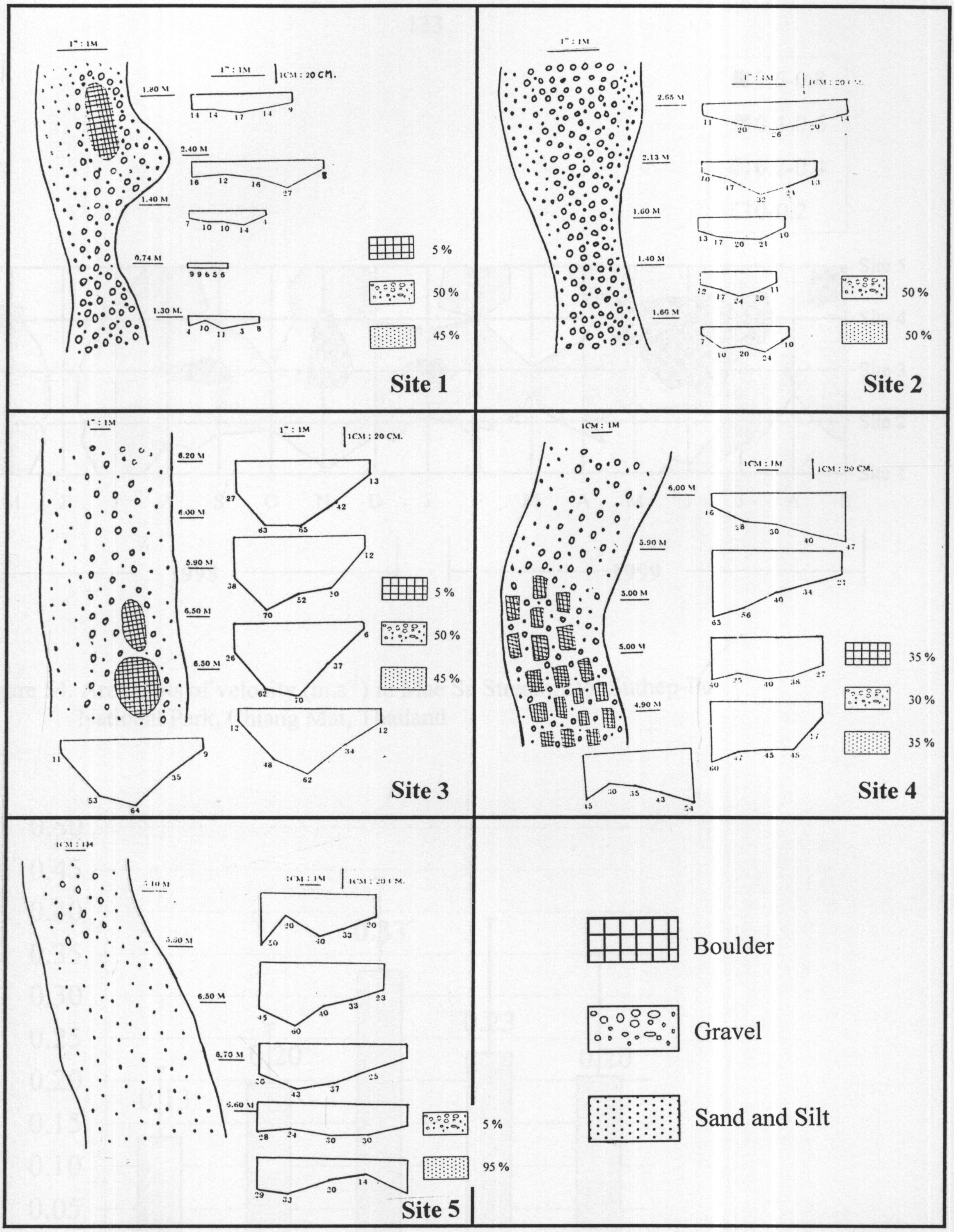


Figure 53. Substrate investigation of Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand. (September 1999)

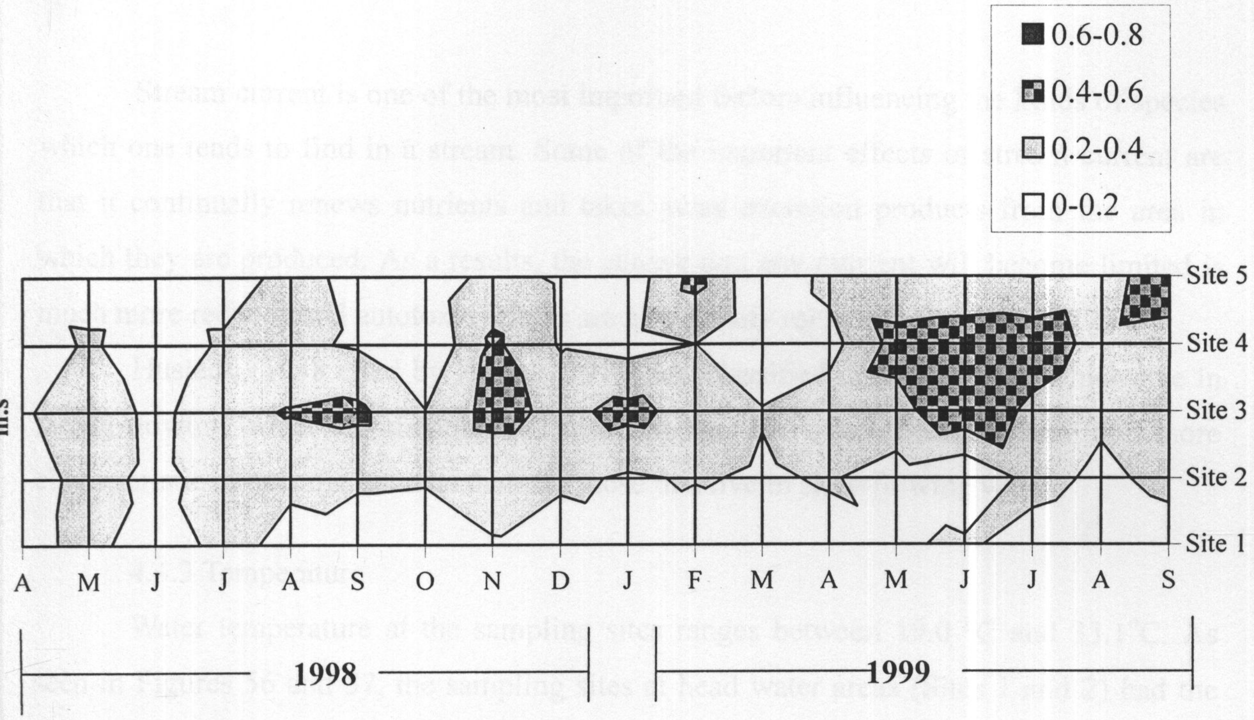


Figure 54. Area plots of velocity (m.s[-1]) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

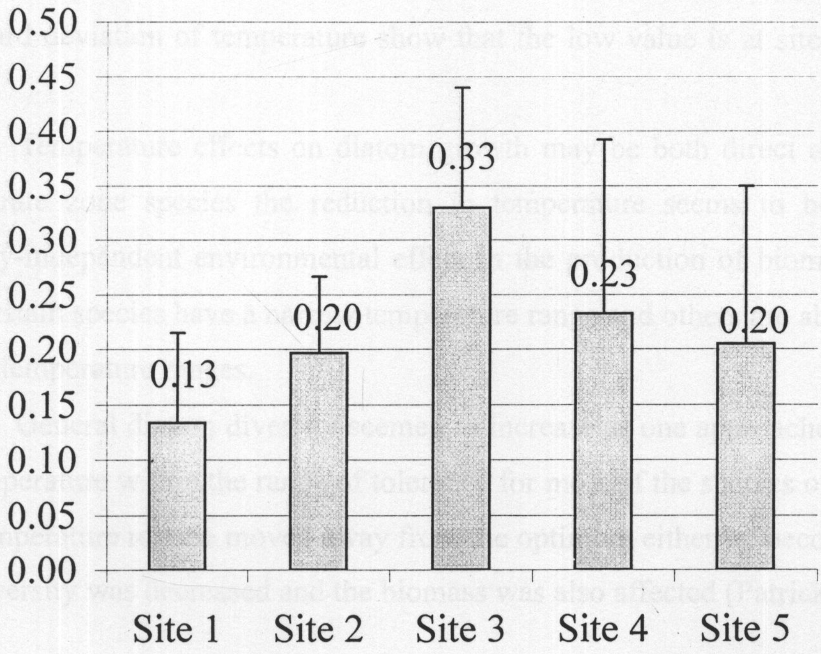


Figure 55. Average values of velocity (m.s[-1]) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

Stream current is one of the most important factors influencing the kinds of species which one tends to find in a stream. Some of the important effects of stream current are that it continually renews nutrients and takes away excretion products from the area in which they are produced. As a results, the chance that any nutrient will become limited is much more reduced and autotoxic effects are also greatly mitigated (Patrick, 1977).

Hustedt, (1938 cited by Patrick, 1977) has classified diatom species which live in strong-flowing water as rheophils. These species are often endemic and are more characteristic of specific habitats than are those that live in slow-flowing water.

4.4.3 Temperature

Water temperature at the sampling sites ranges between 19.0 °C and 33.1°C. As seen in Figures 56 and 57, the sampling sites at head water areas (Sites 1 and 2) had the significantly lowest level of water temperature through 18 months, especially during the cold season (November 1998 – February 1999). Site 1 had the temperature 21.43±1.27°C and site 2 22.15±1.12°C. The temperatures show that the low value is at site 1 and increases until Site 5 (Site 3 had the temperature 25.33±1.63°C, Site 4 had the temperature 27.68±2.32°C and Site 5 had the temperature 27.72±2.02°C). The average bar graphs with standard deviation of temperature show that the low value is at site 1 and increases until site 5.

Temperature effects on diatom growth may be both direct and indirect. To many temperate zone species the reduction in temperature seems to be the most profound density-independent environmental effect in the production of biomass. It is well known that certain species have a narrow temperature range and others are able to withstand rather broad temperature ranges.

General diatom diversity seemed to increase as one approached the optimum range of temperature within the range of tolerance for most of the species of a community. When the temperature regime moved away from the optimum either by becoming colder or hotter the diversity was decreased and the biomass was also affected (Patrick, 1977).

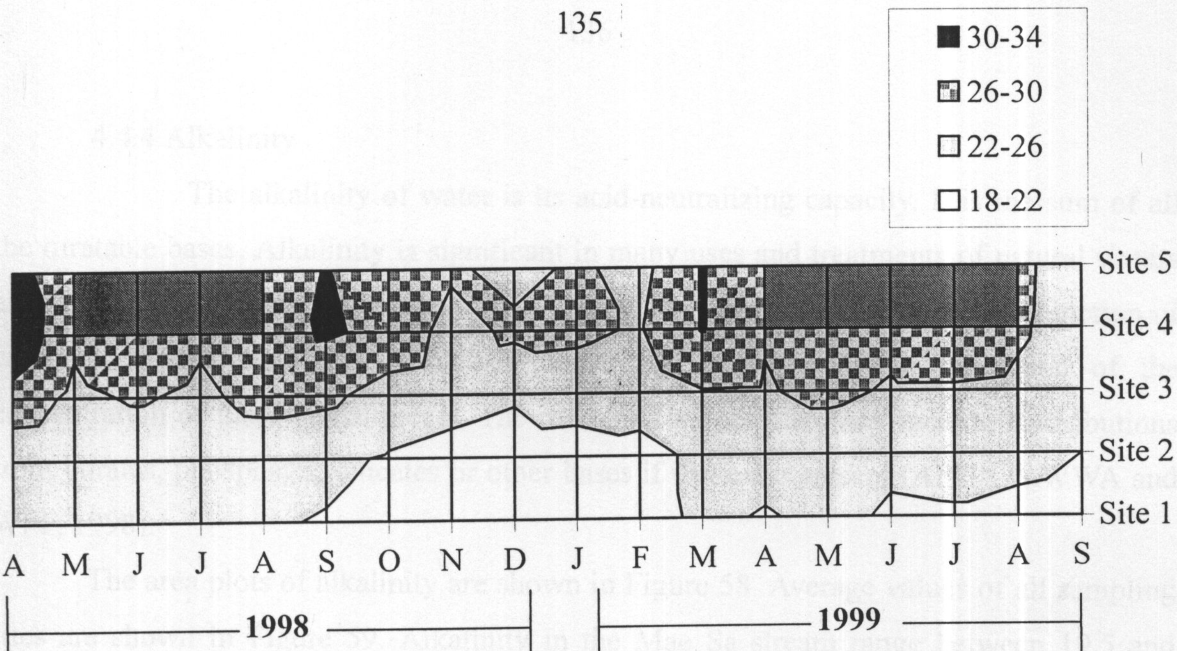


Figure 56. Area plots of temperature (°C) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

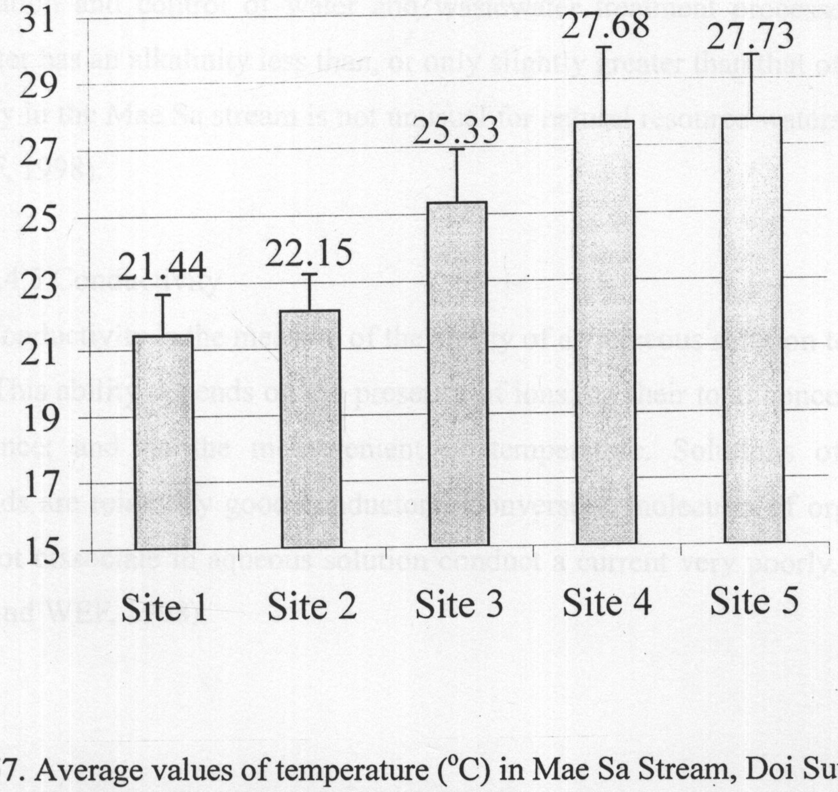


Figure 57. Average values of temperature (°C) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

4.4.4 Alkalinity

The alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titratable bases. Alkalinity is significant in many uses and treatments of natural waters and wastewaters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide content, it is taken as an indication of the concentration of these constitutents. The measured values also may include contributions from borates, phosphates, silicates or other bases if these are present (APHA, AWWA and WEF, 1998).

The area plots of alkalinity are shown in Figure 58. Average values of all sampling sites are shown in Figure 59. Alkalinity in the Mae Sa stream range between 19.5 and 181.0 $mg.l^{-1}$. The alkalinity average taken at head water areas (Sites 1 and 2) had the significantly lowest levels (34.07 ± 6.69 $mg.l^{-1}$ and 90.26 ± 26.43 $mg.l^{-1}$ respectively). By average, Sites 3 and 4 had the significantly highest level of alkaline through the sampling period (143.88 ± 26.54 $mg.l^{-1}$ and 131.88 ± 33.22 $mg.l^{-1}$ respectively).

Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes. Raw domestic wastewater has an alkalinity less than, or only slightly greater than that of the water supply. Alkalinity in the Mae Sa stream is not unusual for natural resource waters (APHA, AWWA and WEF, 1998).

4.4.5 Conductivity

Conductivity is the measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility and valence; and on the measurement of temperature. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all (APHA, AWWA and WEF, 1998).

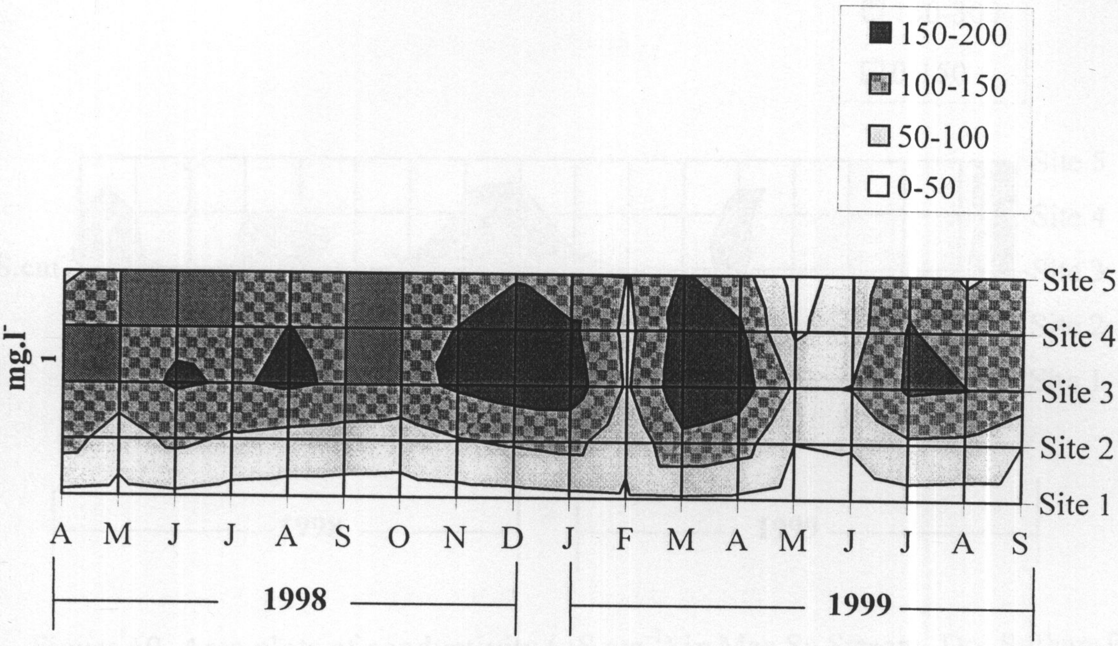


Figure 58. Area plots of alkalinity (mg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

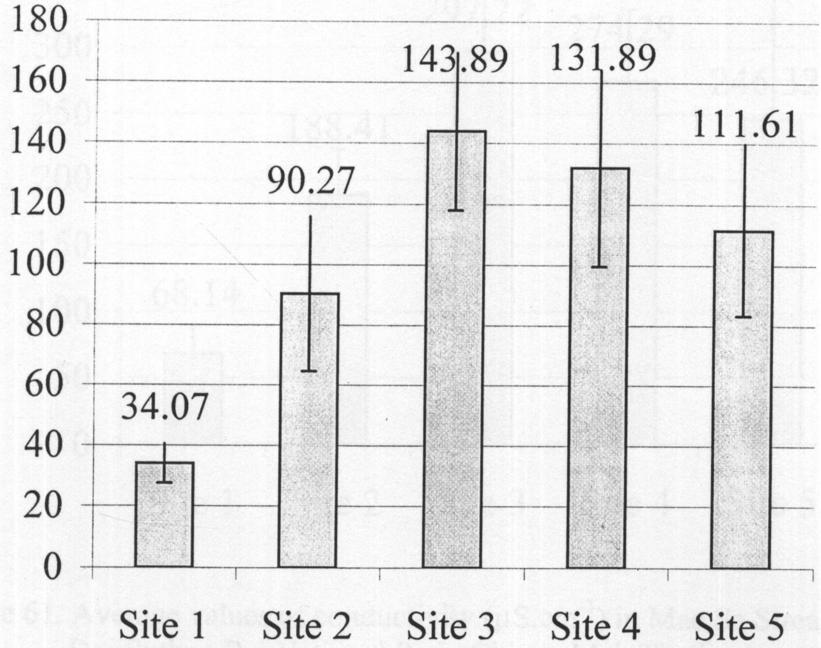


Figure 59. Average values of alkalinity (mg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

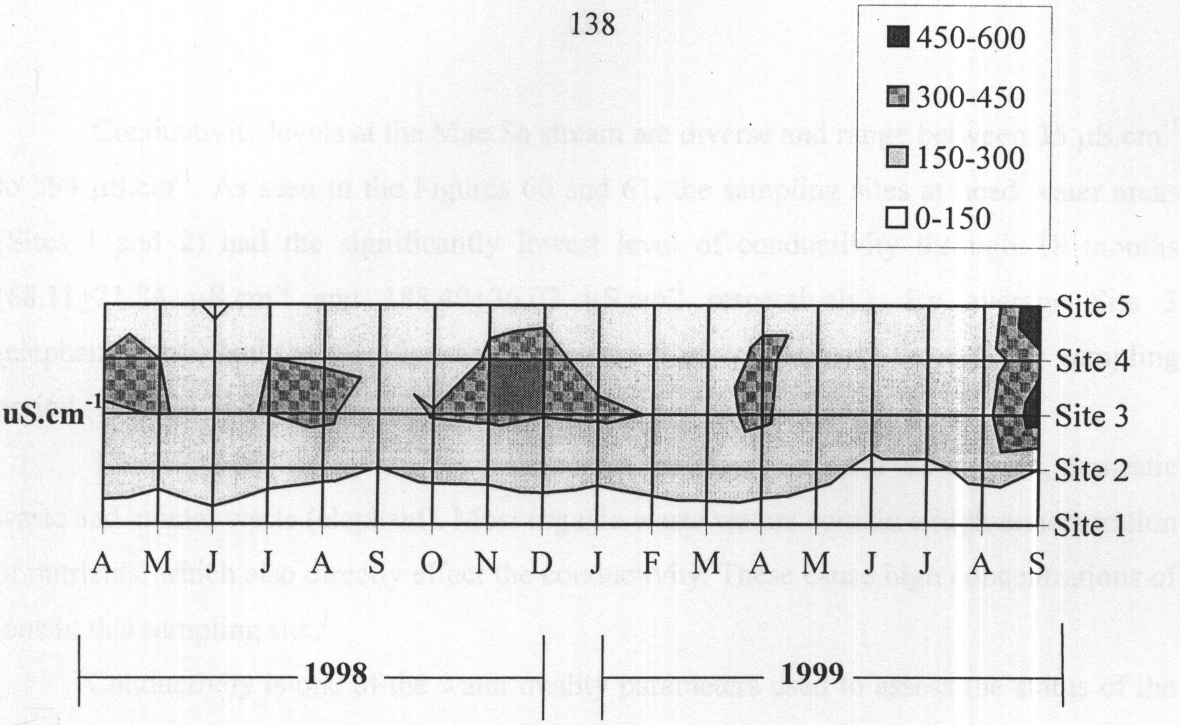


Figure 60. Area plots of conductivity (μS.cm^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

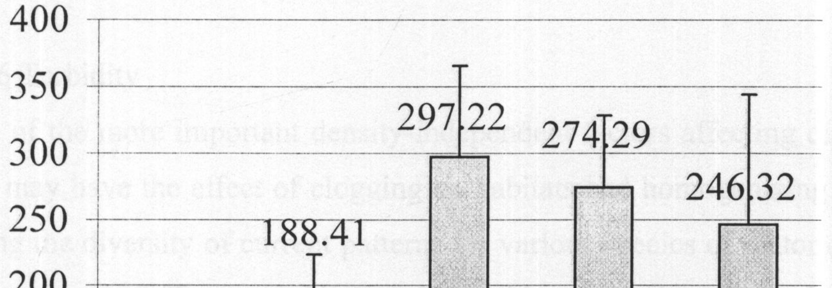


Figure 61. Average values of conductivity (μS.cm^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

Conductivity levels at the Mae Sa stream are diverse and range between 35 $\mu S.cm^{-1}$ to 594 $\mu S.cm^{-1}$. As seen in the Figures 60 and 61, the sampling sites at head water areas (Sites 1 and 2) had the significantly lowest level of conductivity through 18 months (68.11$\pm$21.84 $\mu S.cm^{-1}$ and 188.40$\pm$36.02 $\mu S.cm^{-1}$ respectively). By average Site 3 (elephant camp) had the significantly highest level of conductivity through the sampling period (297.22$\pm$70.15 $\mu S.cm^{-1}$).

The major sources of organic pollution in the Mae Sa stream are sewage, domestic waste and animal waste (elephant). Most organic waste waters contain a high concentration of nutrients, which also directly effect the conductivity. These cause high concentrations of ions in this sampling site.

Conductivity is one of the water quality parameters used to assess the status of the stream. Kelly has suggested that the range for oligo-mesotrophic status range between 50-100 $\mu S.cm^{-1}$ and 100-250 $\mu S.cm^{-1}$ for mesotrophic status. Conductivity values of Site 1 were determined as oligo-mesotrophic status. Conductivity values of Site 2, Site 4 and Site 5 were determined as mesotrophic status. And for sampling Site 3 it was determined as meso-eutrophic status with conductivity ranging between 250-500 $\mu S.cm^{-1}$ (Kelly, 2000).

4.4.6 Turbidity

One of the more important density-independent factors affecting diatom growth is turbidity. It may have the effect of clogging up habitats and homogenizing sediments, and thus reducing the diversity of current patterns for various species of diatoms, or it may cut down light penetration. The type of suspended solids may make a great deal of difference in the amount of light which penetrates.

The area plots of turbidity are shown in Figure 62. Average values of all sampling sites are shown in Figure 63. Turbidity in the Mae Sa stream range between 1.3 NTU and 5100 NTU. By average the turbidity of all sites had no significant difference through the sampling period although there is maximum turbidity value in site 3 on November 1998 (5100 NTU). Sampling sites at head water areas (site 1 and 2) seem to have clear water (low turbidity) during the sampling period (3.59$\pm$1.89 NTU and 8.83$\pm$6.61NTU respectively).

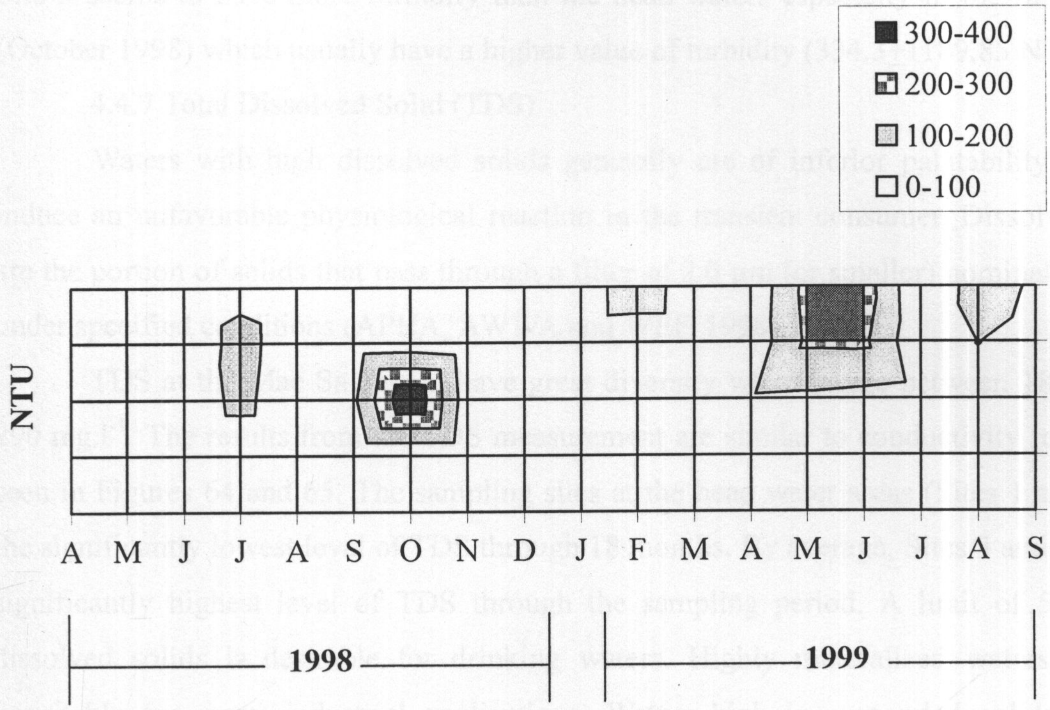


Figure 62. Area plots of turbidity (NTU) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

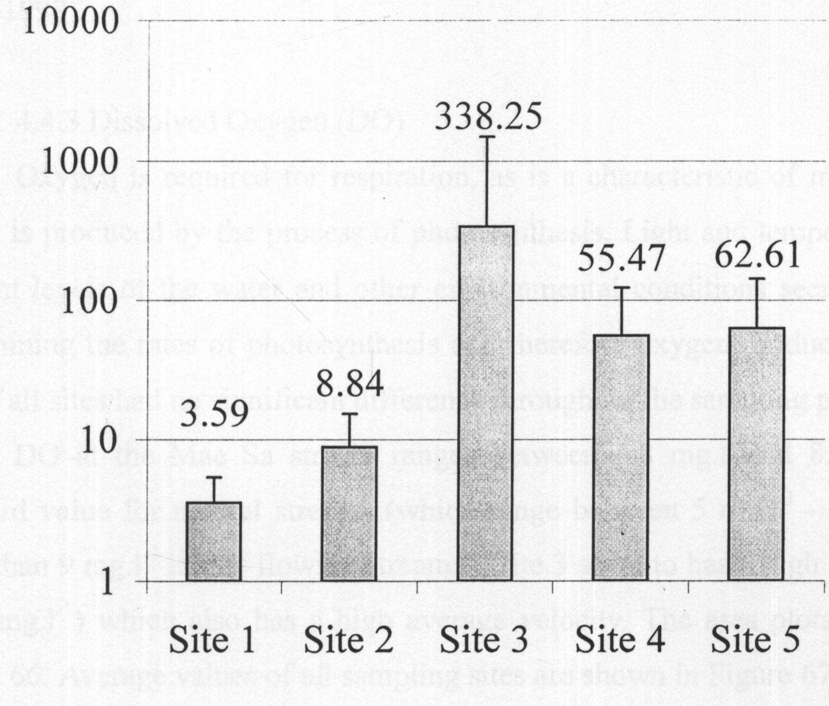


Figure 63. Average values of turbidity (NTU) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

Site 3 seems to have more turbidity than the head waters especially in the rainy season (October 1998) which usually have a higher value of turbidity (334.3±1189.85 NTU).

4.4.7 Total Dissolved Solid (TDS)

Waters with high dissolved solids generally are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. Dissolved solids are the portion of solids that pass through a filter of 2.0 μm (or smaller) nominal pore size under specified conditions (APHA, AWWA and WEF, 1998).

TDS at the Mae Sa stream have great diversity which range between 18 $mg.l^{-1}$ to 290 $mg.l^{-1}$. The results from the TDS measurement are similar to conductivity readings as seen in Figures 64 and 65. The sampling sites at the head water areas (Sites 1 and 2) had the significantly lowest level of TDS through 18 months. By average, Sites 3 and 4 had the significantly highest level of TDS through the sampling period. A limit of 500 $mg.l^{-1}$ dissolved solids is desirable for drinking waters. Highly mineralized waters also are unsuitable for many industrial applications. Waters high in suspended solids may be esthetically unsatisfactory for such purposes as bathing. Solids analyses is important in the control of the biological and physical wastewater treatment processes and for assessing compliance with regulatory agency wastewater effluent limitations (APHA, AWWA and WEF, 1998).

4.4.8 Dissolved Oxygen (DO)

Oxygen is required for respiration, as is a characteristic of most forms of aquatic life. It is produced by the process of photosynthesis. Light and temperature as well as the nutrient levels of the water and other environmental conditions seem to be important in determining the rates of photosynthesis and therefore oxygen production. By average the DO of all sites had no significant difference throughout the sampling period.

DO at the Mae Sa stream ranges between 4.8 $mg.l^{-1}$and 8.8 $mg.l^{-1}$ which is a standard value for natural streams (which range between 5 $mg.l^{-1}$ - 9 $mg.l^{-1}$ and may be more than 9 $mg.l^{-1}$ in fast flowing streams). Site 3 seem to has a high value of average DO (7.36 $mg.l^{-1}$) which also has a high average velocity. The area plots of DO is shown in Figure 66. Average values of all sampling sites are shown in Figure 67. By average the DO of all sites had no significant difference throughout the sampling period.

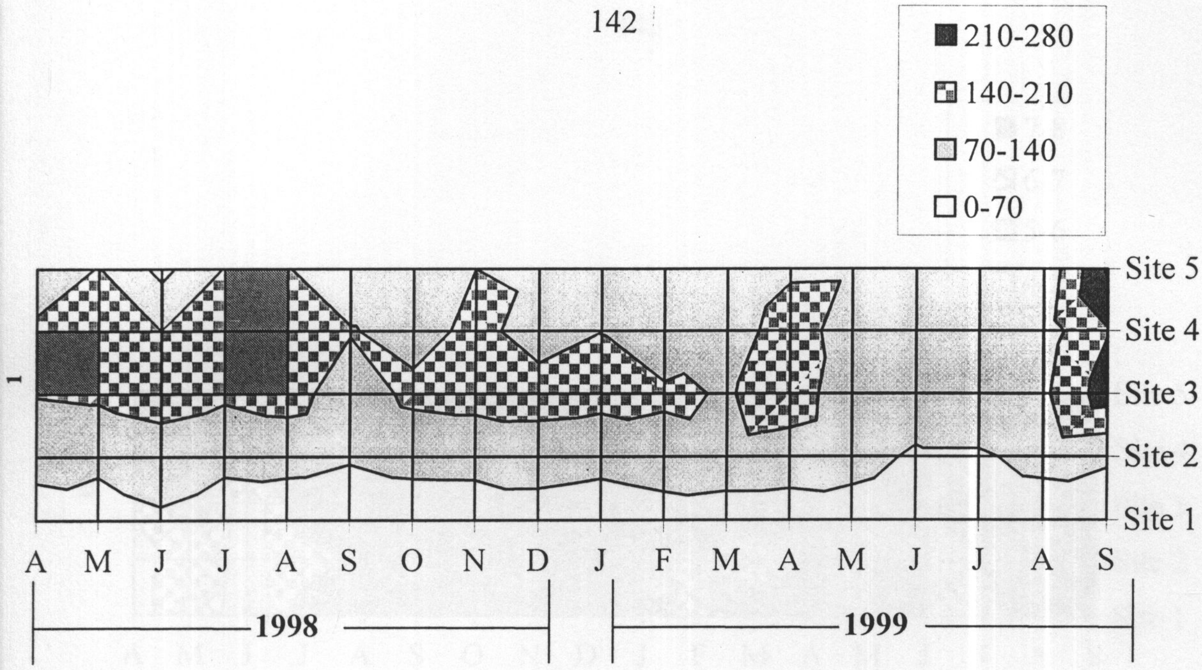


Figure 64. Area plots of TDS ($mg.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

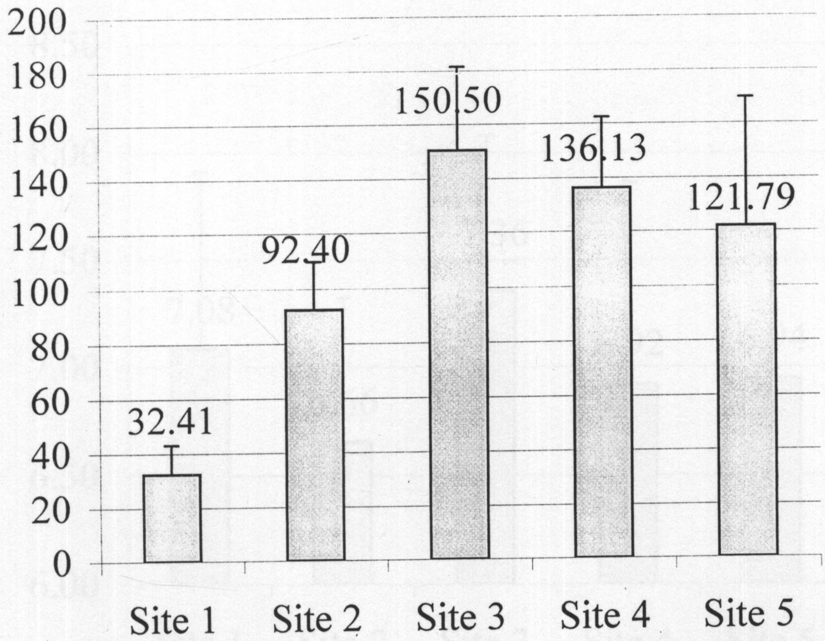


Figure 65. Average values of TDS ($mg.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

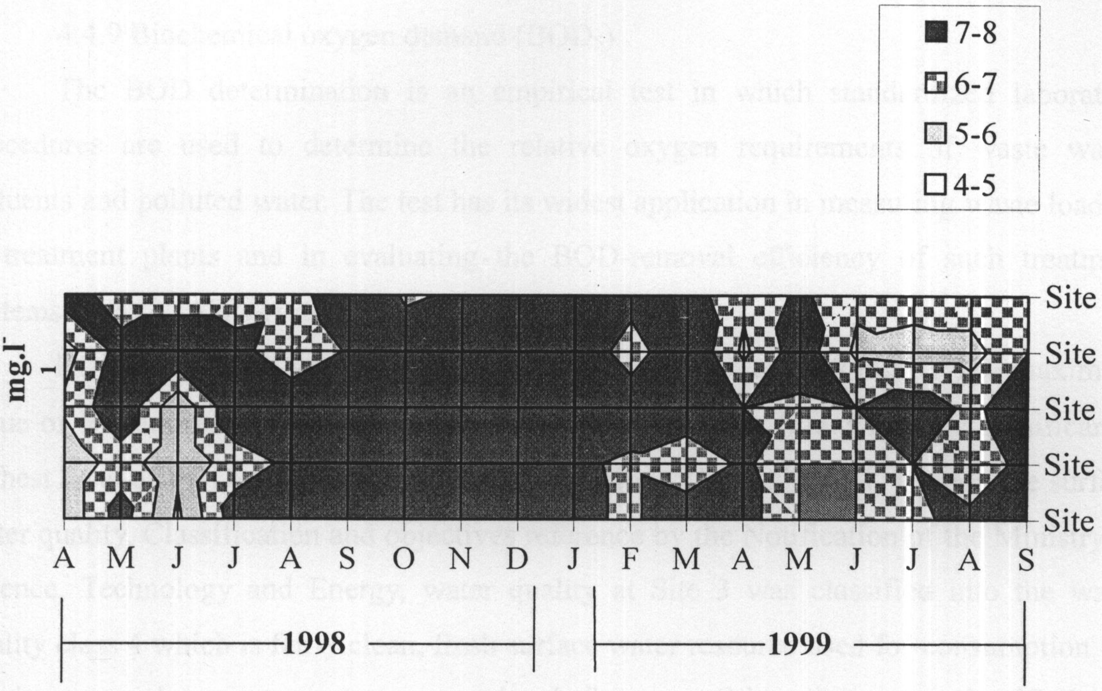


Figure 66. Area plots of DO (mg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

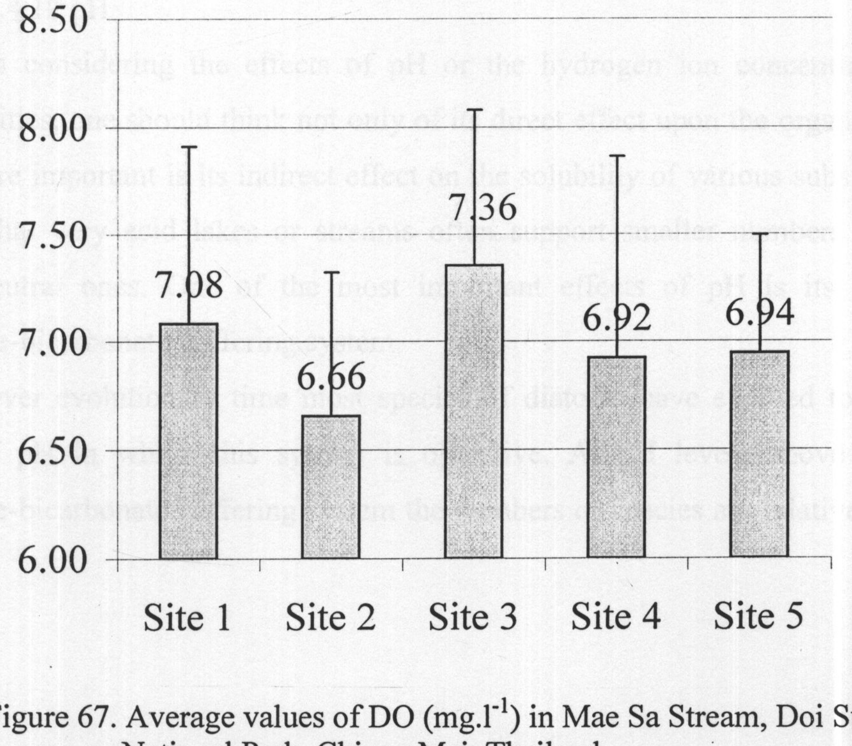


Figure 67. Average values of DO (mg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

4.4.9 Biochemical oxygen demand (BOD_5)

The BOD determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of waste water, effluents and polluted water. The test has its widest application in measuring waste loading to treatment plants and in evaluating the BOD-removal efficiency of such treatment systems (APHA, AWWA and WEF, 1998).

BOD_5 at the Mae Sa stream ranges between 0.2 $mg.l^{-1}$and 6.7 $mg.l^{-1}$. The maximum value of BOD_5 present in Site 3 was 6.7 $mg.l^{-1}$. By average, Site 3 had the significantly highest level of BOD_5 throughout the sampling period (2.27$\pm$1.79 $mg.l^{-1}$). Upon the surface water quality, Classification and objectives reference by the Notification of the Ministry of Science, Technology and Energy, water quality at Site 3 was classified into the water quality class 4 which is fairly clean, fresh surface water resource used for consumption but requires special water treatment processing before use. Other sites were classified into water quality class 2 which is a very clean fresh water resource used for consumption which requires ordinary water treatment processing before use. The area plots of BOD_5 are shown in Figure 68. Average values of all sampling sites are shown in Figure 69.

4.4.10 pH

In considering the effects of pH or the hydrogen ion concentration on diatom communities, one should think not only of its direct effect upon the organisms but what is even more important is its indirect effect on the solubility of various substances. It is well known that very acid lakes or streams often support smaller numbers of species than circumneutral ones. One of the most important effects of pH is its effect upon the carbonate-bicarbonate buffering system.

Over evolutionary time most species of diatoms have evolved to live within the range of pH in which this system is operative. At pH levels above and below the carbonate-bicarbonate buffering system the numbers of species are relatively few (Patrick, 1977).

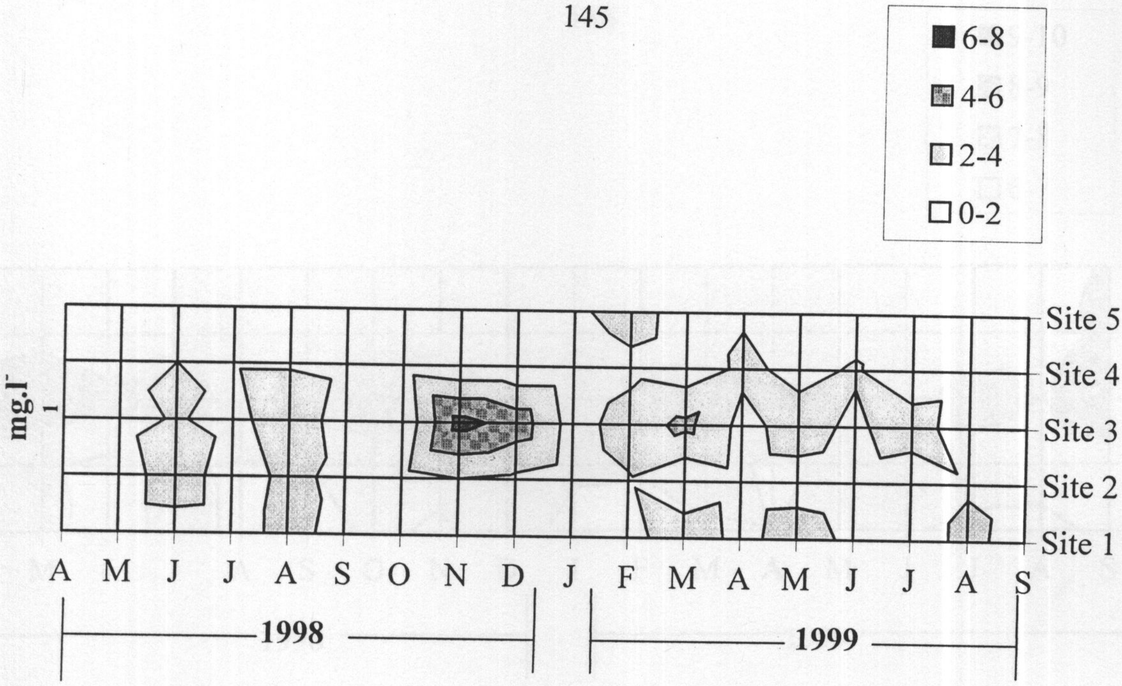


Figure 68. Area plots of BOD_5 ($mg.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

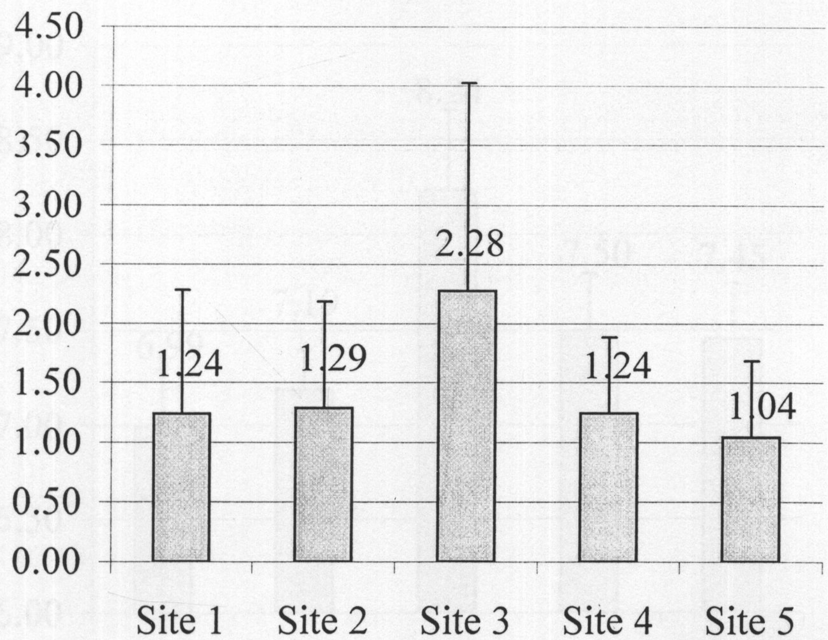


Figure 69. Average values of BOD_5 ($mg.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

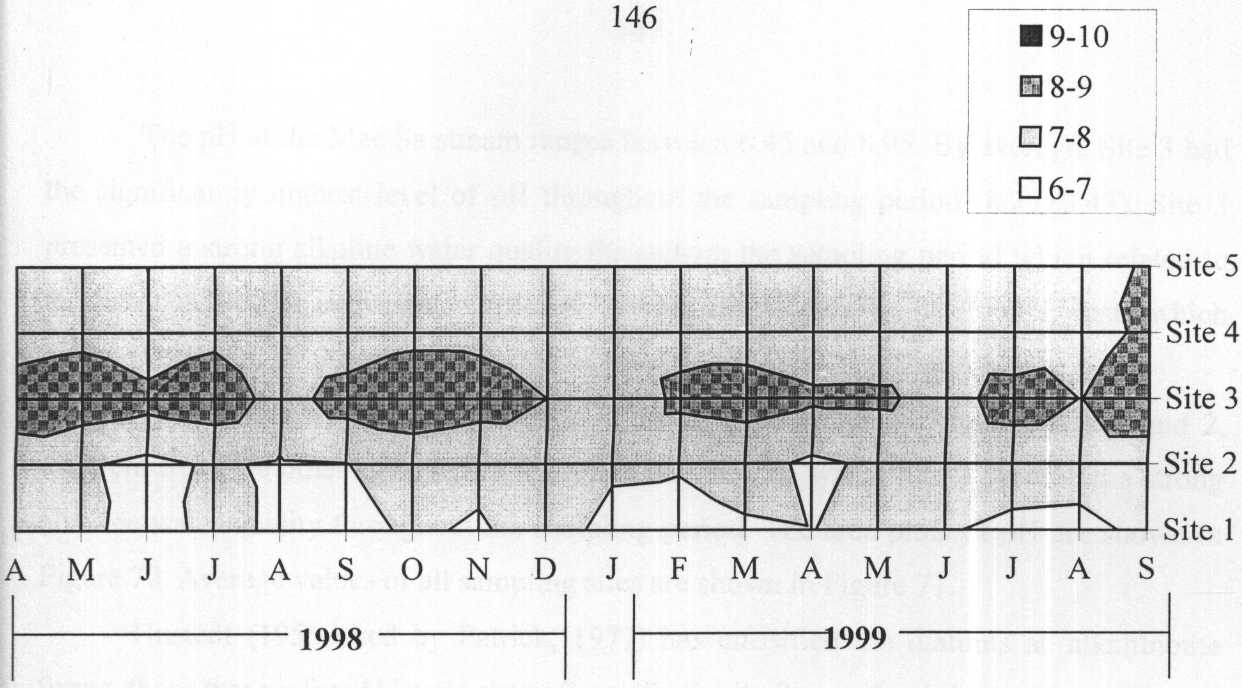


Figure 70. Area plots of pH in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

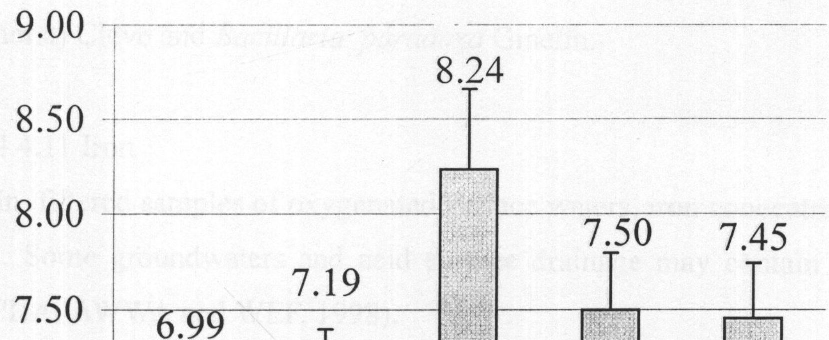


Figure 71. Average values of pH in Mae Sa Stream, National Park, Doi Suthep-Pui Chiang Mai, Thailand

The pH at the Mae Sa stream ranges between 6.45 and 8.95. By average, Site 3 had the significantly highest level of pH throughout the sampling period (8.23$\pm$0.43). Site 3 presented a strong alkaline water quality throughout the sampling period which related to the few numbers of investigated species. The high concentration of organic waste which contains ammonium nitrogen causes the high values of pH in this sampling site.

The bar graphs show the average value of good water quality for sites 1 and 2, different from the other sites, which tended to be alkaline water. Site 3 presented a strong alkaline water quality throughout the sampling period. The area plots of pH are shown in Figure 70. Average values of all sampling sites are shown in Figure 71.

Hustedt (1956 cited by Patrick, 1977) has classified the diatoms as alkalibionte forms, those that prefer pH levels above 7; as alkaliphile forms, those that prefer a pH level around 7; as indifferent forms, those that live in a fairly wide range of pH levels above and below 7; as acidophile forms, those that prefer a pH level below 7; and acidobionte forms those that prefer a pH level of 5 or lower.

At Site 3, which maintains the pH level above 7, the alkaliphile species are listed as follows: *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Melosira varians* Agardh, *Gyrosigma scalproides* (Rabenhorst) Cleve and *Bacillaria paradoxa* Gmelin.

4.4.11 Iron

In filtered samples of oxygenated surface waters, iron concentrations seldom reach 1 $mg.l^{-1}$. Some groundwaters and acid surface drainage may contain considerably more iron (APHA, AWWA and WEF, 1998).

The iron concentration at the Mae Sa stream ranges between 0 and 1520 $\mu g.l^{-1}$. The maximum value is representative for site 4. The concentration of iron in site 1 shows the significantly lowest level throughout the sampling period (173.61$\pm$263.79). The concentration of iron in site 4 shows the significantly highest level throughout the sampling period (547.88$\pm$367.76). The area plots of iron are shown in Figure 72. Average values of all sampling sites are shown in Figure 73. Iron in water can cause the staining of laundry and porcelain. A bittersweet astringent taste is detectable by some persons at levels above 1 $mg.l^{-1}$.

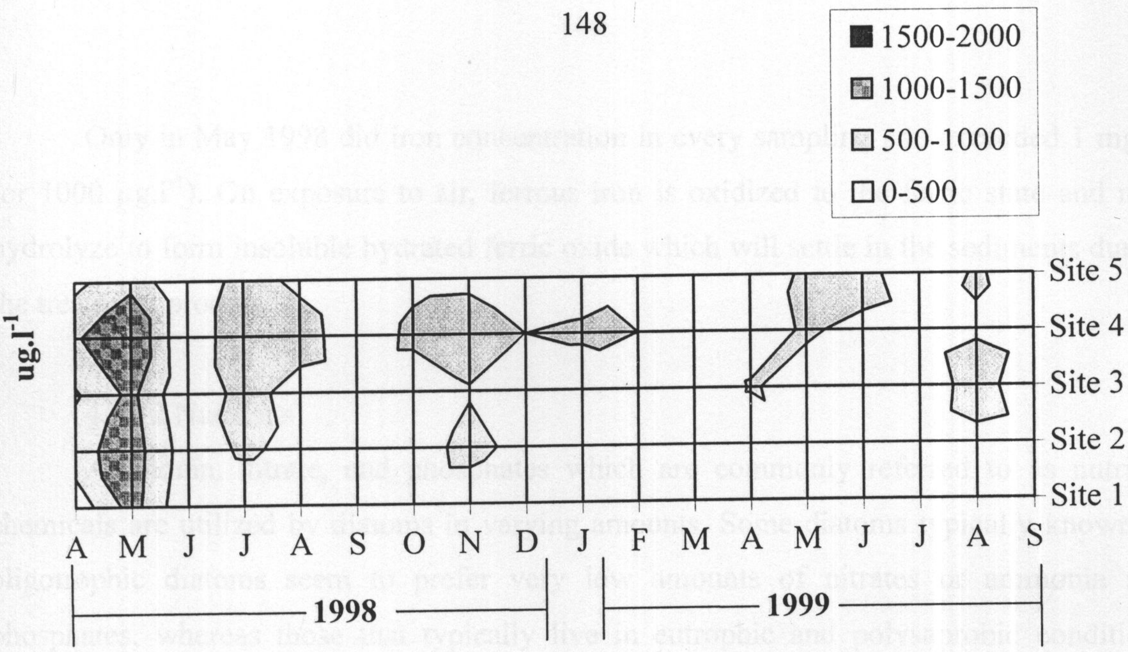


Figure 72. Area plots of Iron (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

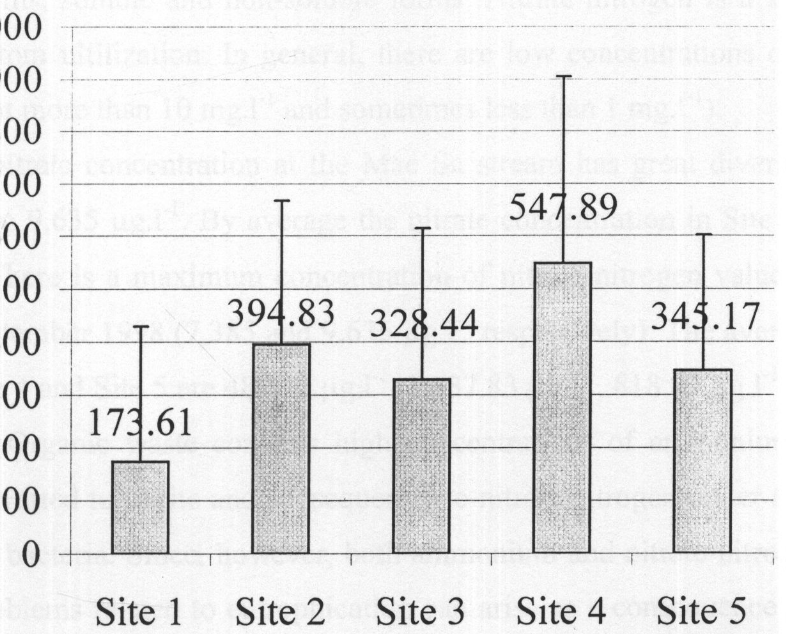


Figure 73. Average values of Iron (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

Only in May 1998 did iron concentration in every sampling site exceeded 1 mg.l^{-1} (or 1000 µg.l^{-1}). On exposure to air, ferrous iron is oxidized to the ferric state and may hydrolyze to form insoluble hydrated ferric oxide which will settle in the sediments during the treatment process.

4.4.12 Nutrients

Ammonia, nitrate, and phosphates which are commonly referred to as nutrient chemicals are utilized by diatoms in varying amounts. Some diatoms typically known as oligotrophic diatoms seem to prefer very low amounts of nitrates or ammonia and phosphates, whereas those that typically live in eutrophic and polysaprobic conditions seem to prefer high amounts of these substances. The preference of various species of diatoms for varying amounts of these chemicals has led to the development of the saprobic system. Phosphorus and nitrogen are the most commonly investigated nutrients, these two nutrients are the most likely to be growth limiting.

4.4.12.1 Nitrate Nitrogen

There are many forms of nitrogen in aquatic ecosystems for example organic forms, inorganic forms, soluble and non-soluble forms. Nitrate nitrogen is a soluble and usable form for diatom ultilization. In general, there are low concentrations of nitrate in water resources (not more than 10 mg.l^{-1} and sometimes less than 1 mg.l^{-1}).

The nitrate concentration at the Mae Sa stream has great diversity which ranges between 38 to 9,635 µg.l^{-1}. By average the nitrate concentration in Site 3 had great value (1,693.67). There is a maximum concentration of nitrate nitrogen value in these Sites in August - September 1998 (7,385 and 9,635 µg.l^{-1} respectively). The average values of Site 1, Site 2, Site 4 and Site 5 are 489.72 µg.l^{-1}, 1,337.83 µg.l^{-1}, 818.89 µg.l^{-1} and 705.67 µg.l^{-1} respectively. Organic waste contains high concentrations of ammonium nitrogen which could be converted to nitrite and subsequently to nitrate nitrogen under aerobic conditions by nitrifying bacteria. Since, however, both ammonium and nitrate nitrogen are important nutrients, problems related to eutrophication can arise as a consequence of organic inputs to water (Abel, 1989).

The area plots of nitrate nitrogen concentration are shown in Figure 74. Average values of all sampling sites are shown in Figure 75.

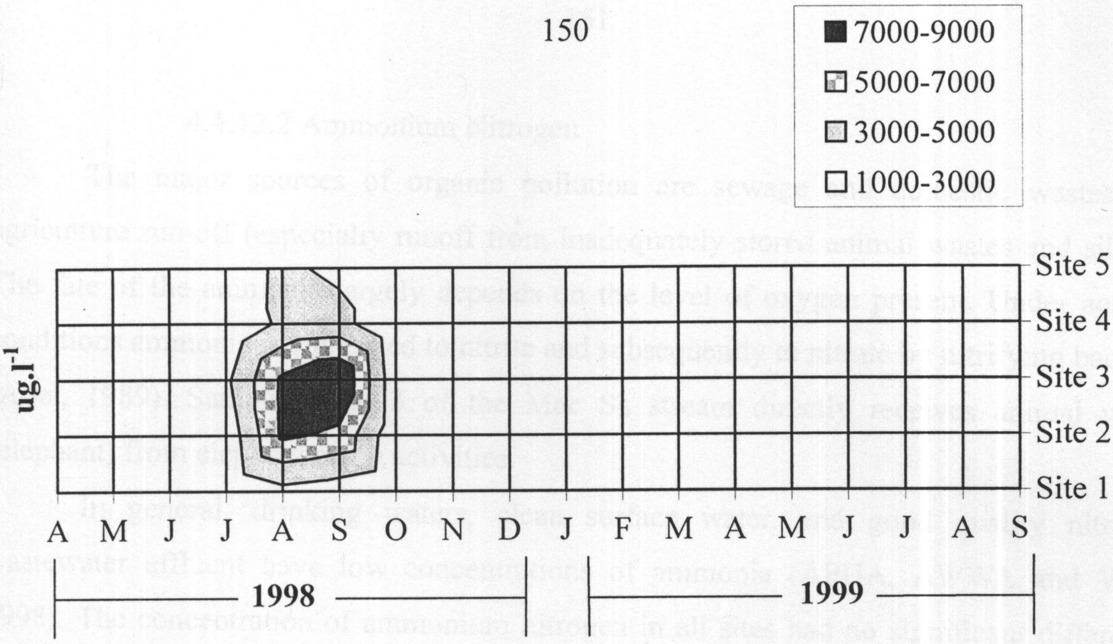


Figure 74. Area plots of nitrate nitrogen ($\mu g.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

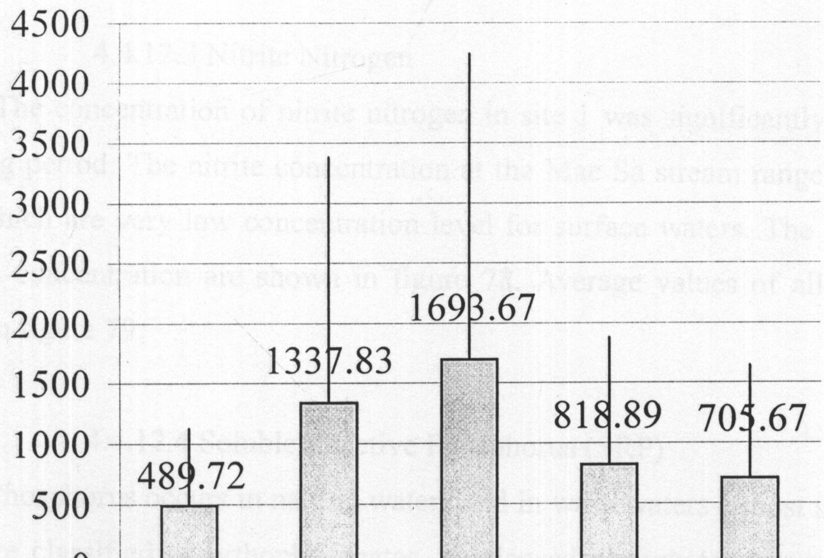


Figure 75. Average values of nitrate nitrogen ($\mu g.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

4.4.12.2 Ammonium Nitrogen

The major sources of organic pollution are sewage and domestic wastes and agriculture run-off (especially runoff from inadequately stored animal wastes and silage). The fate of the ammonia largely depends on the level of oxygen present. Under aerobic conditions ammonia is converted to nitrite and subsequently to nitrate by nitrifying bacteria (Abel, 1989). Sampling site 3 of the Mae Sa stream directly receives animal waste (elephant) from elephant camp activities.

In general, drinking waters, clean surface water, and good quality nitrified wastewater effluent have low concentrations of ammonia (APHA, AWWA and WEF, 1998). The concentration of ammonium nitrogen in all sites had no significant difference throughout the sampling period, although in Site 3 there seemed to be a higher average value of ammonium nitrogen (214.06 $\mu g.l^{-1}$). The ammonium concentration at the Mae Sa stream ranges between 0 and 525 $\mu g.l^{-1}$, the average amount of sites 1,2,4 and 5 are 98.50 $\mu g.l^{-1}$, 167.26 $\mu g.l^{-1}$, 171.29 $\mu g.l^{-1}$ and 123.33 $\mu g.l^{-1}$ respectively. The area plots of ammonium nitrogen concentration are shown in Figure 76. Average values of all sampling sites are shown in Figure 77.

4.4.12.3 Nitrite Nitrogen

The concentration of nitrite nitrogen in site 1 was significantly lowest through the sampling period. The nitrite concentration at the Mae Sa stream ranges between 1 and 47 $ug.l^{-1}$ which are very low concentration level for surface waters. The area plots of nitrite nitrogen concentration are shown in figure 78. Average values of all sampling sites are shown in figure 79.

4.4.12.4 Soluble Reactive Phosphorus (SRP)

Phosphorus occurs in natural waters and in wastewaters almost solely as phosphate. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates), and organically bound phosphates. They occur in solution, in particles or detritus, and in bodies of aquatic organisms.

Phosphorus is essential for the growth of organisms and can be the nutrient that limits the primary productivity of a body of water (APHA, AWWA and WEF, 1998).

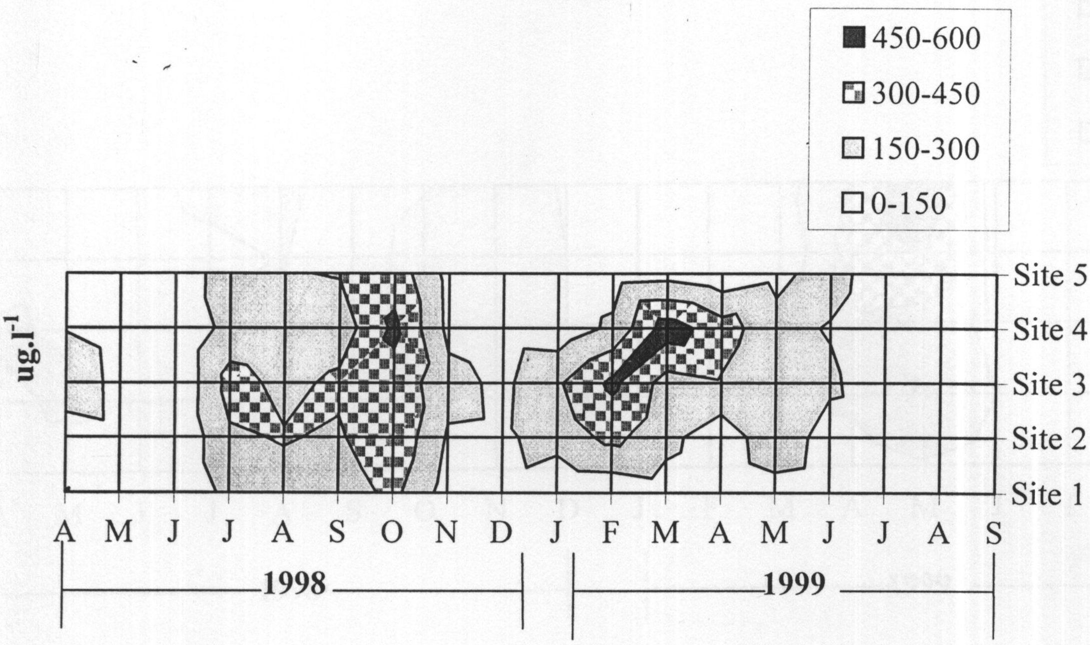


Figure 76. Area plots of ammonium nitrogen (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

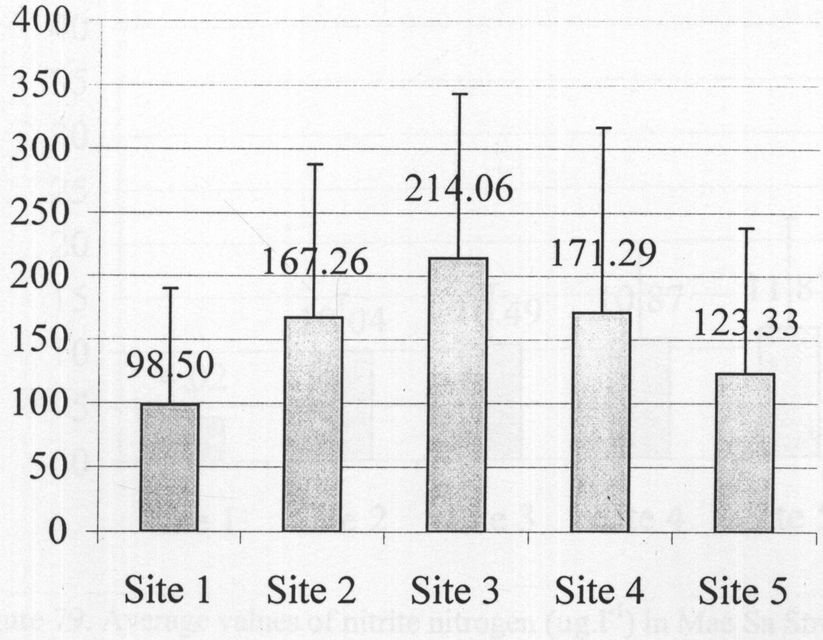


Figure 77. Average values of ammonium nitrogen (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

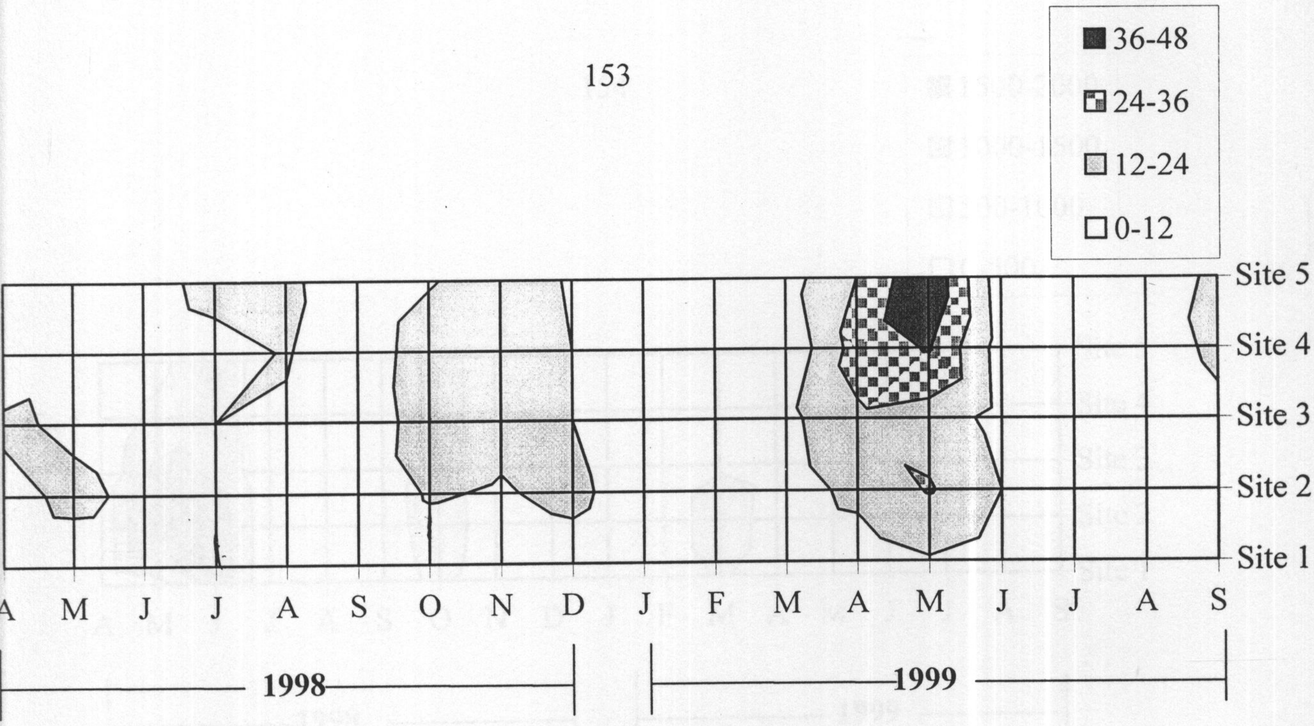


Figure 78. Area plots of nitrite nitrogen (µg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

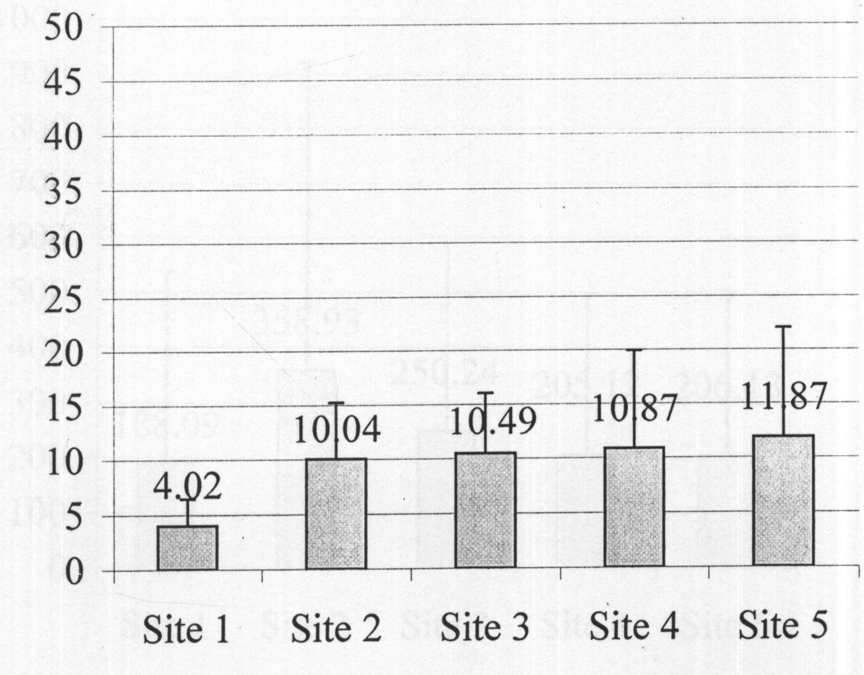


Figure 79. Average values of nitrite nitrogen (µg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

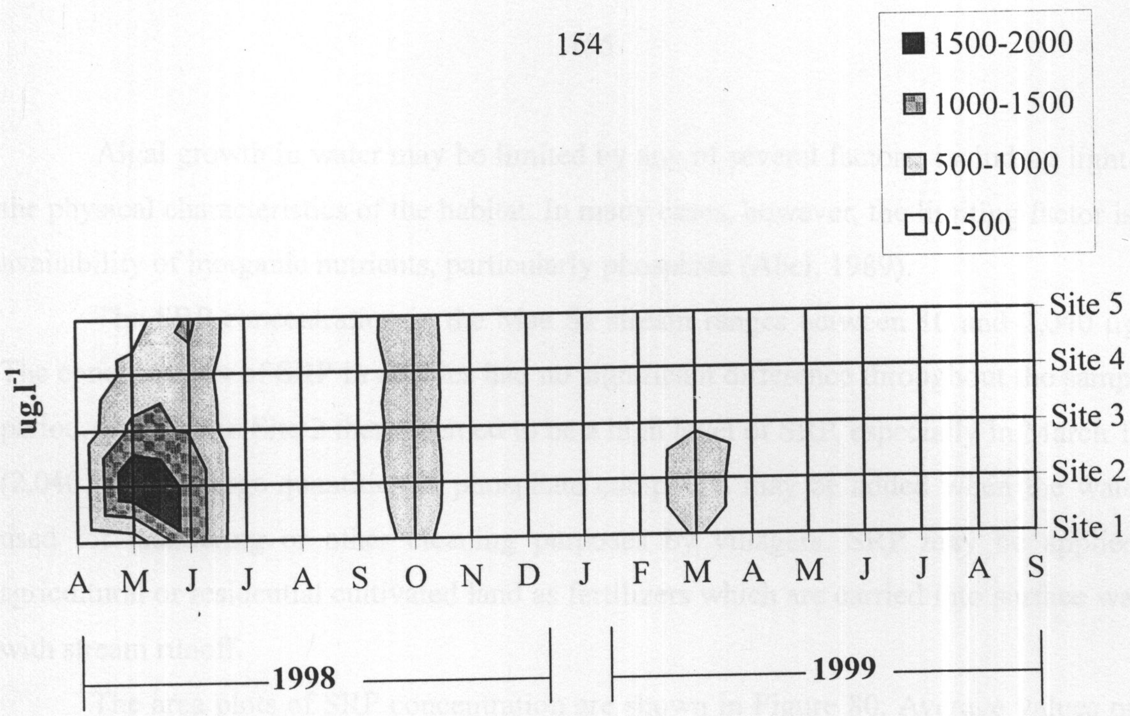


Figure 80. Area plots of SRP ($\mu g.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

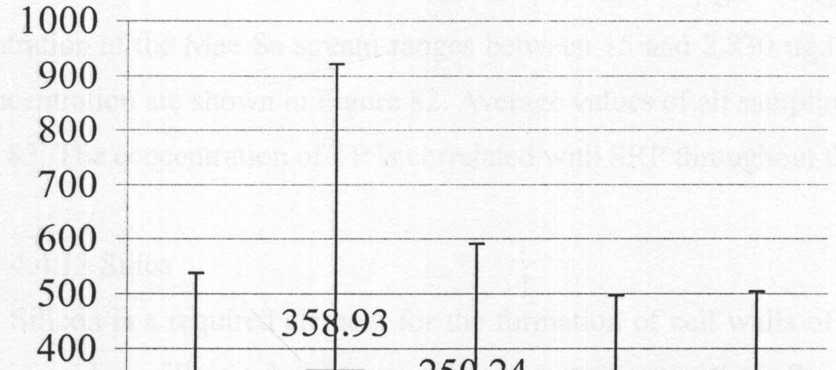


Figure 81. Average values of SRP ($\mu g.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

Algal growth in water may be limited by any of several factors, including light and the physical characteristics of the habitat. In many cases, however, the limiting factor is the availability of inorganic nutrients, particularly phosphate (Abel, 1989).

The SRP concentration in the Mae Sa stream ranges between 10 and 2,040 $\mu g.l^{-1}$. The concentration of SRP in all sites had no significant difference throughout the sampling period, although in Site 2 there seemed to be a high level of SRP, especially in March 1998 (2,040 $\mu g.l^{-1}$). Large quantities of phosphate compound may be added when the water is used for laundering or other cleaning purposes by villagers. SRP may be applied to agricultural or residential cultivated land as fertilizers which are carried into surface waters with stream runoff.

The area plots of SRP concentration are shown in Figure 80. Average values of all sampling sites are shown in Figure 81.

4.4.12.5 Total Phosphorus

In the same way, the concentration of TP in all sites had no significant difference throughout the sampling period, although Site 2 seemed to have higher levels of SRP especially in March - June 1998 (2,830 and 2,470 $\mu g.l^{-1}$ respectively). The TP concentration at the Mae Sa stream ranges between 15 and 2,830 $ug.l^{-1}$. The area plots of TP concentration are shown in Figure 82. Average values of all sampling sites are shown in Figure 83. The concentration of TP is correlated with SRP throughout the sampling period.

4.4.13 Silica

Silicon is a required element for the formation of cell walls of diatoms. Its uptake as silicic acid or silicates by diatom cells seem to be greatly influenced by sulphydryl groups. In the cell membrane there are enzymes containing sulphydryl groups. It is also known to be important in cell division (Patrick, 1977).

The silica (SiO_2) content of natural water most commonly is in the 1,000-30,000 $\mu g.l^{-1}$ range, although concentrations as high as 100,000 $\mu g.l^{-1}$ are not unusual and concentrations exceeding 1,000,000 $\mu g.l^{-1}$ are found in some brackish waters and brines (APHA, AWWA and WPCF, 1992).

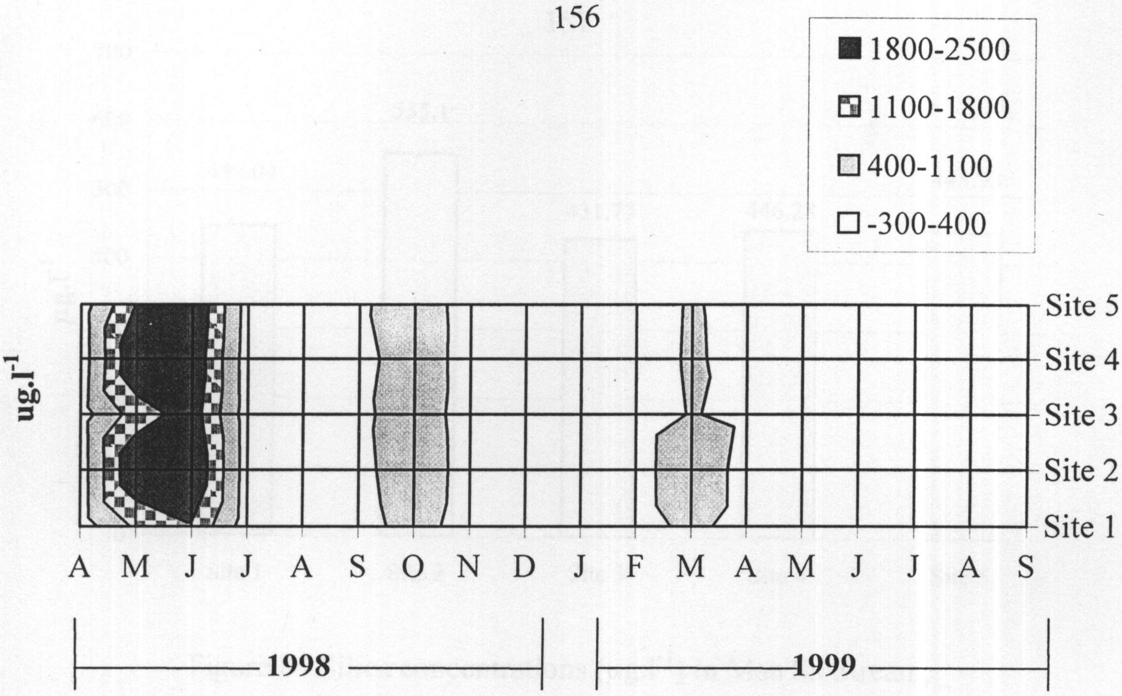


Figure 82. Area plots of TP (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

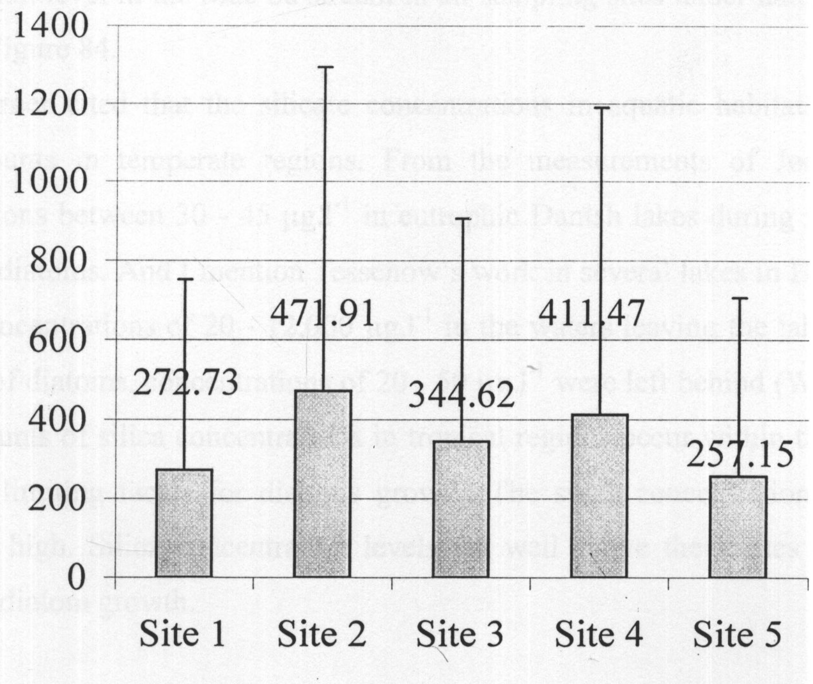


Figure 83. Average values of TP (μg.l^{-1}) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

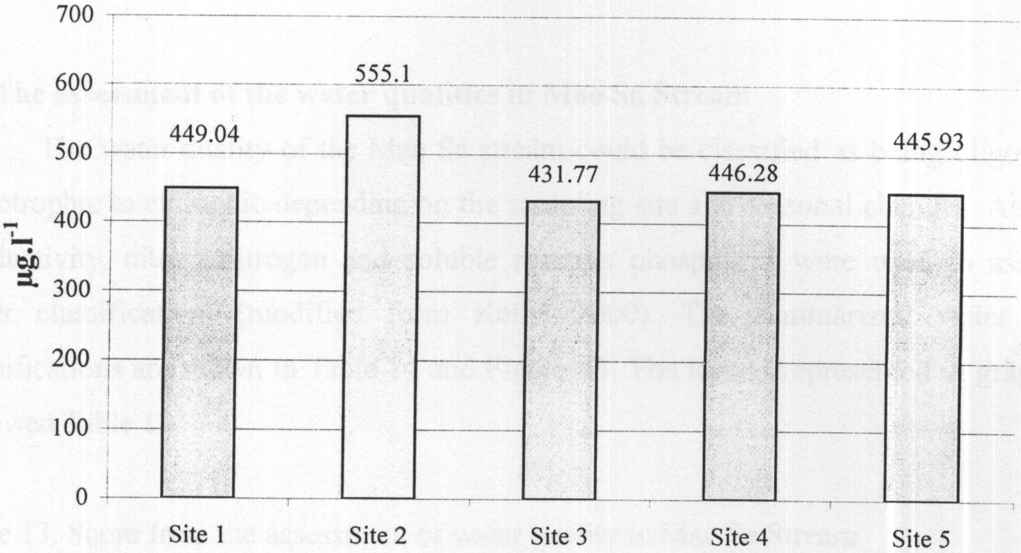


Figure 84.Silica concentrations ($\mu g.l^{-1}$) in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand

The silica concentration in the Mae Sa stream was recorded only once at the different sites (September 1999), which were 449.04 $\mu g.l^{-1}$ (Site 1), 555.10 $\mu g.l^{-1}$ (Site 2), 431.77 $\mu g.l^{-1}$ (Site 3), 446.28 $\mu g.l^{-1}$ (Site 4) and 445.93 $\mu g.l^{-1}$ (Site 5). The silica concentration level in the Mae Sa stream in all sampling sites under natural conditions are shown in Figure 84.

Werner cited that the silicate concentrations in aquatic habitats are varied with small amounts in temperate regions. From the measurements of Jørgensen, he gave concentrations between 30 - 45 $\mu g.l^{-1}$ in eutrophic Danish lakes during maximum growth periods of diatoms. And I mention Tessenow's work in several lakes in Holstein. He found average concentrations of 20 - 12,000 $\mu g.l^{-1}$ in the waters leaving the lakes. And after the blooming of diatoms, concentrations of 20 - 50 $\mu g.l^{-1}$ were left behind (Werner, 1977). The larger amounts of silica concentrations in tropical regions occur within this parameter and is not the limiting factor for diatoms growth. The silica concentrations in the Mae Sa stream are high. Silica concentration levels are well above the values considered to be limiting to diatom growth.

4.5 The assessment of the water qualities in Mae Sa Stream

The water quality of the Mae Sa stream could be classified as being oligotrophic-mesotrophic to eutrophic depending on the sampling site and seasonal changes. Alkalinity, conductivity, nitrate nitrogen and soluble reactive phosphorus were used to assess the water classification. (modified from Kelly, 2000). The summarized water quality classifications are shown in Table 14 and Figure 85. The legend represented in graph were followed Table 13.

Table 13. Score from the assessment of water quality in Mae Sa Stream

Scores	Trophic status	Color in graph
1.00 – 1.80	Oligotrophic	pale blue
1.80 – 2.60	Oligo-mesotrophic	blue
2.60 – 3.40	Mesotrophic	light green
3.40 – 4.20	Meso-eutrophic	dark green
4.20 – 5.00	Eutrophic	orange
5.00 – 5.80	Hypereutrophic	red

4.6 PCA of diatom species in the Mae Sa Stream

The cell count results of epilithic diatoms present in the Mae Sa stream were put into MVSP. For the PCA, the data was transformed to Log_{10} and the axes were extracted according to Kaiser's rule.

The PCA graph shows the dominant species from the counting process and is considered far from the diagram center as follows: *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Nitzschia palea* Kützing, *G. pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Navicula viridula* (Kützing) Ehrenberg var. *viridula*, *A. exigua* Grunow var. *exigua*, *N. schroeterii* Meister, *A. oblongella* Oestrup, *Sellaphora pupula* (Kützing) Mereschkowsky, *Cocconeis placentula* Ehrenberg, *Gyrosigma scalproides* (Rabenhorst) Cleve, *G. clevei* Fricke, *Bacillaria paradoxa* Gmelin, *Amphora libyca* Ehrenberg, *N. cryptotenella* Lange-Bertalot, *Cymbella tumida* (Brébisson) Van Heurck, *C. turgidula* Grunow and *Melosira varians* Agardh (Figure 86).

The dominant species from PCA may be considered to be the indicator species for indicating water quality, however these may be considered together with the results from correlation.

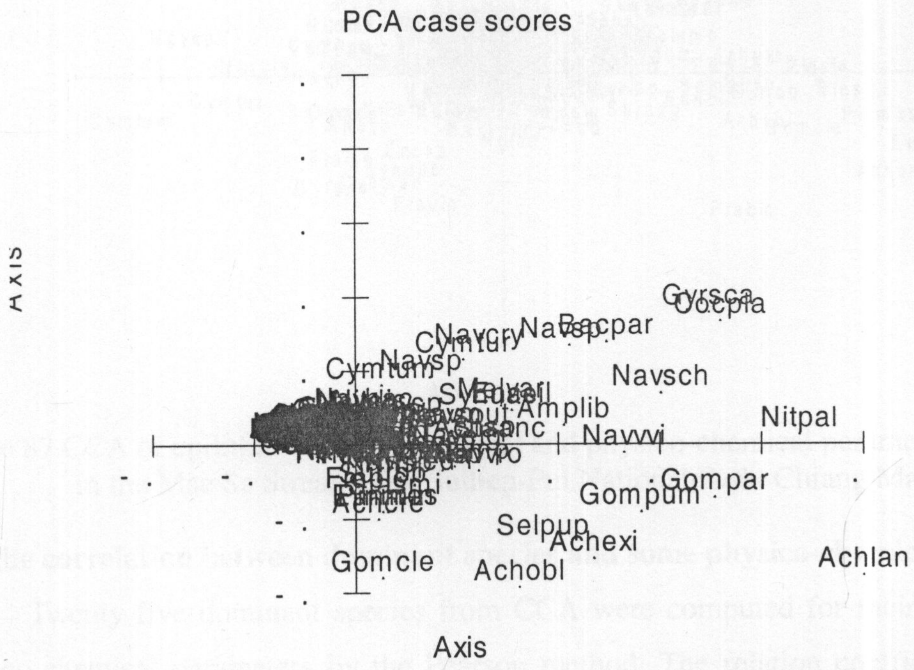


Figure 86. PCA of epilithic diatoms cell count in the Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

4.7 CCA of physico-chemical parameters and diatom species in the Mae Sa Stream

The results of the CCA can be presented in a diagram, the species which are present in distance far from the center indicate relevant significance which may be more important than other species closer to the center. The position of the species points indicates the environmental preference of the species (Figure 87).

Twenty five dominant taxa were selected from the CCA for develop the Mae Sa Index which are shown in Table 15. The selected species were considered together with the percentage of relative abundance from the counting. The recommended number of relative abundance (percentage of presented species) should be more than 1 % (see Table 16).

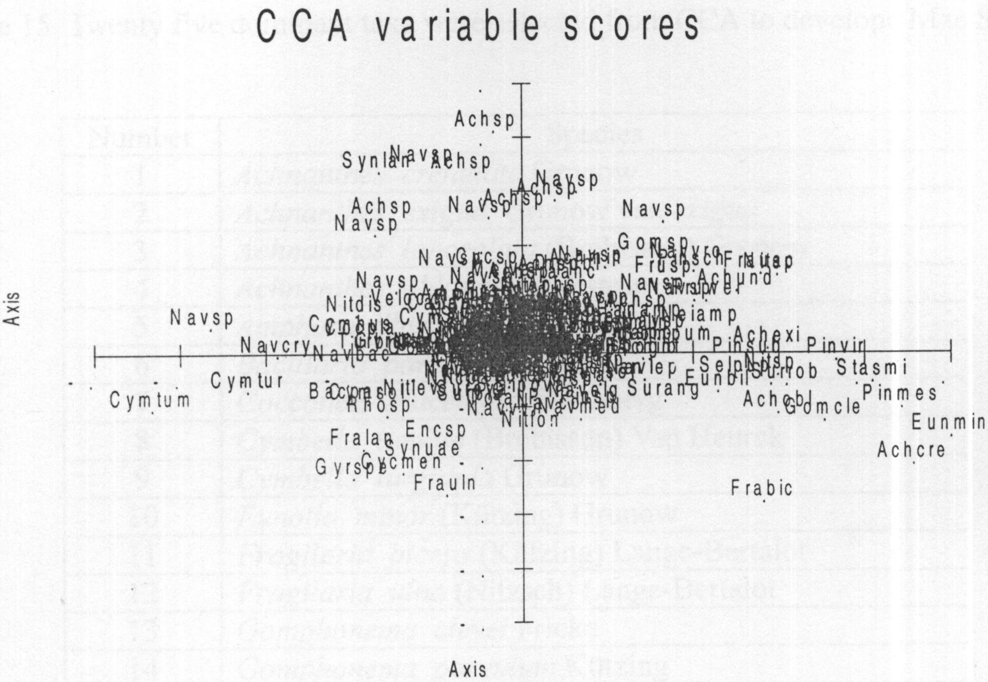


Figure 87 CCA of epilithic diatoms cell count and physico-chemical parameters in the Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai, Thailand.

4.8 The correlation between dominant species and some physico-chemical parameters

Twenty five dominant species from CCA were computed for their relation to the physico-chemical parameters by the Pearson method. The relation coefficients represent the level of relationships between diatoms and each set of parameters. The star symbol indicates the significant correlations (* for $p \leq 0.05$ and ** for $p \leq 0.01$) (Table 17).

Correlation coefficience is useful to looking for specific correlations such as: *Achnanthes crenulata* Grunow and *Fragilaria biceps* (Kützing) Lange-Bertalot which are significantly correlated to the SRP. *Gomphonema parvulum* (Kützing) Kützing, *Melosira varians* Agardh and *Synedra lanceolata* Kützing are highly significant as correlated to nitrate nitrogen. And *Gyrosigma scalproides* (Rabenhorst) Cleve is correlated to ammonium nitrogen. However, it show that the three dominant species such as *Navicula viridula* (Kützing) Ehrenberg, *Amphora libyca* Ehrenberg and *Fragilaria ulna* (Nitzsch) Lange-Bertalot are not significantly correlated to any physico-chemical parameters. Therefore, indicator species could not be exactly considered from the correlation of statistical methods. These results may be compiled with distribution and relative abundance.

Table 15. Twenty five dominant taxa were selected from CCA to develope Mae Sa Index

Number	Species
1	*Achnanthes crenulata* Grunow
2	*Achnanthes exigua* Grunow var. *exigua*
3	*Achnanthes lanceolata* (Brébisson) Grunow
4	*Achnanthes oblongella* Oestrup
5	*Amphora libyca* Ehrenberg
6	*Bacillaria paradoxa* Gmelin
7	*Cocconeis placentula* Ehrenberg
8	*Cymbella tumida* (Brébisson) Van Heurck
9	*Cymbella turgidula* Grunow
10	*Eunotia minor* (Kützing) Grunow
11	*Fragilaria biceps* (Kützing) Lange-Bertalot
12	*Fragilaria ulna* (Nitzsch) Lange-Bertalot
13	*Gomphonema clevei* Fricke
14	*Gomphonema parvulum* Kützing
15	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot
16	*Gyrosigma scalproides* (Rabenhorst) Cleve
17	*Melosira varians* Agardh
18	*Navicula cryptotenella* Lange-Bertalot
19	*Navicula schroeterii* Meister
20	*Navicula viridula* (Kützing) Ehrenberg var. *viridula*
21	*Nitzschia palea* Kützing
22	*Pinnularia mesolepta* (Ehrenberg) W. Smith
23	*Sellaphora pupula* (Kützing) Mereschkowsky
24	*Stauroneis anceps* Ehrenberg
25	*Synedra lanceolata* Kützing

Table 16. The percentage of relative abundance of twenty five dominant taxa.

No. of selected species	Species	No. from counting	Percentage
1	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	1154	7.76
2	*Nitzschia palea* Kützing	1075	7.22
3	*Achnanthes lanceolata* (Brébisson) Grunow	883	5.93
4	*Bacillaria paradoxa* Gmelin	750	5.04
5	*Cocconeis placentula* Ehrenberg	639	4.29
6	*Gyrosigma scalproides* (Rabenhorst) Cleve	543	3.65
7	*Gomphonema parvulum* Kützing	496	3.33
8	*Achnanthes oblongella* Oestrup	428	2.88
9	*Navicula schroeterii* Meister	426	2.86
10	*Navicula viridula* (Kützing) Ehrenberg var. *viridula*	394	2.65
11	*Achnanthes exigua* Grunow var. *exigua*	329	2.21
12	*Gomphonema clevei* Fricke	320	2.15
13	*Stauroneis anceps* Ehrenberg	301	2.02
14	*Melosira varians* Agardh	289	1.94
15	*Amphora libyca* Ehrenberg	265	1.78
16	*Navicula cryptotenella* Lange-Bertalot	258	1.73
17	*Sellaphora pupula* (Kützing) Mereschkowsky	219	1.47
18	*Encyonema silesiacum* (Bleisch) D. G. Mann	193	1.30
19	*Cymbella turgidula* Grunow	131	0.88
20	*Pinnularia mesolepta* (Ehrenberg) W. Smith	97	0.65
21	*Cymbella tumida* (Brébisson) Van Heurck	61	0.41
22	*Achnanthes crenulata* Grunow	60	0.40
23	*Eunotia minor* (Kützing) Grunow	53	0.36
	Fragilaria ulna (Nitzsch) Lange-Bertalot	48	0.32
24	*Fragilaria biceps* (Kützing) Lange-Bertalot	36	0.24
25	*Synedra lanceolata* Kützing	40	0.27

4.9 Mae Sa Index

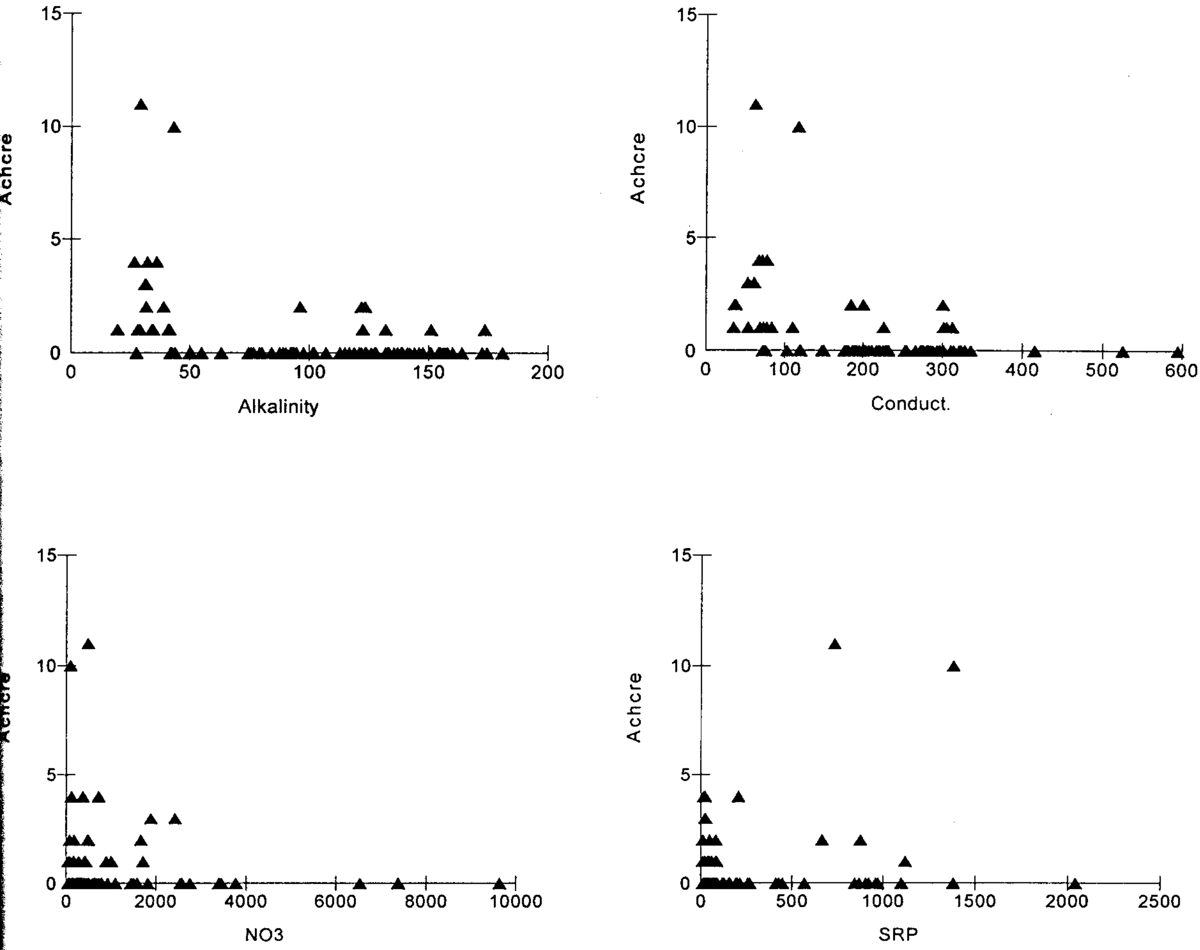
The most abundance of epilithic diatoms which were extracted from the CCA method and were listed in the Mae Sa Index. The selected species were plotted in a scatter diagram against some physico-chemical parameters which are; alkalinity, conductivity, nitrate nitrogen and SRP in order to avoid making too many generalisations. The methods to calculate the trophic index value were modified from Kelly (Kelly, 2000).

The concentrations of alkalinity, conductivity, nitrate nitrogen and SRP are divided into six classes as shown in Table 18. The scatter plots diagram and table for summarization are shown in Figures 88-112. Indicator values depended on the spread of values around the peak. The Index value of each species are given at the end of the table. Summaries for the index values of all species are listed in Table 19.

Table 18. The six classes of alkalinity, conductivity, nitrate nitrogen and SRP and the scores for calculating the Mae Sa Index (modified from Kelly, 2000).

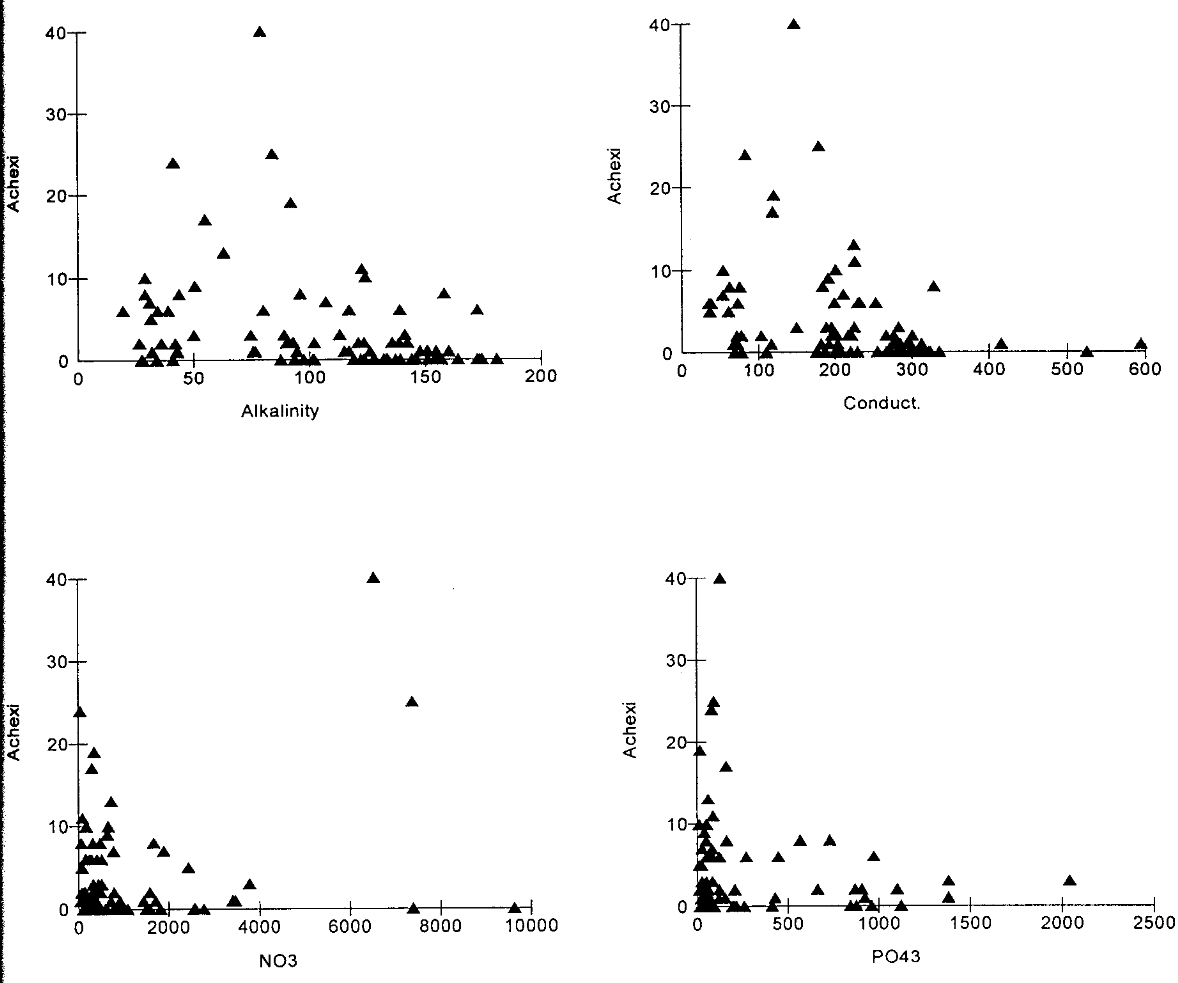
Scores	1	2	3	4	5	6
Alkalinity ($mg.l^{-1}$)	<50	50-100	100-150	150-200	200-500	>500
Conductivity* ($\mu S.cm^{-1}$)	<50	50-100	100-250	250-500	500-1000	>1000
Nitrate nitrogen ($\mu g.l^{-1}$)	<10	10-100	100-1000	1000-5000	5000-10000	>10000
SRP* ($\mu g.l^{-1}$)	<10	10-35	35-100	100-350	350-1000	>1000
Trophic Status	Oligotrophic	Oligo-mesotrophic	Mesotrophic	Meso-eutrophic	Eutrophic	Hyper-eutrophic

* (from Kelly, 2000)



gure 88. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
k	*						
nd		*					
3		*					
P					*		
dex Value		2					**Oligo-mesotrophi**



gure 89. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
k		*					
nd			*				
O3			*				
P				*			
dex Value			3				**Mesotrophic**

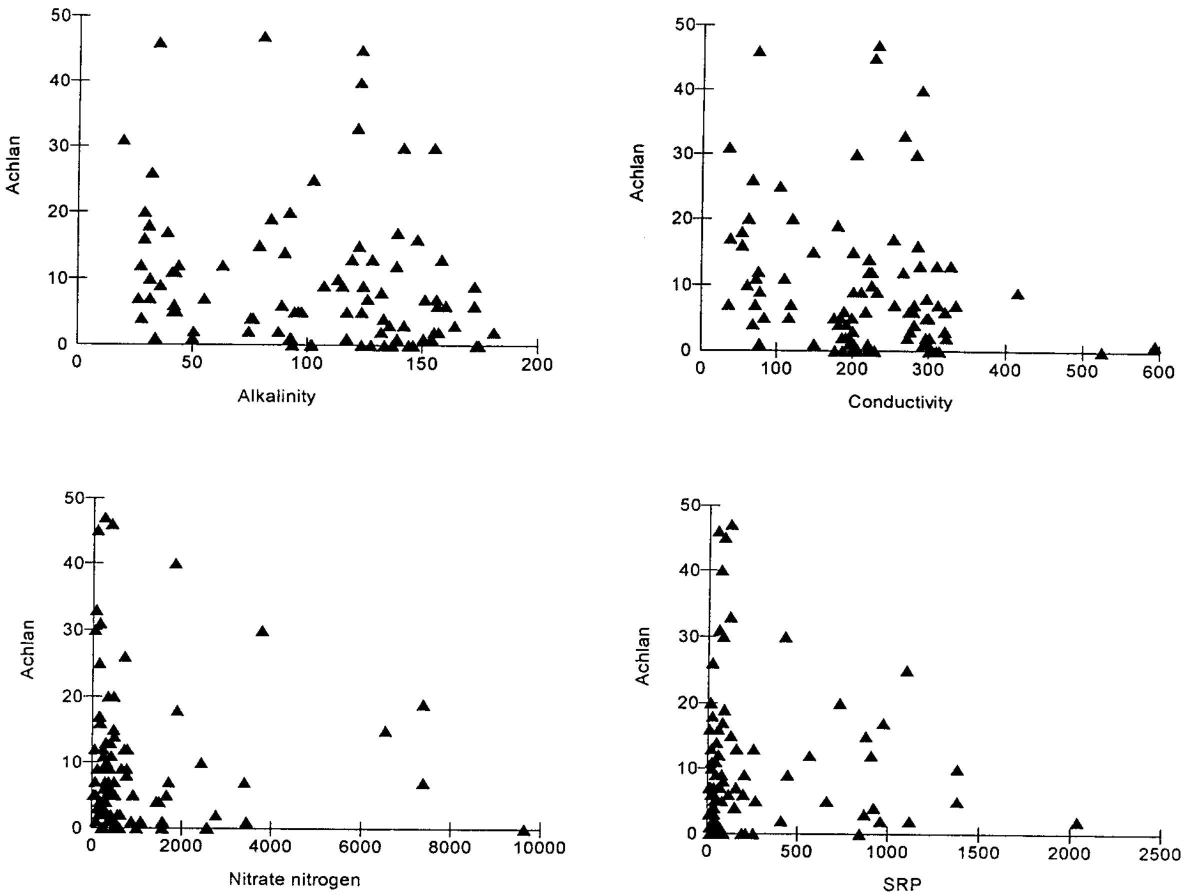
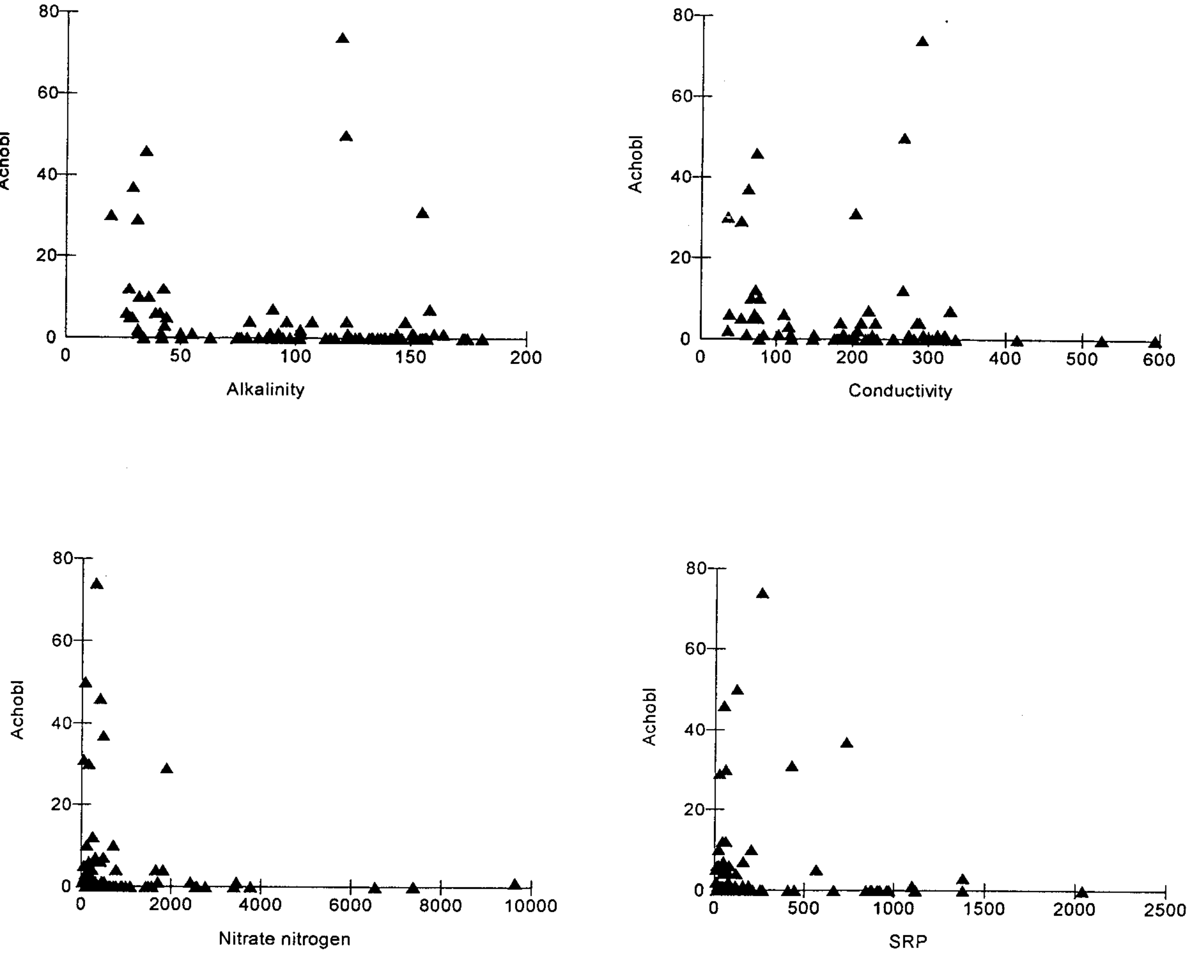


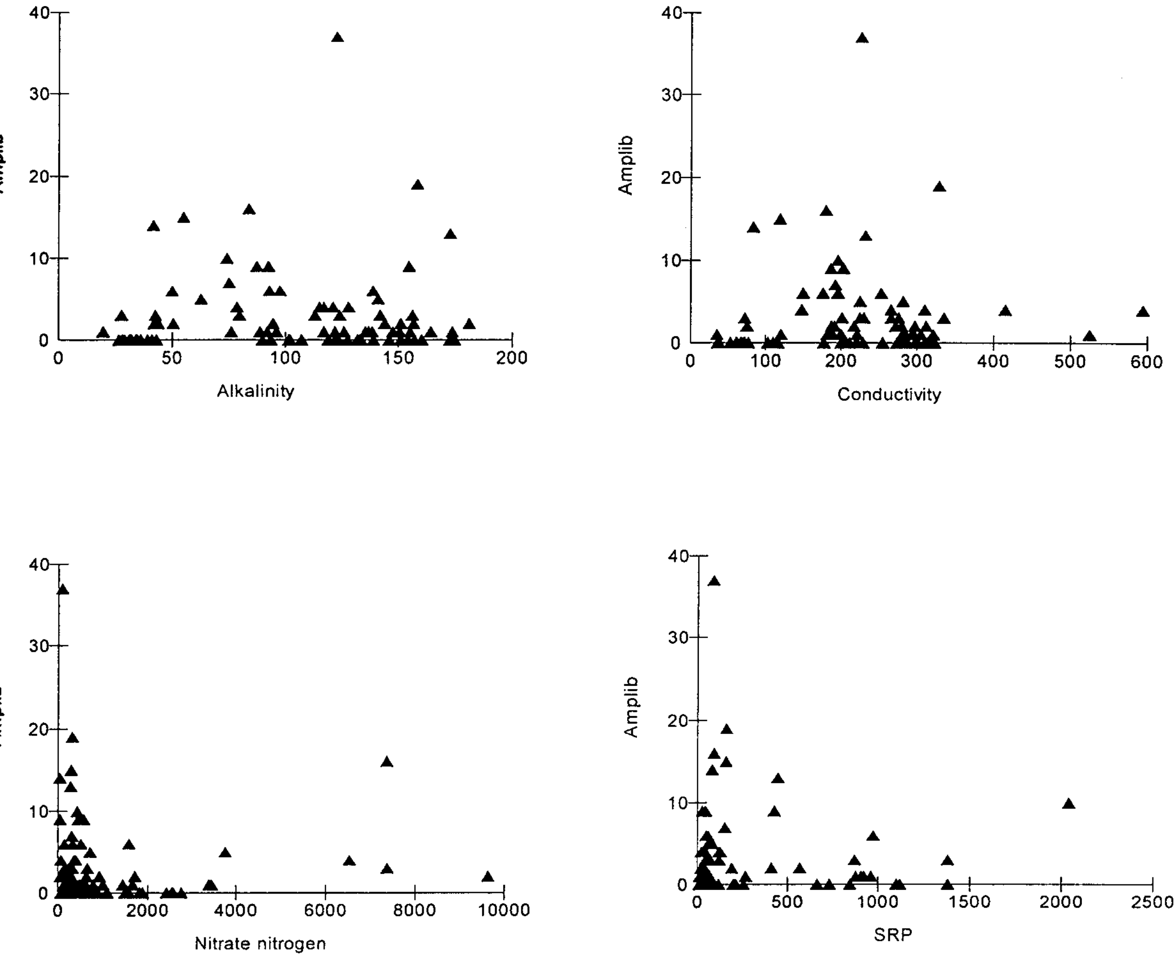
Figure 90. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk		*					
Cond			*				
NO3			*				
SRP			*				
Index Value			3				**Mesotrophic**



gure 91. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
k			*				
nd				*			
D3			*				
RP				*			
dex Value			3				**Mesotrophic**



gure 92. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
k			*				
nd			*				
O3			*				
RP			*				
dex Value			3				**Mesotrophic**

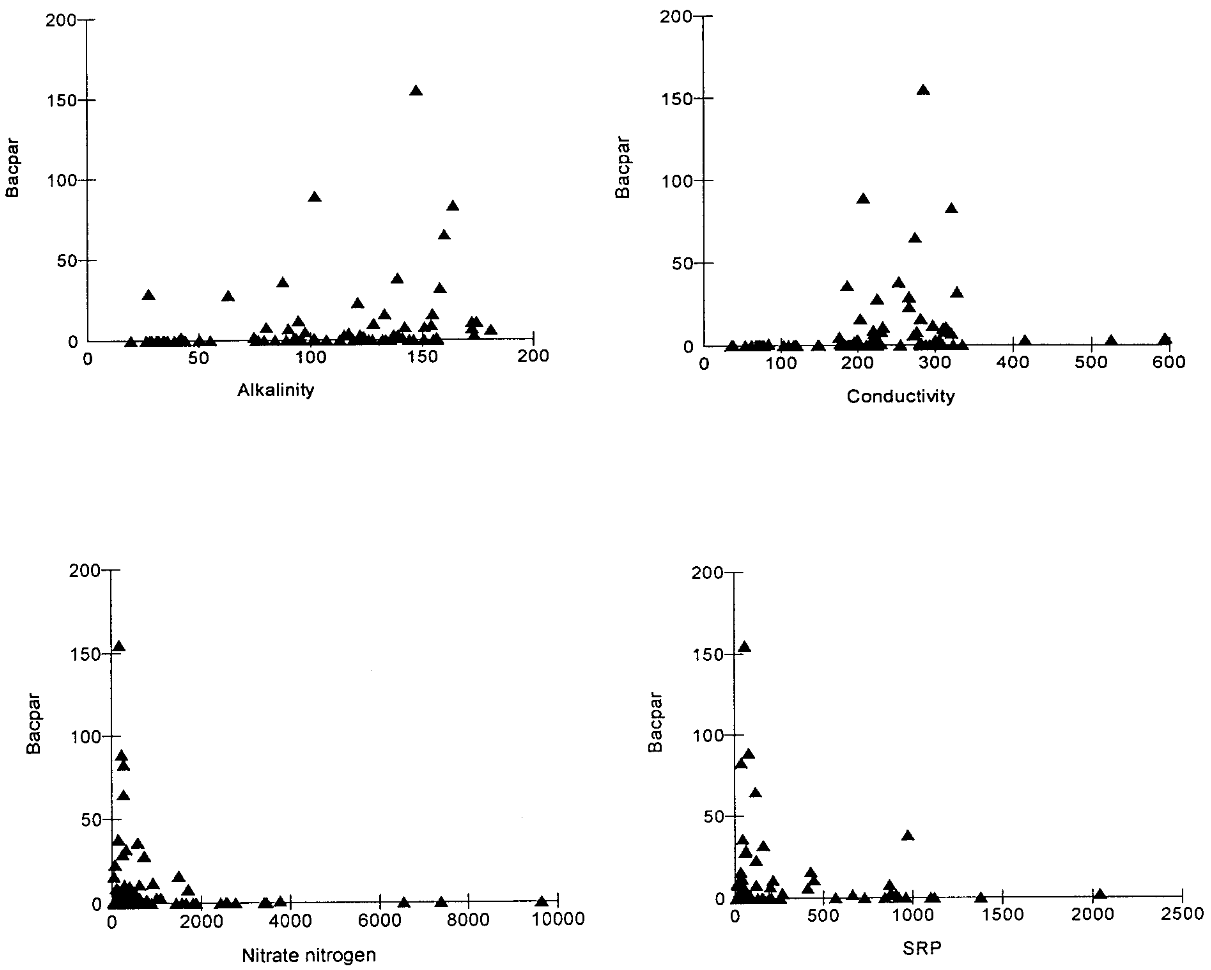


Figure 93. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk			*				
Cond				*			
NO3			*				
SRP				*			
Index Value				4			**Meso-eutrophic**

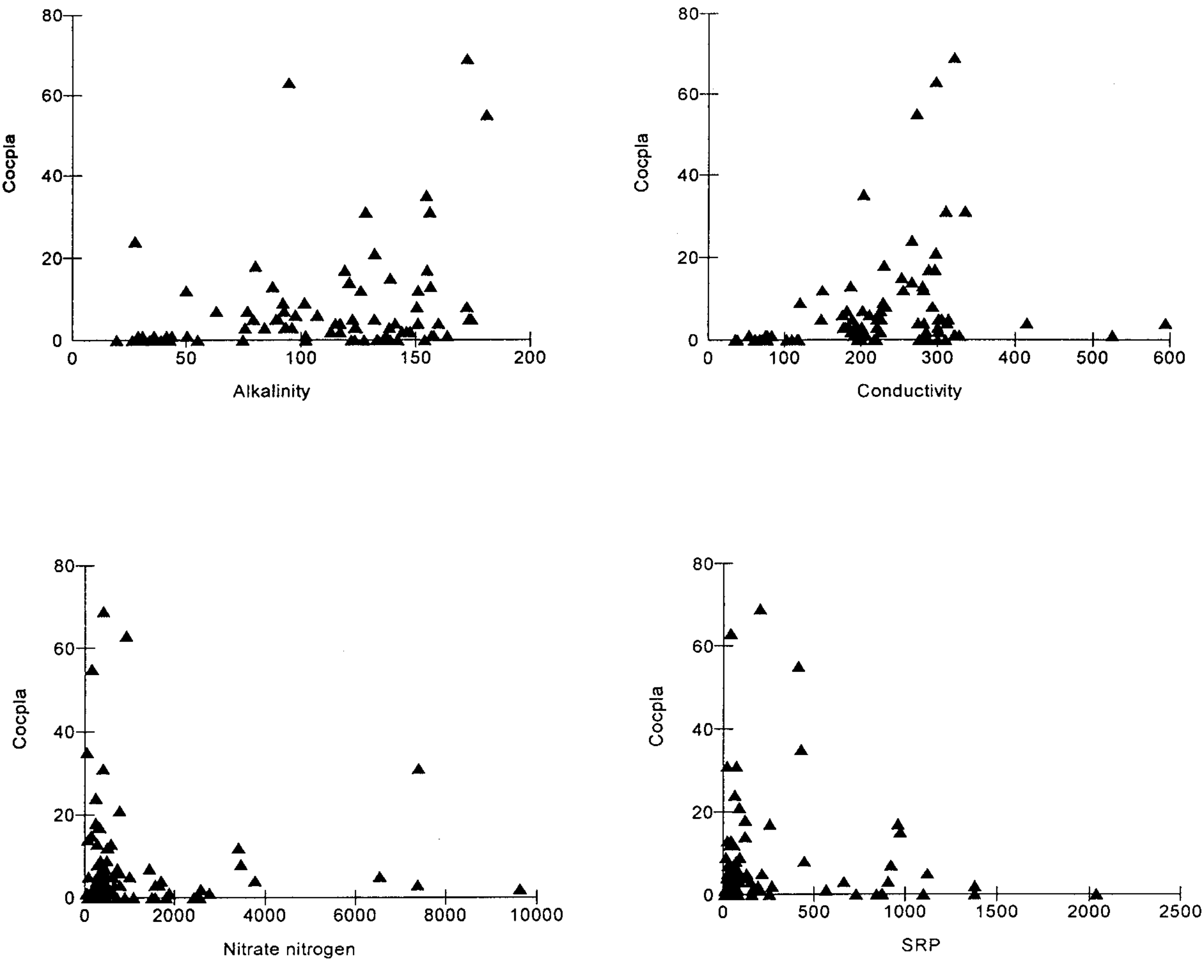


Figure 94. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk				*			
Cond				*			
NO3			*				
SRP				*			
Index Value				4			**Meso-eutrophic**

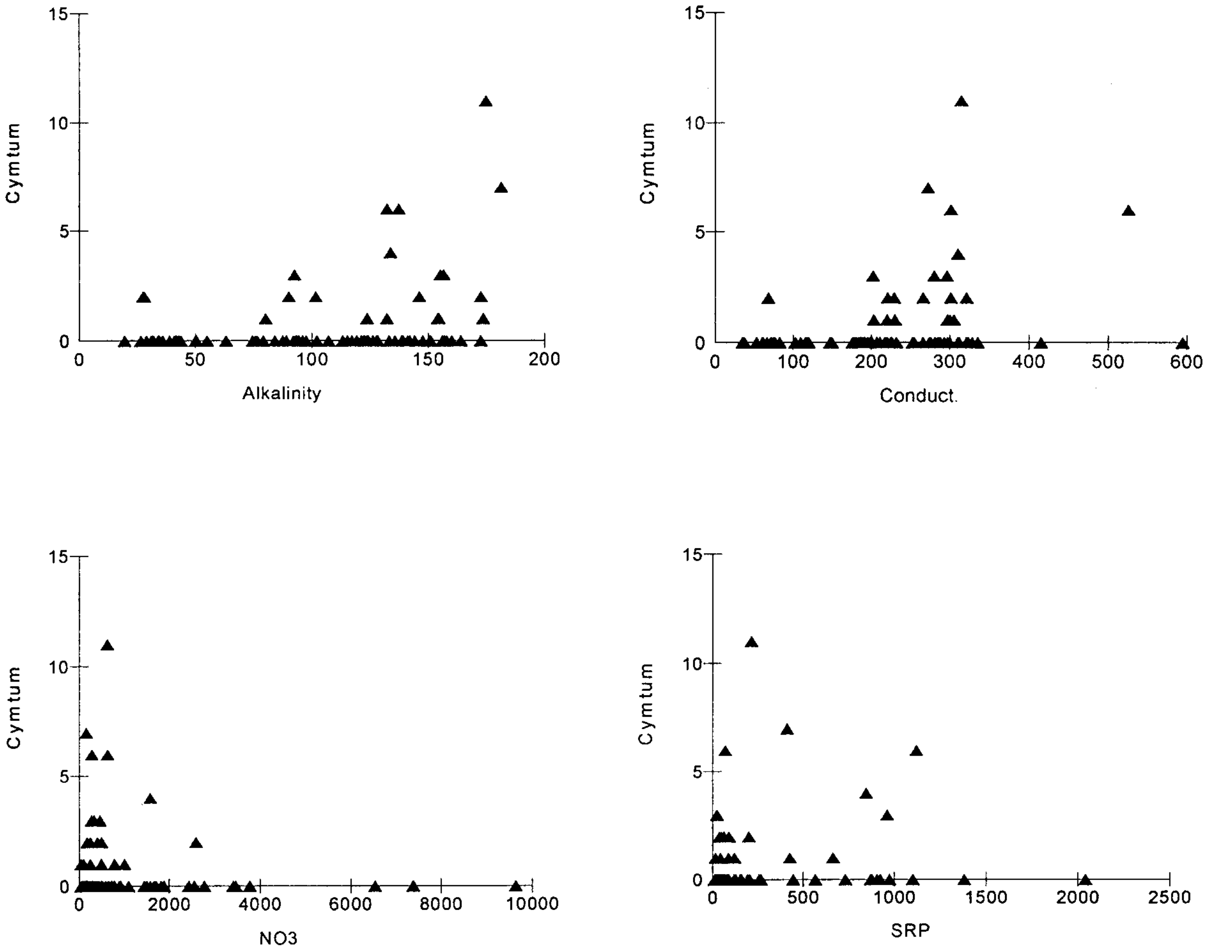


Figure 95. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk				*			
Cond				*			
NO3			*				
SRP				*			
Index Value				4			**Meso-eutrophic**

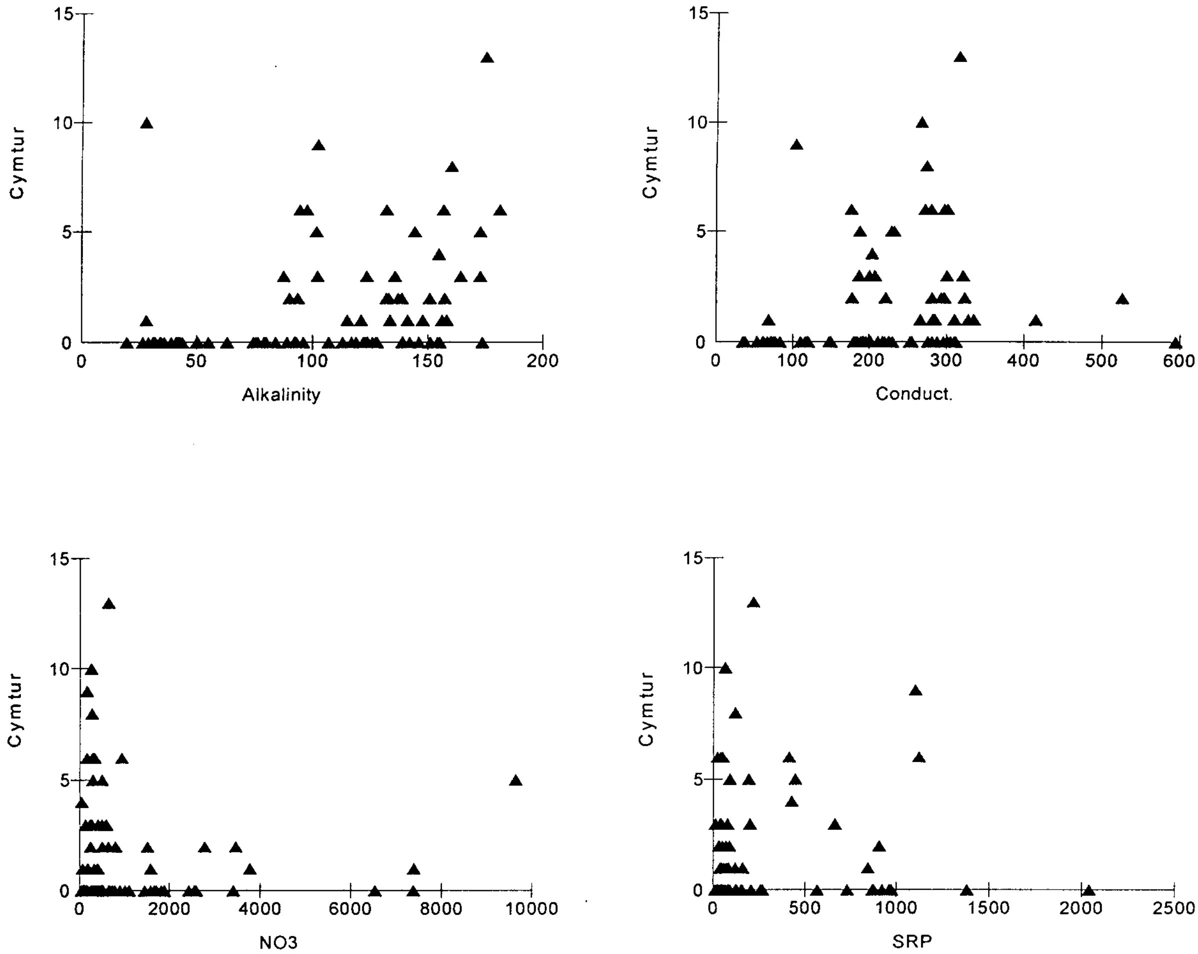
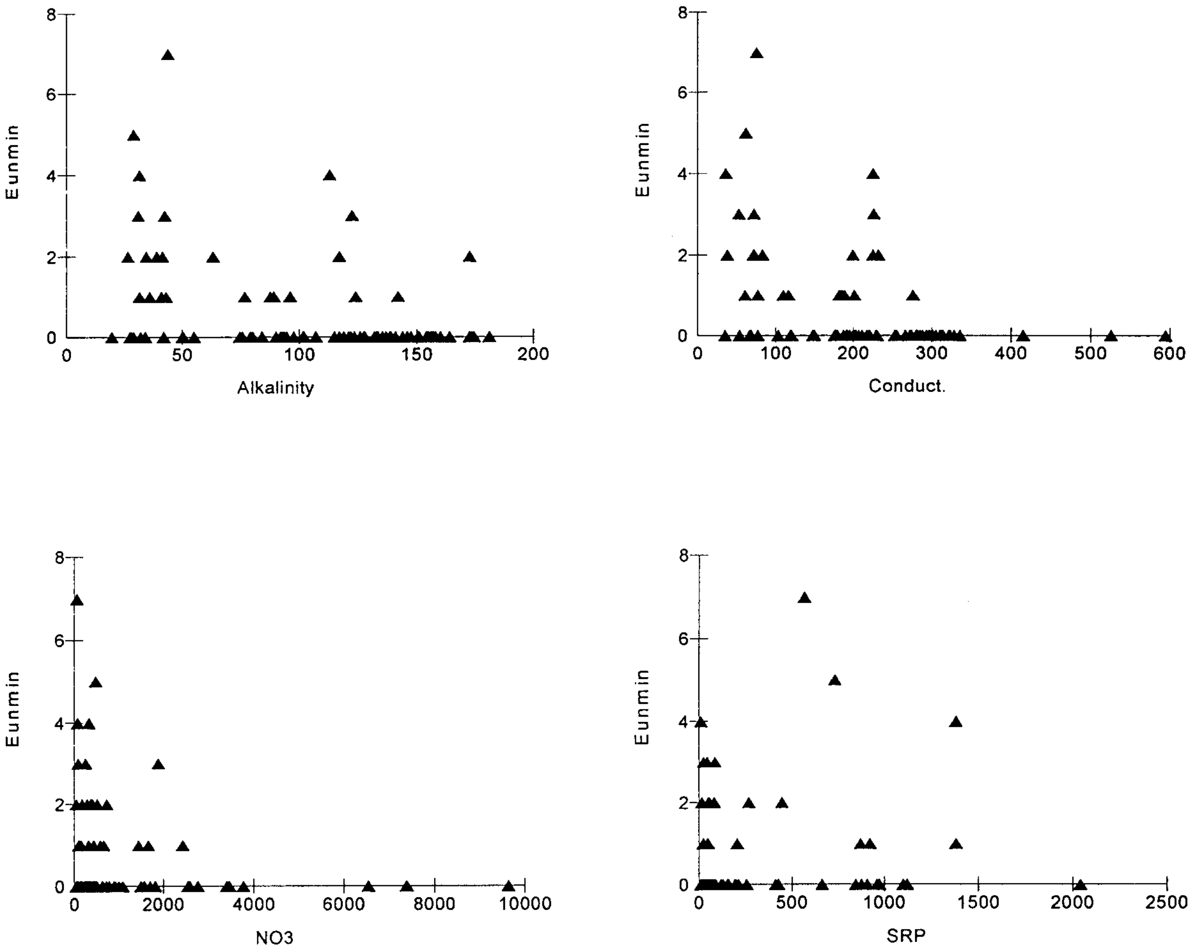


Figure 96. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk				*			
Cond				*			
NO3			*				
SRP					*		
Index Value				4			**Meso-eutrophic**



igure 97. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk	*						
ond		*					
O3	*						
RP					*		
ndex Value	1						**Oligotrophic**

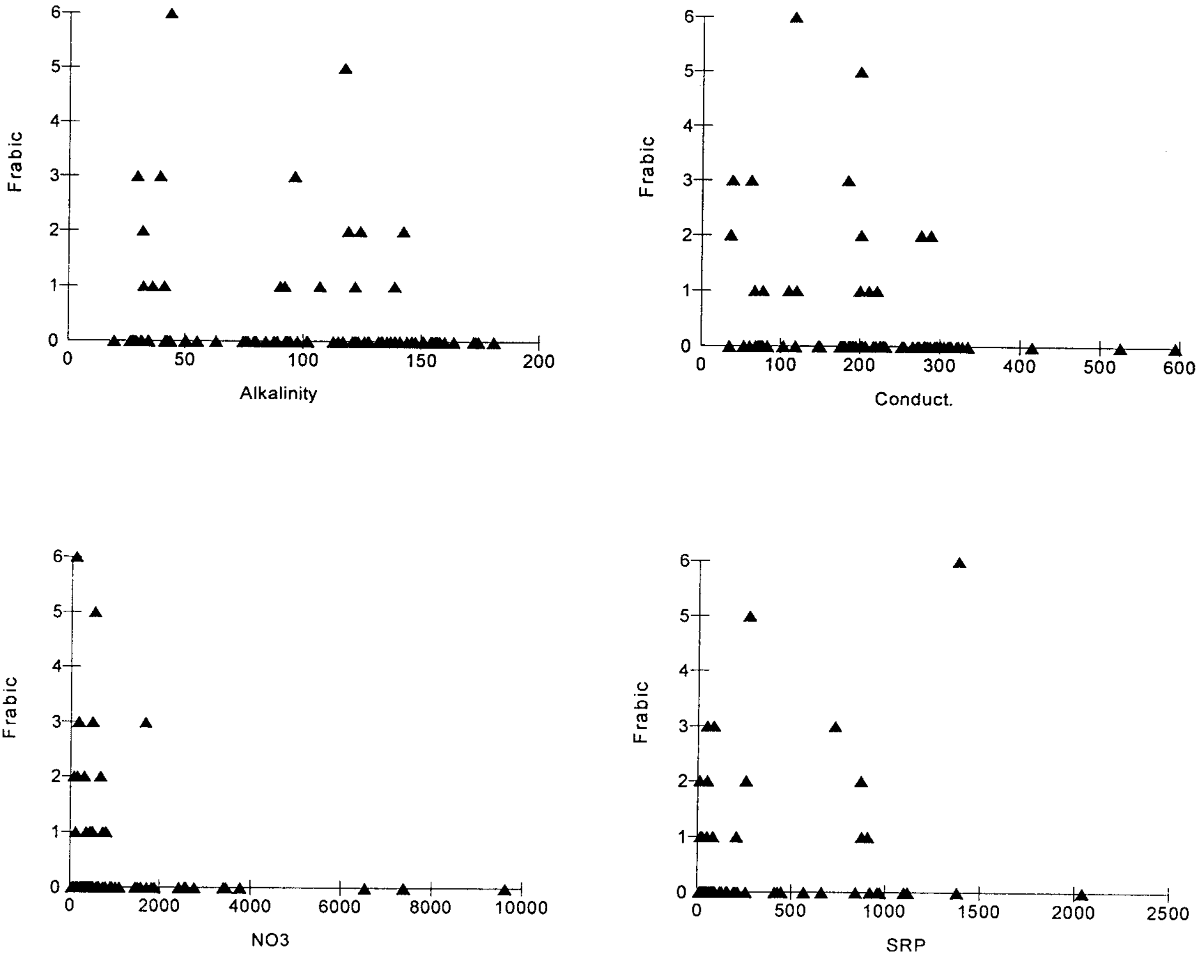
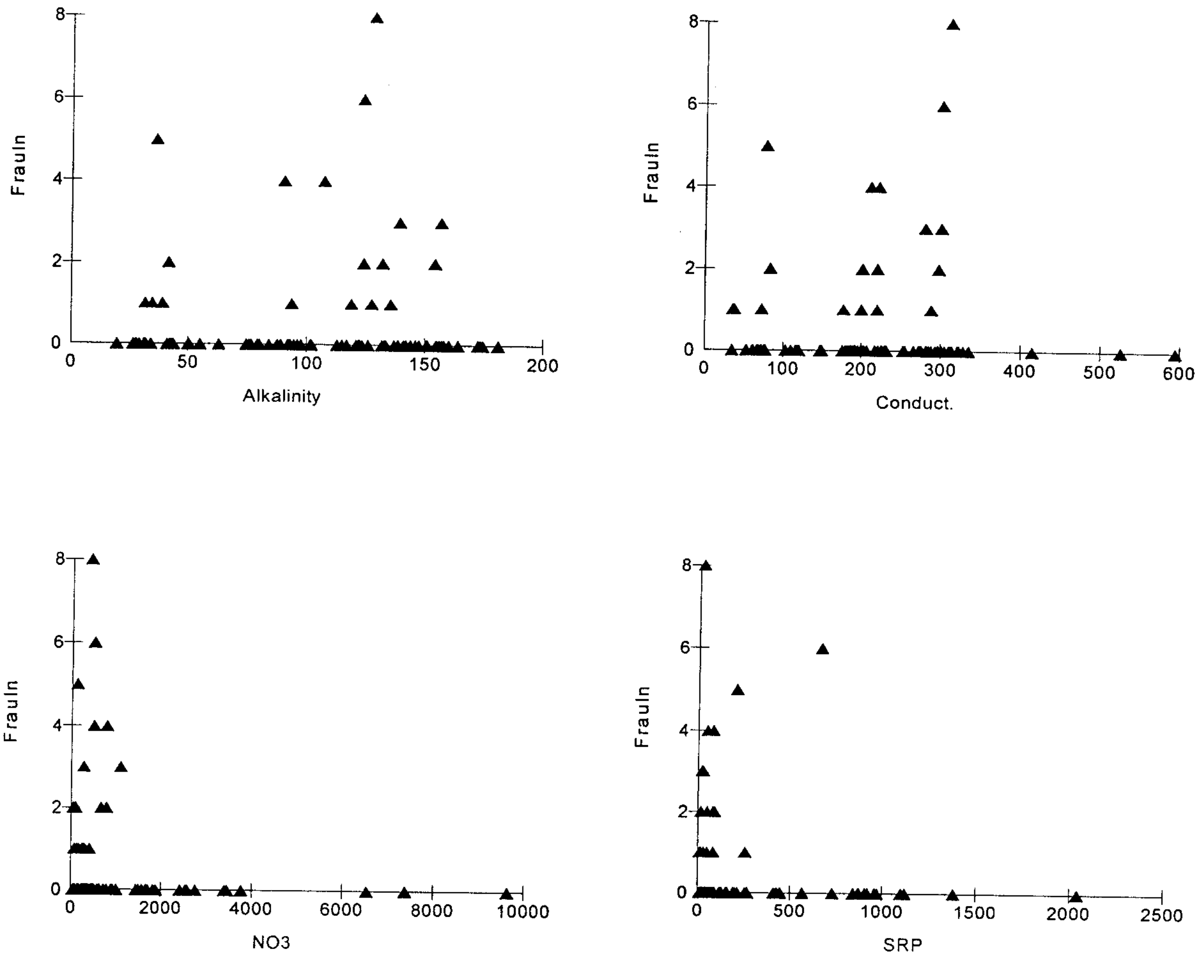


Figure 98. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk			*				
Cond			*				
NO3	*						
SRP				*			
Index Value			3				**Mesotrophic**



igure 99. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk			*				
ond				*			
O3			*				
RP				*			
dex Value				4			**Meso-eutrophic**

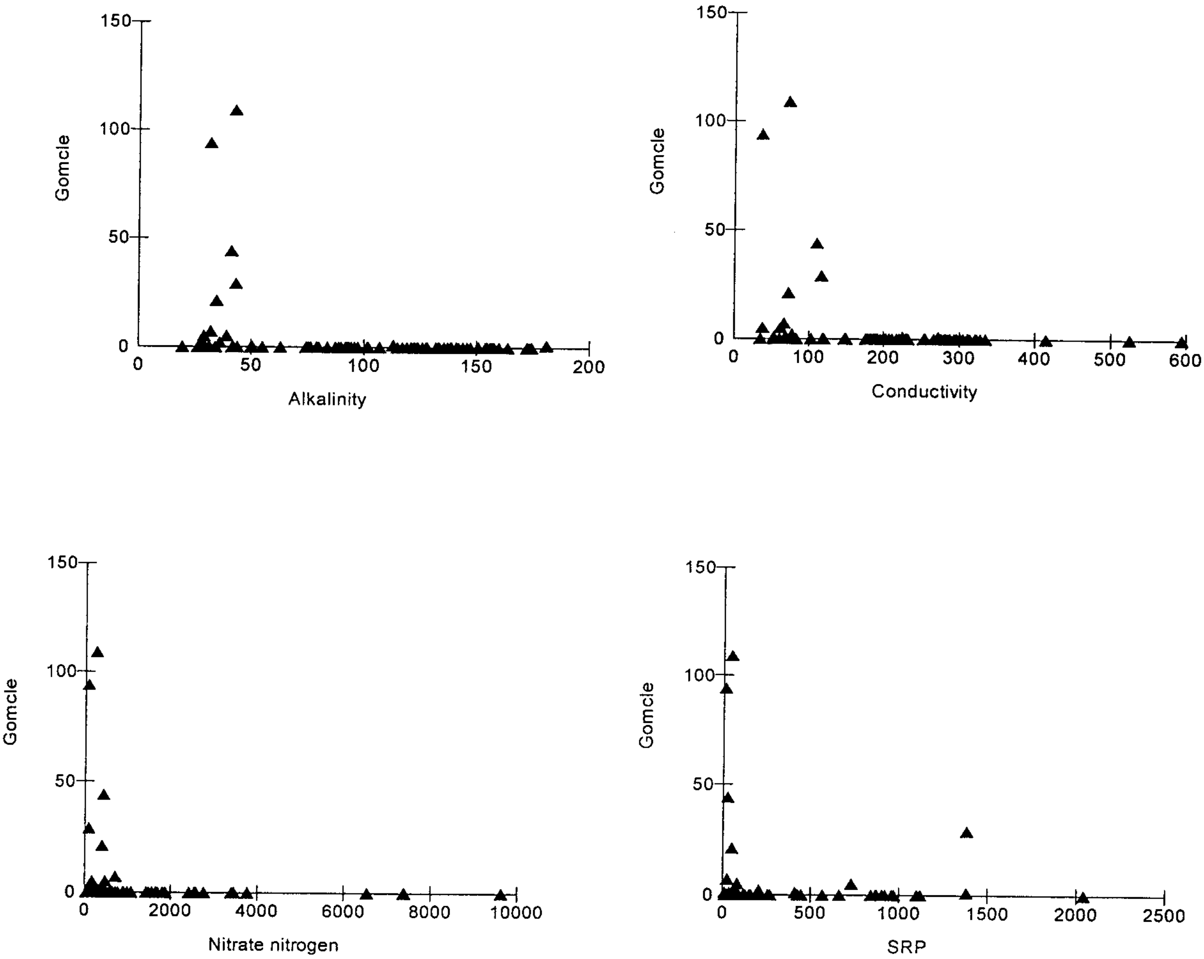


Figure 100. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk	*						
Cond		*					
NO3		*					
SRP		*					
Index Value		2					**Oligo-mesotrophic**

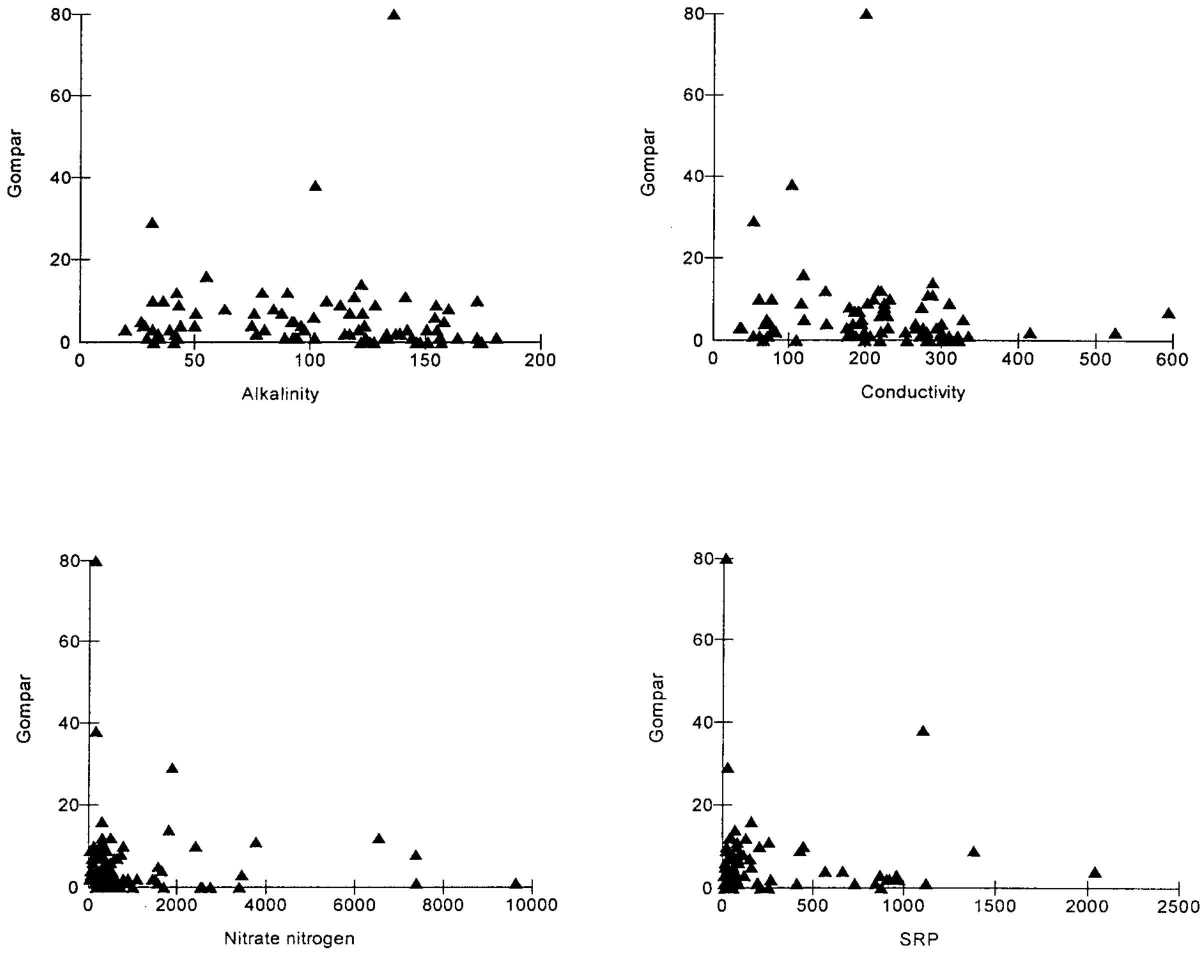
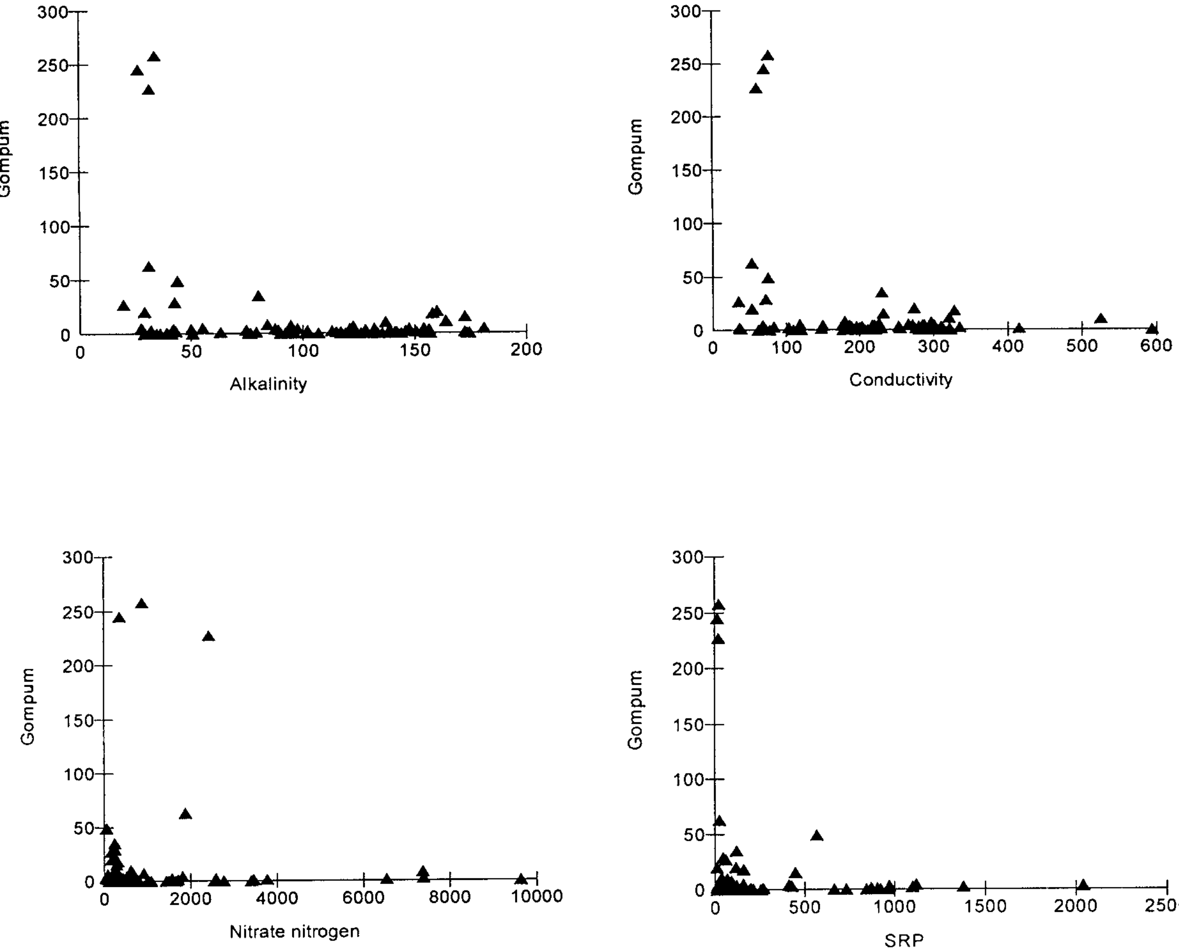


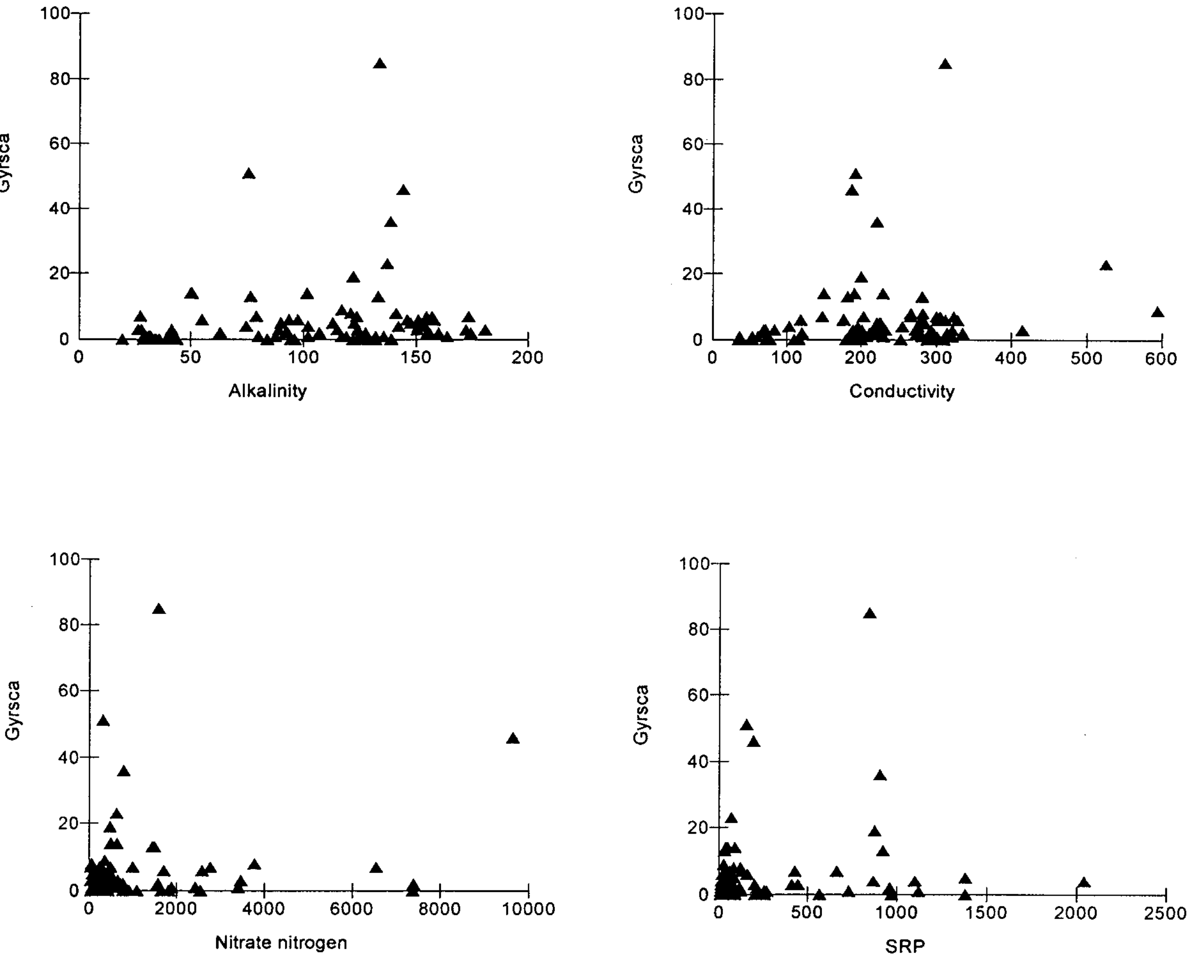
Figure 101. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk			*				
Cond			*				
NO3		*					
SRP						*	
Index Value					5		**Eutrophic**



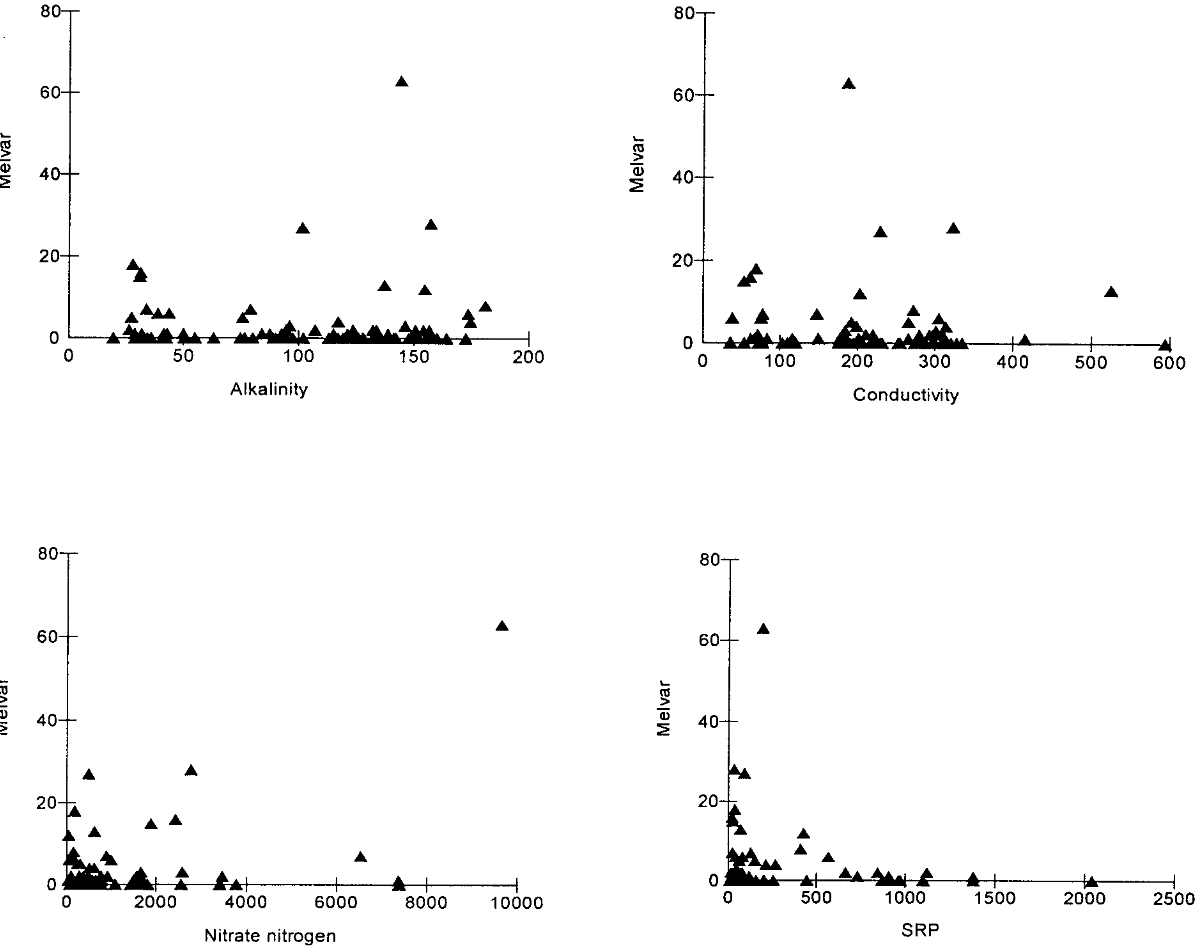
igure 102. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk	*						
ond		*					
O3			*				
RP		*					
ndex Value		2					**Oligo-mesotrophi**



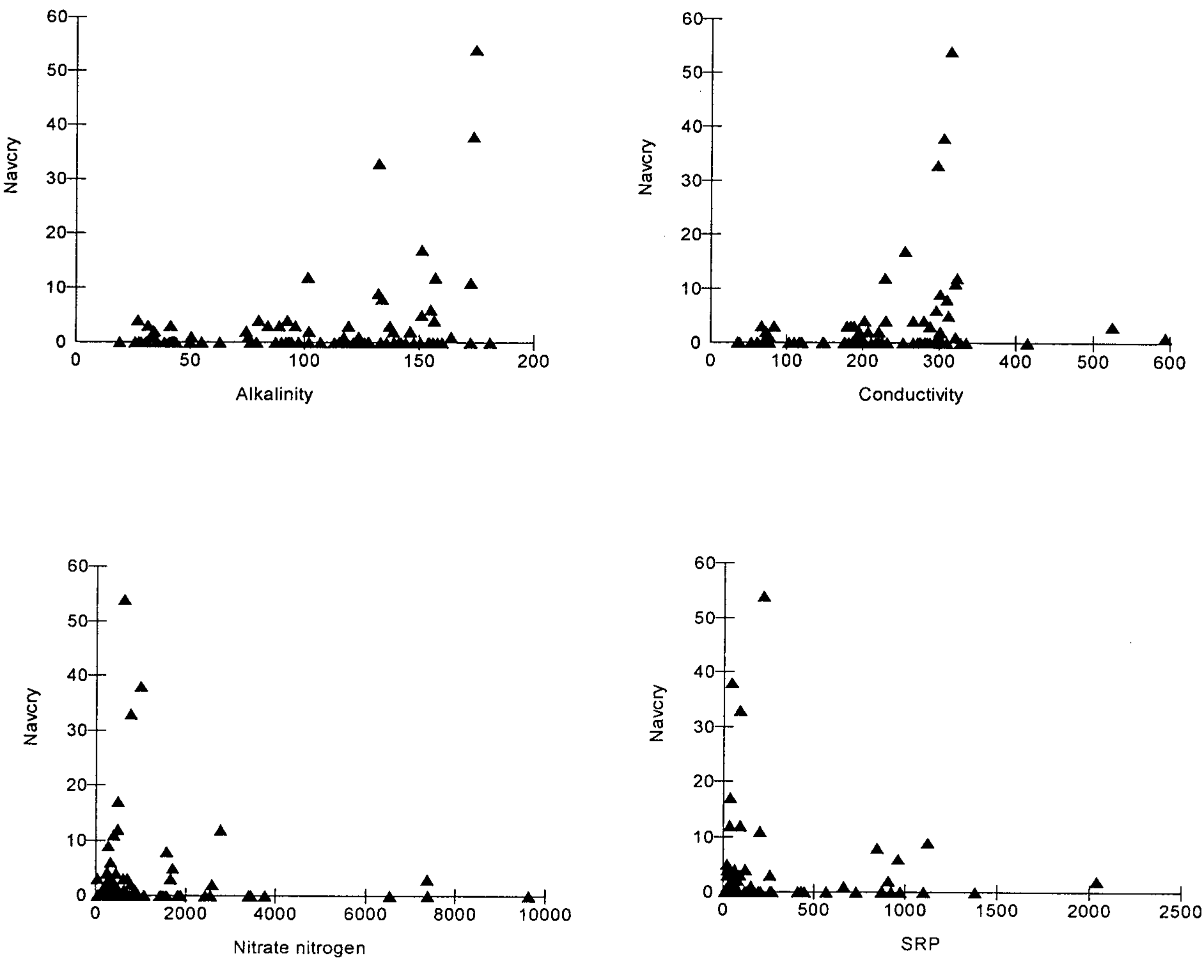
gure 103. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk			*				
ond				*			
O3				*			
RP					*		
dex Value					5		**Eutrophic**



gure 104. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk			*				
ond			*				
O3					*		
RP				*			
dex Value					5		**Eutrophic**



igure 105. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk				*			
ond				*			
O3			*				
RP				*			
dex Value				4			**Meso-eutrophic**

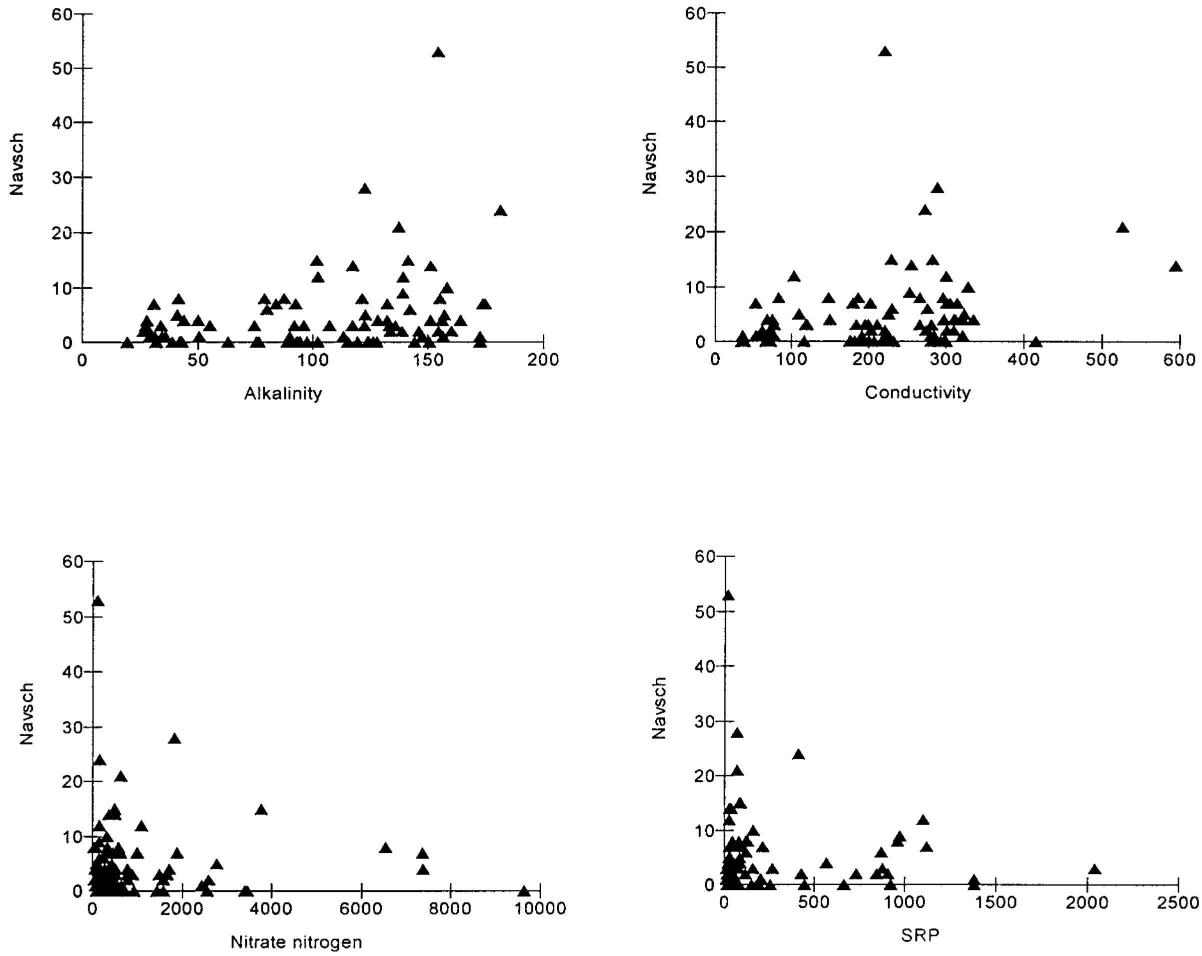


Figure 106. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk				*			
Cond			*				
NO3			*				
SRP			*				
Index Value			3				**Mesotrophic**

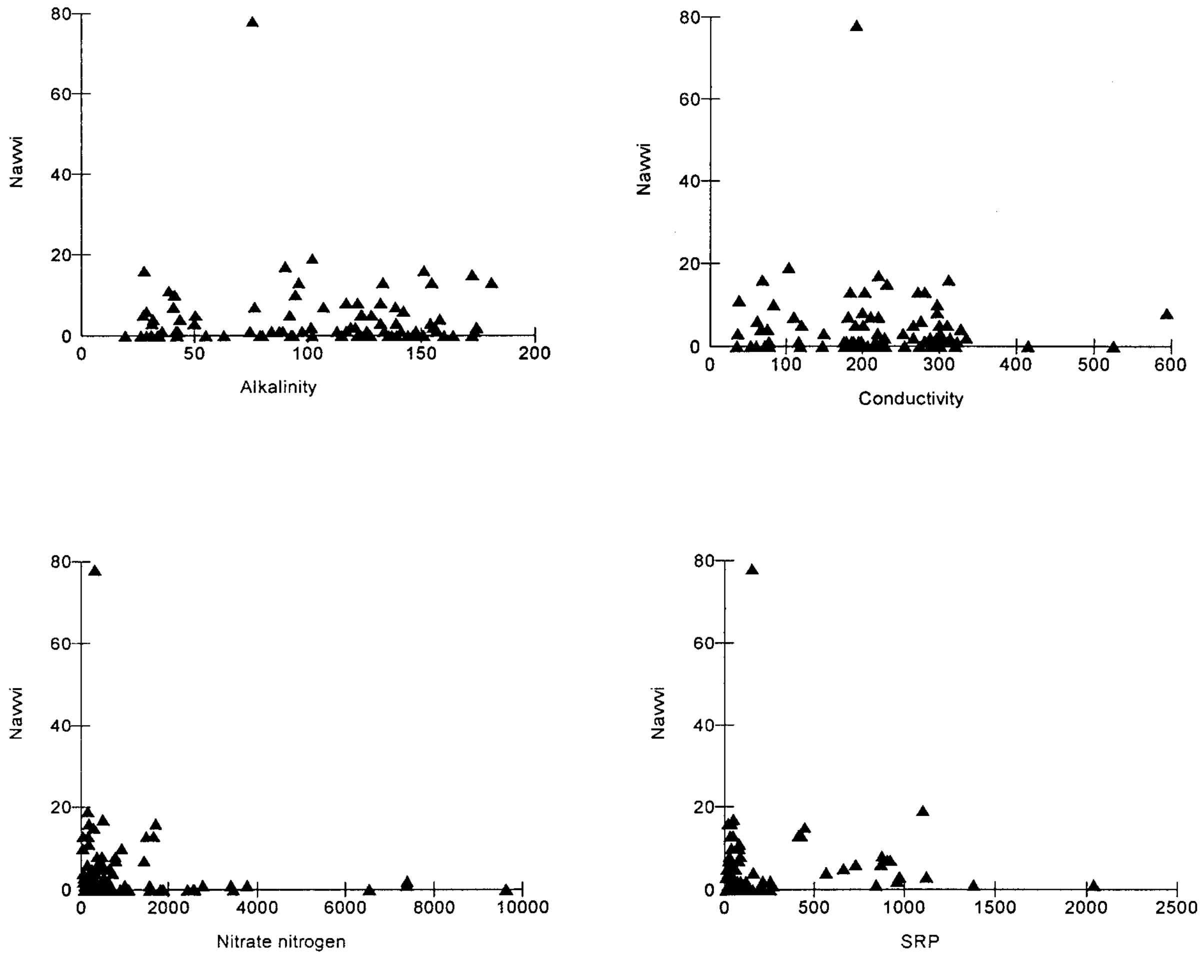


Figure 107. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk		*					
Cond			*				
NO3			*				
SRP				*			
Index Value				4			**Meso-eutrophic**

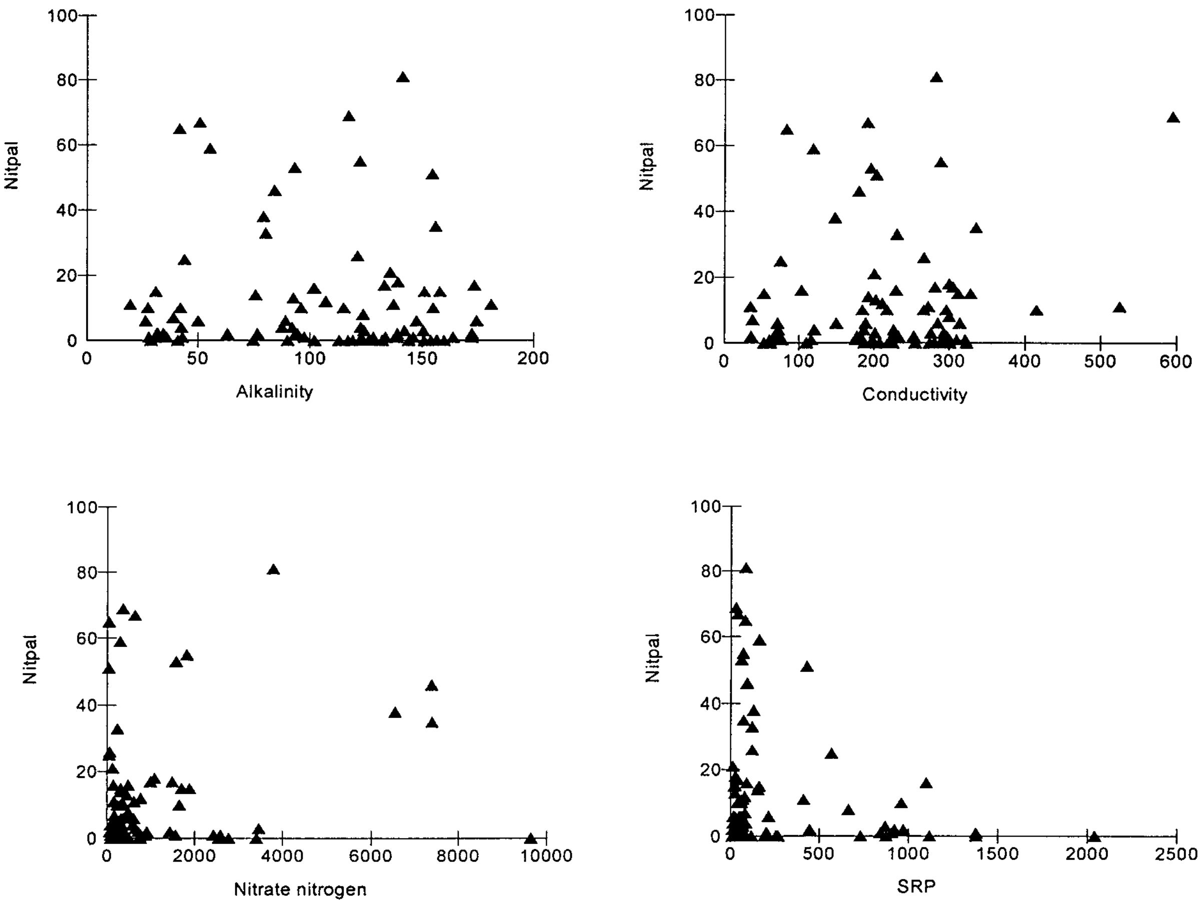
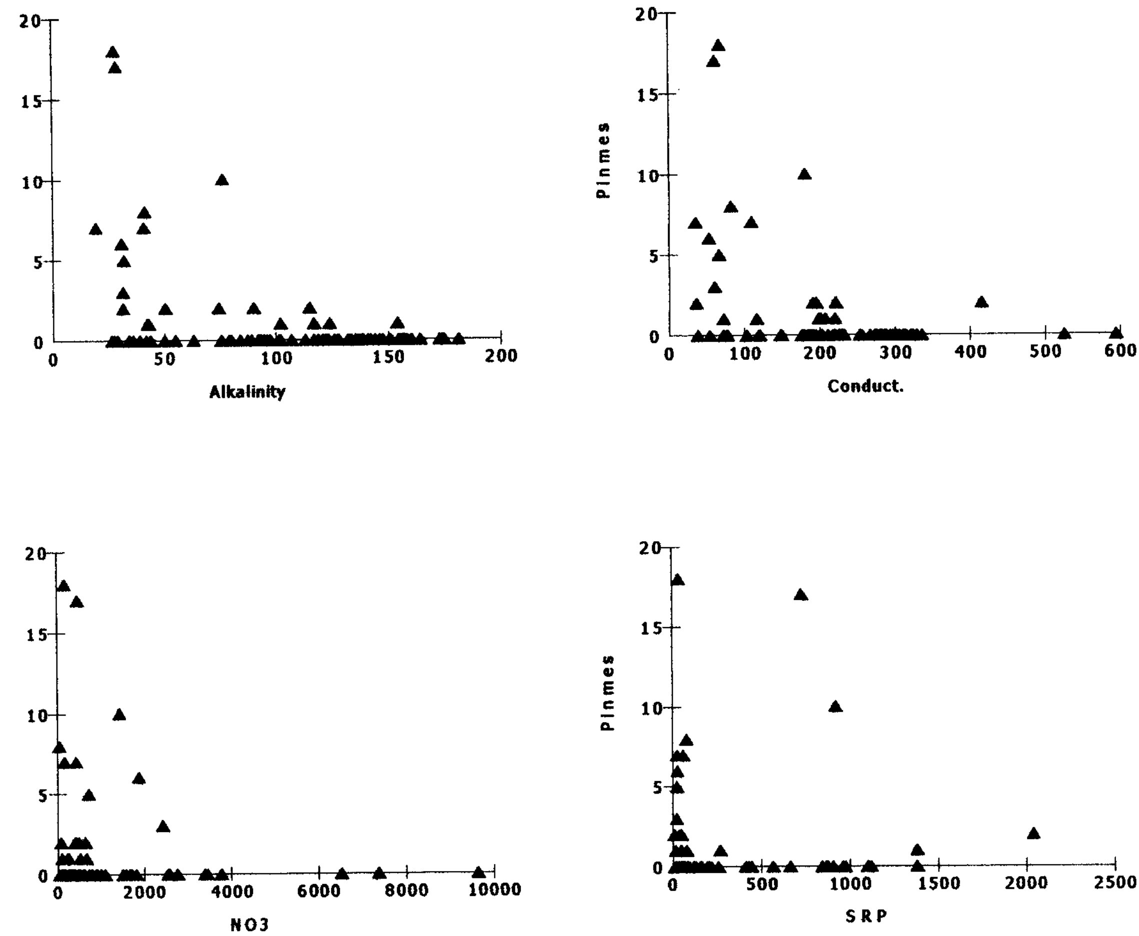


Figure 108. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk				*			
Cond				*			
NO3					*		
SRP					*		
Index Value					5		**Eutrophic**



gure 112. Scatter plots of selected species (number of cells) against with some physico-chemic parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk	*						
ond		*					
O3		*					
RP		*					
dex Value		2					**Oligo-mesotrophi**

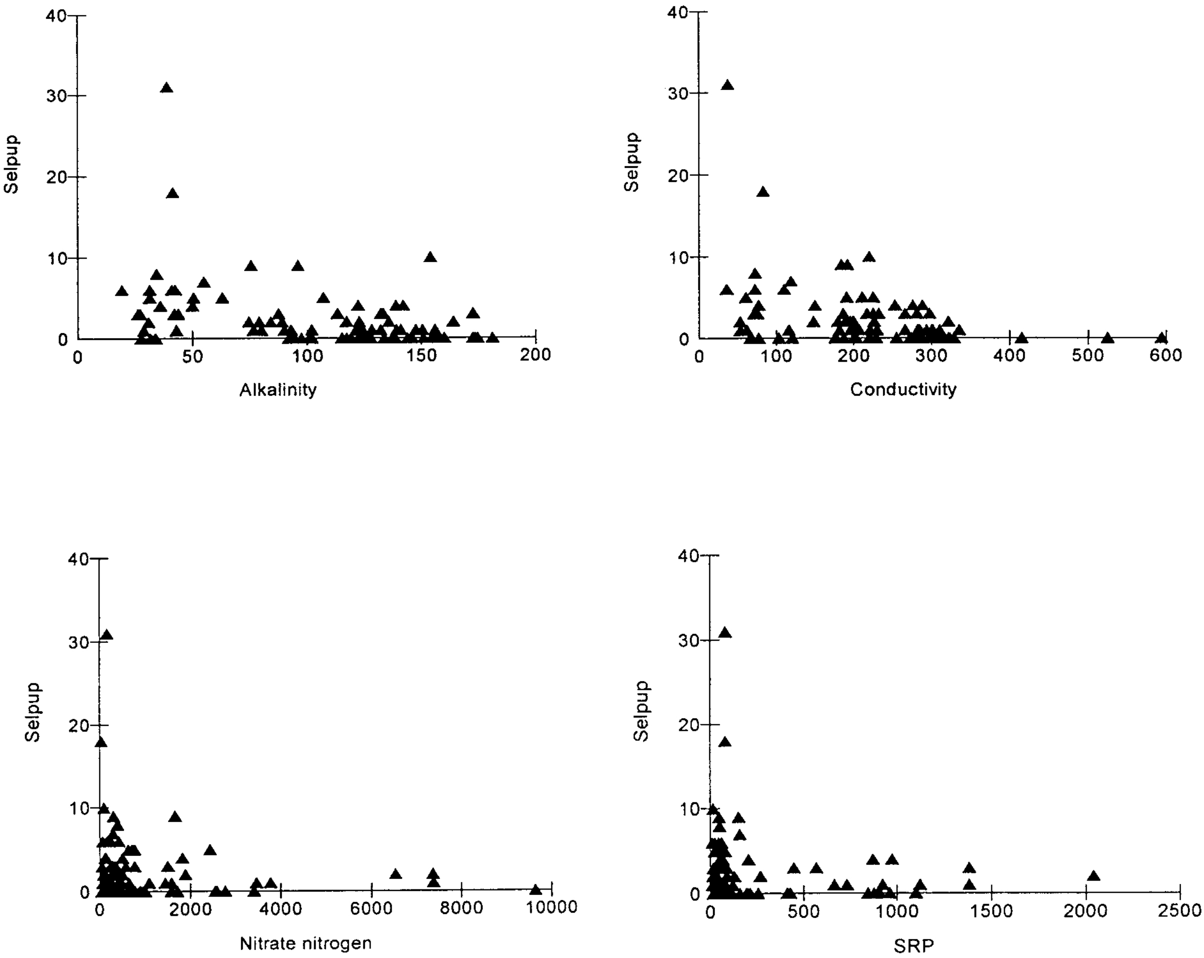


Figure 110. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk	*						
Cond	*						
NO3		*					
SRP			*				
Index Value		2					**Oligo-mesotrophic**

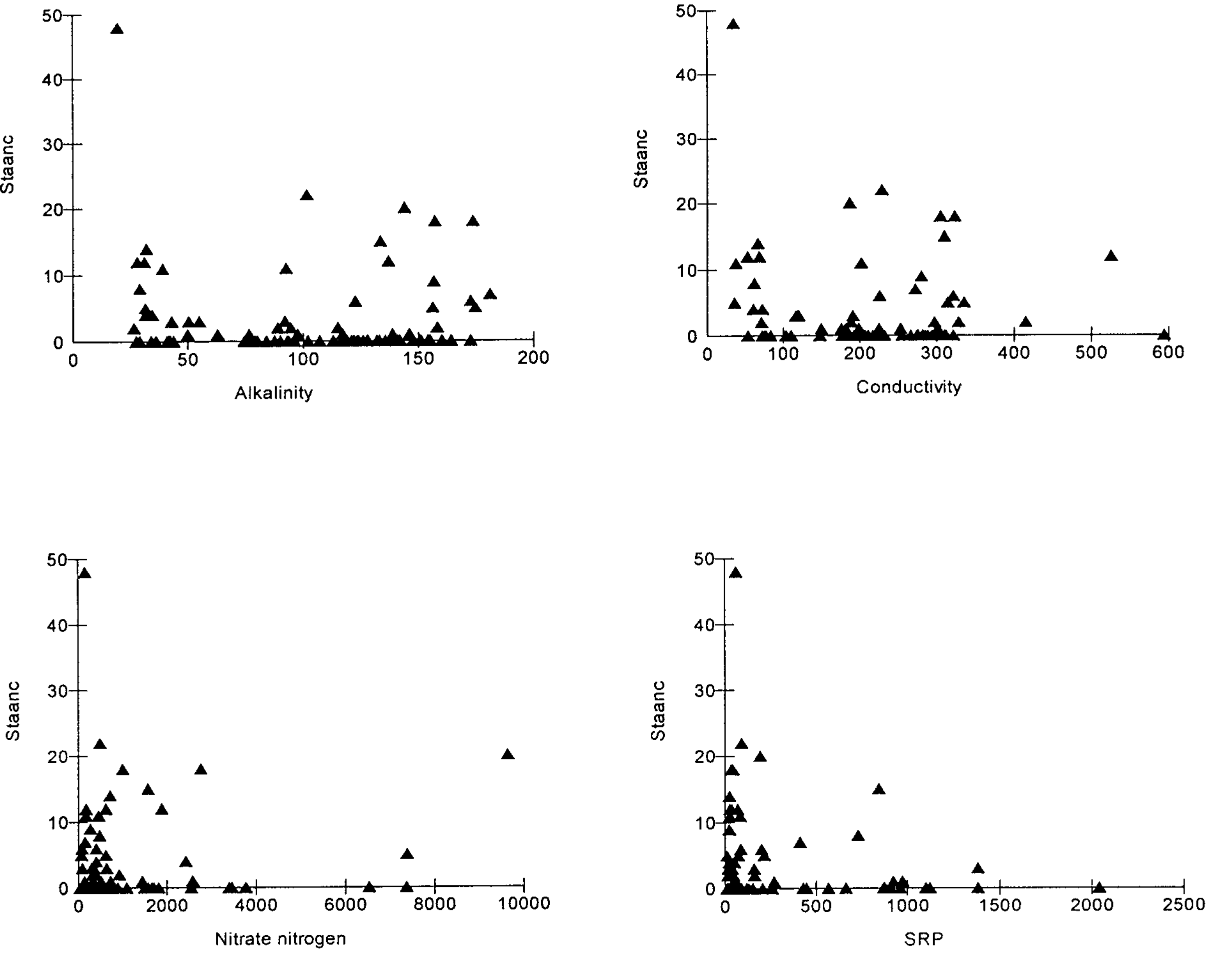
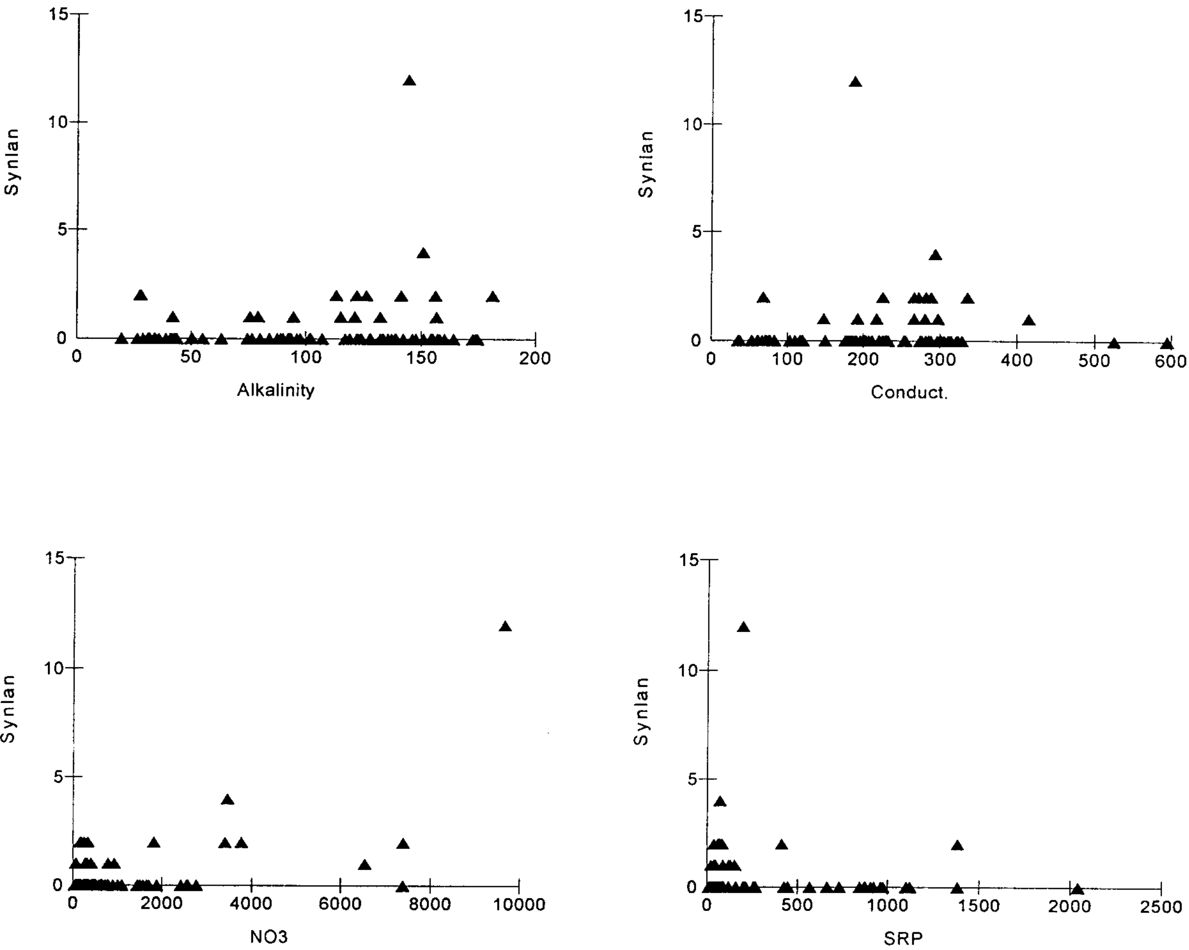


Figure 111. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
Alk	*						
Cond	*						
NO3		*					
SRP			*				
Index Value		2					**Oligo-mesotrophic**



igure 112. Scatter plots of selected species (number of cells) against with some physico-chemical parameters for Mae Sa Index development

	1	2	3	4	5	6	
lk			*				
ond			*				
O3					*		
RP				*			
dex Value				4			**Meso-eutrophic**

Table 19. Index values of all species list for Mae Sa Index

Abbreviation	Species	Index value
Achcre	*Achnanthes crenulata* Grunow	2
Achexi	*Achnanthes exigua* Grunow var. *exigua*	3
Achlan	*Achnanthes lanceolata* (Brébisson) Grunow	3
Achobl	*Achnanthes oblongella* Oestrup	3
Amplib	*Amphora libyca* Ehrenberg	3
Bacpar	*Bacillaria paradoxa* Gmelin	4
Cocpla	*Cocconeis placentula* Ehrenberg	4
Cymtum	*Cymbella tumida* (Brébisson) Van Heurck	4
Cymtur	*Cymbella turgidula* Grunow	4
Eunmin	*Eunotia minor* (Kützing) Grunow	1
Frabic	*Fragilaria biceps* (Kützing) Lange-Bertalot	3
Frauln	*Fragilaria ulna* (Nitzsch) Lange-Bertalot	4
Gomcle	*Gomphonema clevei* Fricke	2
Gompar	*Gomphonema parvulum* (Kützing) Kützing	5
Gompum	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	2
Gyrsca	*Gyrosigma scalproides* (Rabenhorst) Cleve	5
Melvar	*Melosira varians* Agardh	5
Navcry	*Navicula cryptotenella* Lange-Bertalot	4
Navsch	*Navicula schroeterii* Meister	3
Navvvi	*Navicula viridula* (Kützing) Ehrenberg var. *viridul*	4
Nitpal	*Nitzschia palea* (Kützing) W. Smith	5
Pinmes	*Pinnularia mesolepta* (Ehrenberg) W. Smith	2
Selpup	*Sellaphora pupula* (Kützing) Mereschkowsky	2
Staanc	*Stauroneis anceps* Ehrenberg	2
Synlan	*Synedra lanceolata* Kützing	4

4.10 The applications of the Trophic index of van Dam, Saprobic index of Rott *et al.* and Mae Sa Index

The trophic Diatom Index of van Dam *et al.* in 1997 and the Saprobic Index of Rott *et al.* in 1997, were applied to the epilithic cell count data of the Mae Sa stream. The lists of taxa with trophic index values for computing the van Dam Index and Rott *et al.* are shown in Tables 20 and 21 respectively.

The table results of the calculation are not shown, but the summary results are shown in Tables 22 and 23. The summarized area plot graphs are in Figures 113 and 114.

For the van Dam index, they classified the water quality level into 6 categories with scores ranging from 1.0- 6.0. But for Rott *et al.*, they classified the water quality at different level (7 categories with score range from 1.30-3.50).

The Mae Sa Index was re-applied to the raw data of epilithic cell count to check the accuracy of the index. The classification of water quality were divided into 6 categories with score ranging from 1.0-5.8 (Figure 115).

Table 20. List of taxa with trophic index values for computing the van Dam Index

Species	Index values	Species	Index values
Achnanthes exigua Grunow var. *exigua*	7	*Cymbella tumida* (Brébisson) Van Heurck	4
Achnanthes helvetica (Hustedt) Lange-Bertalot	3	*Diploneis elliptica* (Kützing) Cleve	3
Achnanthes lanceolata (Brébisson) Grunow	5	*Encyonema silesiacum* (Bleisch) D. G. Mann	7
Achnanthes minutissima Kützing	7	*Eunotia bilunaris* (Ehrenberg) Mills var. *bilunaris*	7
Achnanthes oblongella Oestrup	1	*Eunotia soleirolii* (Kützing) Rabenhorst	1
Achnanthes pseudoswazi Carter	1	*Fragilaria biceps* (Kützing) Lange-Bertalot	5
Achnanthes pusilla (Grunow) De Toni	1	*Fragilaria bidens* Heiberg	5
Amphora ovalis (Kützing) Kützing	5	*Fragilaria elliptica* Schumann	4
Amphora pediculus (Kützing) Grunow	5	*Fragilaria ulna* (Nitzsch) Lange-Bertalot	7
Aulacoseira granulata (Ehrenberg) Simonsen	5	*Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot	5
Bacillaria paradoxa Gmelin	5	*Frustulia rhomboides* (Ehrenberg) De Toni	1
Caloneis bacillum (Grunow) Cleve	4	*Frustulia weinholdii* Hustedt	2
Caloneis lauta Carter & Bailey-Watts	1	*Gomphonema augur* Ehrenberg	4
Caloneis silicula (Ehrenberg) Cleve	4	*Gomphonema gracile* Ehrenberg	3
Cocconeis placentula Ehrenberg	5	*Gomphonema minutum* (Agardh) Agardh	5
Cyclotella meneghiniana Kützing	5	*Gomphonema parvulum* (Kützing) Kützing	5
Cymatopleura solea (Brébisson) W. Smith	5	*Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot	7
Cymbella affinis Kützing	5	*Hantzschia amphioxys* (Ehrenberg) Grunow	7
Cymbella amphicephala Naegeli	2	*Melosira varians* Agardh	5
Cymbella hustedtii Krasske	2	*Navicula bacillum* Ehrenberg	4
Cymbella naviculiformis (Auerswald) Cleve	5	*Navicula clementis* Grunow	4

Table 20. Continued

Species	Index values	Species	Index values
Navicula cohnii (Hilse) Lange-Bertalot	5	*Nitzschia umbonata* (Ehrenberg) Lange-Bertalot	6
Navicula cryptotenella Lange-Bertalot	7	*Pinnularia acrosphaeria* W. Smith	2
Navicula elginensis (Gregory) Ralfs var. *elginensis*	5	*Pinnularia appendiculata* (Agardh) Cleve	2
Navicula insociabilis Krasske	3	*Pinnularia borealis* var. *scalaris* (Ehrenberg) Rabenhorst	2
Navicula leptostriata Jørgensen	2	*Pinnularia mesolepta* (Ehrenberg) W. Smith	4
Navicula mutica Kützing	5	*Pinnularia subinterrupta* Krammer & Schroeter	7
Navicula radiosa Kützing	4	*Pinnularia viridis* (Nitzsch) Ehrenberg	7
Navicula schroeterii Meister	5	*Reimeria sinuata* (Gregory) Kociolek & Stoermer	3
Navicula trivialis Lange-Bertalot	5	*Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba*	5
Navicula viridula var. *rostellata* (Kützing) Cleve	5	*Rhopalodia gibba* var. *parallela* (Grunow) Fryxell & Hasle	1
Navicula viridula (Kützing) *Ehrenberg* var. *viridula*	5	*Sellaphora pupula* (Kützing) Mereschkowsky	4
Neidium affine (Ehrenberg) Pfitzer	4	*Stauroneis anceps* Ehrenberg	4
Neidium ampliatum (Ehrenberg) Krammer	2	*Stauroneis smithii* Gronow	7
Neidium binodis (Ehrenberg) Hustedt	4	*Surirella angusta* Kützing	5
Neidium iridis (Ehrenberg) Cleve	3	*Surirella bifrons* Ehrenberg	5
Nitzschia cf. *acula* Hantzsch	5	*Surirella biseriata* Brébisson	5
Nitzschia dissipata (Kützing) Grunow	4	*Surirella elegans* Ehrenberg	4
Nitzschia dubia W. Smith	5	*Surirella ovalis* Brébisson	5
Nitzschia fonticola Grunow	4	*Surirella roba* Leclercq	1
Nitzschia levidensis (W. Smith) Grunow var. *levidensis*	5	*Surirella robusta* Ehrenberg	7
Nitzschia palea (Kützing) W. Smith	6	*Surirella tenera* Gregory	5

Table 21. List of taxa with trophic index values for computing the Rott *et al.* Index

Species	Indicator weight	Saprobic Index Values
Achnanthes helvetica (Hustedt) Lange-Bertalot	5	1.0
Achnanthes lanceolata var. *lanceolata* (Brébisson) Grunow	0	2.3
Achnanthes minutissima Kützing	1	1.7
Achnanthes oblongella Oestrup	5	1.0
Achnanthes pusilla (Grunow) De Toni	5	1.0
Amphora libyca Ehrenberg	2	1.6
Amphora ovalis (Kützing) Kützing	2	1.5
Amphora pediculus (Kützing) Grunow	2	2.1
Bacillaria paradoxa Gmelin	3	2.3
Caloneis bacillum (Grunow) Cleve	4	2.0
Caloneis silicula (Ehrenberg) Cleve	4	1.2
Cocconeis placentula Ehrenberg var. *placentula*	2	1.8
Cymatopleura solea (Brébisson) W. Smith	3	2.1
Cymbella affinis Kützing	4	1.2
Cymbella amphicephala Naegeli	4	1.1
Cymbella minuta Hilse	2	1.6
Cymbella naviculiformis (Auerswald) Cleve	3	1.3
Cymbella tumida (Brébisson) Van Heurck	4	1.6
Diploneis elliptica (Kützing) Cleve	4	1.1
Diploneis oblongella (Naegeli) Cleve-Euler	5	1.0
Diploneis ovalis (Hilse) Cleve	5	1.0
Encyonema silesiacum (Bleisch) D. G. Mann	0	2.0
Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris*	2	1.7
Eunotia minor (Kützing) Grunow	2	1.5
Fragilaria ulna (Nitzsch) Lange-Bertalot	0	2.7
Frustulia rhomboides (Ehrenberg) De Toni	5	1.0
Gomphonema augur Ehrenberg	3	2.1
Gomphonema gracile Ehrenberg	4	1.2
Gomphonema minutum (Agardh) Agardh	5	2.0
Gomphonema parvulum (Kützing) Kützing	0	2.6
Gomphonema pumilum var. *rigidum* E. Reichardt et Lange-Bertalot	3	1.6
Hantzschia amphioxys (Ehrenberg) Grunow	1	1.8
Melosira varians Agardh	2	2.3
Navicula bacillum Ehrenberg	4	1.6

Table 21. Continued

Species	Indicator weight	Saprobic Index Values
Navicula clementis Grunow	4	1.7
Navicula cryptotenella Lange-Bertalot	2	1.5
Navicula elginensis (Gregory) Ralfs var. *elginensis*	3	1.5
Navicula goeppertiana var. *dapaliformis* (Hustedt) Lange-Bertalot	2	3.3
Navicula mutica Kützing	3	2.0
Navicula radiosa Kützing	4	1.3
Navicula schroeterii Meister	4	1.6
Navicula trivialis Lange-Bertalot	3	2.7
Navicula viridula var. *rostellata* (Kützing) Cleve	4	2.2
Navicula viridula (Kützing) *Ehrenberg* var. *viridula*	4	2.2
Neidium affine (Ehrenberg) Pfitzer	5	1.0
Neidium ampliatum (Ehrenberg) Krammer	5	1.0
Neidium binodis (Ehrenberg) Hustedt	3	1.3
Neidium iridis (Ehrenberg) Cleve	5	1.0
Nitzschia cf. *acula* Hantzsch	3	2.0
Nitzschia dissipata (Kützing) Grunow	3	2.0
Nitzschia fonticola Grunow	4	2.1
Nitzschia levidensis (W. Smith) Grunow var. *levidensis*	4	2.9
Nitzschia palea (Kützing) W. Smith	0	2.8
Nitzschia umbonata (Ehrenberg) Lange-Bertalot	4	3.8
Pinnularia borealis var. *scalaris* (Ehrenberg) Rabenhorst	3	1.4
Pinnularia viridis (Nitzsch) Ehrenberg	4	1.2
Reimeria sinuata (Gregory) Kociolek & Stoermer	2	2.0
Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba*	3	1.5
Rhopalodia gibba var. *parallela* (Grunow) Fryxell & Hasle	5	1.0
Sellaphora pupula (Kützing) Mereschkowsky	2	2.4
Stauroneis anceps Ehrenberg	4	1.2
Stauroneis smithii Gronow	2	1.5
Surirella angusta Kützing	2	2.2
Surirella ovalis Brébisson	4	2.9
Surirella roba Leclercq	5	1.0

Chapter 5
Discussion

5.1 Diatoms diversity

The present study gives a total of 278 diatoms taxa. Fifty-one species of these have never been recorded in Thailand before. According to the research, it is obvious that Thailand has made slow progress in freshwater algal biodiversity studies. If we consider the aquatic environment more intimately, we shall see that the most important producers are algae in either planktonic or benthic forms. Therefore, extensive biodiversity of freshwater algae is urgently needed as supporting knowledge for all biological sciences and for the development of the country as well.

The data from table 16 will support the situation of the study of algal diversity in Thailand.

Table 24. The number of algal species known in the world compared with the number known in Thailand (Baimai, 1995).

Algal group	No. of species in the world	No. of species in Thailand	No. of species expected to be new 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
Phyrrophyta	1,100	300	600

Diatoms were classified into Division Chrysophyta in this table. The highest number of species known in the world (12,000 species) indicate how many numbers of species can be expected to be new discoveries in Thailand. The source of this data is from Thailand's study on biodiversity in 1992 (Baimai, 1995). The checklist of algae in Thailand by Lewmanomont *et al.* in 1995 is the outcome from this study (Lewmanomont *et al.*, 1995).

The most abundant are diatoms in the Order Pennales. The majority of the species belonged to the diatom genera *Navicula* (47 species), *Nitzschia* (29 species), *Achnanthes* (29 species), *Pinnularia* (20 species), *Surirella* (19 species) and *Gomphonema* (18 species). Sampling site 2 which is located upstream, seems to have a high value of diversity index which ranges into 2.523 - 3.520 and also has a maximum number in of investigated species (153 species for epilithic diatoms and 56 species for epipelic diatoms). The diatom flora differs considerably in various parts of the stream. In the headwaters which often derive most of their water from springs, we find those species which like cool, rather constant temperatures. Among the species found under these conditions are many species of *Navicula.* Further downstream where the temperature of the water is more variable and where the current is usually stronger, quite different types of diatom communities are formed. In the fast-flowing waters on rocks and other hard surfaces one typically finds those kinds of diatoms that can grow attached to substrates such as *Achnanthes* and *Cocconeis.* In slower flowing water on hard substrates one often finds *Melosira varians,* various species of *Synedra, Gomphonema,* and *Cymbella,* whereas on the sediments one typically finds, as in lakes, many species of *Campylodiscus, Cyclotella, Cymatoplusra, Diploneis, Fragilaria, Gyrosigma, Navicula, Nitzschia, Surirella* etc. (Patrick, 1977).

Two hundred and seventy eight taxa of investigated diatoms are represented, among these 161 taxa could be classified into species category (58 %) and 117 taxa could be classified into genera category (42%). Kelly (1997) mentions about the sources of error in estimations of the Trophic Diatom Index which can occur from the mis-identifications of taxa, particularly dominants, and the level of the identifications. The unidentified taxa could not be assessed by the Index (Kelly, 1997). An important problem on taxonomic study is the classification for species category. The taxonomic expertise needed is a limitation of the applications and potential for the use of diatoms as biological indicators.

Studies of freshwater algae in Thailand started at the end of the 19th century and were carried out by foreign scientists. From 1971 to the present, Thai scientists also worked on diatoms but not as intensively as before.

Most work has been done on plankton and reported in "The status of phytoplankton diversity in Thailand" by Wongrat in 1998 (Wongrat, 1998). The material studied was collected from all parts of Thailand but mostly from the northern and northeastern parts of the country.

The Convention on Biological Diversity (CDB) has encouraged governments to focus attention on the conservation of biodiversity. Currently more than 127 countries have ratified the convention. Although Thailand is preparing to ratify the convention, it has not yet done so. Preparation for eventual ratification of the CDB, however has encouraged the government of Thailand to establish several institutions to implement biodiversity conservation, including monitoring programmes of phytoplankton, although progress has been slow. Such programmes include the Biodiversity Research and Training Program (BRT), financed by the National Center for Genetic Engineering and Biotechnology, which has supported several projects to monitor phytoplankton. The Biodiversity Research and Training Program was established jointly by the Thailand Research Fund (TRF) and BIOTEC. The aim is to provide support and funding for research into and management of Thailand's biodiversity resources. This research will extend the knowledge on diversity of freshwater algae in Thailand by Thai scientists.

Results from the research have extended our knowledge of biodiversity in Thailand, with regard to benthic diatoms in stream ecosystems as valuable natural resources. The publication of newly recorded species will be added to the checklist of algae in Thailand.

5.2 Assessment of the water quality in the Mae Sa Stream

The water quality in the Mae Sa Stream is moderately polluted by organic matter (ammonium, nitrate and phosphate) and could be classified into oligotrophic-mesotrophic to eutrophic depending on sampling sites and seasonal changes.

The discharge of excessive quantities of organic matter is the most widespread form of water pollution. The major sources of organic pollution in the Mae Sa stream are sewage, domestic waste and animal waste (elephants). Most organic wastewater contains a high concentration of nutrients, which can affect the diatom communities, especially benthic diatoms. Increased input of nutrients can rapidly increase algal growth, which if excessive, leads to changes in the biological characteristics of the receiving water.

In the Mae Sa stream, the discharge of organic matter into the water is an important source of algal nutrients, since the aerobic decomposition of organic matter results in the release of phosphate, nitrate and other nutrients. Moreover, domestic sewage which was observed to be commonly drained directly in the stream from the villagers, typically contains high levels of phosphate because detergent washing powder formulations contain high levels of phosphate.

The Mae Sa watershed is the agricultural area where fertilizers are used intensively, run off from land can also carry large amounts of nutrients into the stream. And in the areas with a high degree of soil erosion, nutrients carried from the land to water is expected to be much higher than that of the flat areas.

Water pollution is most commonly associated with the discharge of effluents from sewage treatment plants, drains and factories. Outfalls of this kind are known as point-source discharges. Some of the more serious forms of pollution arise, however, from diffused sources, the pollution does not enter the water from a single point. For example, in the agricultural areas, surface water runoff and groundwater infiltration into lakes and rivers can introduce plant nutrients (from fertilizers and manure) and pesticides in substantial quantities to water bodies (Abel, 1989). The main effluents of the Mae Sa stream are nonpoint-source discharges associated with agricultural areas, residential areas and tourist spots in Site 3 (Mae Sa Elephant Camp). The Mae Sa Elephant Camp is one of two elephant camps located in Mae Rim district.

Alkalinity, conductivity, pH and nutrient content (ammonium, nitrate and SRP) are the major parameters affecting the water quality in the Mae Sa stream. In spite of the water temperature, turbidity, DO, BOD_5, iron concentration and silica concentrations do not affect the water quality significantly. The substrate and water current directly affect the distribution of diatoms.

5.3 Species and relative abundance related to water chemistry

The measurement of physical and chemical parameters has been investigated to assess the water quality. Furthermore, to look for the relation between benthic diatoms and the quality of the water.

When water qualities are considered for correlation with dominant diatoms, there are only a few species correlated with the nutrients (ammonium, nitrate and SRP) ($p \leq 0.01$) and all of the significant species are positively correlated with nutrients.

Indicator species may be considered from the correlation of statistical method but not every correlation between diatoms and physico-chemical parameters. On the other hand, it is helpful for us to look for some specific correlations such as *Achnanthes crenulata* Grunow and *Fragilaria biceps* (Kützing) Lange-Bertalot which are significantly correlated to the SRP. Additionally, *Gomphonema parvulum* (Kützing) Kützing, *Melosira varians* Agardh and *Synedra lanceolata* Kützing are highly significant when correlated to nitrate nitrogen. And *Gyrosigma scalproides* (Rabenhorst) Cleve are correlated to ammonium nitrogen. However, it show that the three dominant species such as *Navicula viridula* (Kützing) Ehrenberg, *Amphora libyca* Ehrenberg and *Fragilaria ulna* (Nitzsch) Lange-Bertalot are not significantly correlated to any physico-chemical parameters. Therefore, indicator species could not be exactly considered from the correlation of statistical methods. These may be compiled with distribution and relative abundance. However, the diatom index is useful tool for assess the aquatic environment. Individual species of diatoms indicate the level of water quality by given the score.

Consider from PCA and correlation between diatom species and physico-chemical of the water, given *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Eunotia minor* (Kützing) Grunow and *Gomphonema clevei* Fricke are the species for clean water and found in upstream. And the species for polluted water are *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Melosira varians* Agardh, *Gyrosigma scalproides* (Rabenhorst) Cleve and *Bacillaria paradoxa* Gmelin. There is no clearly physiological reason for presented indicator species in different habitat.

5.4 TDI as a monitoring tool

Individual species of diatoms could be exactly indicate the water quality. Many works gave the list of them from the different area including the stream and lake. Wetzel in 1975 characterized the common major algal association of the phytoplankton in lake for example he concluded that desmids, diatoms especially *Cyclotella* and *Tabellaria* are general present in oligotrophic lake (Wetzel, 1975). But the index method is more accuracy for the assessment of water quality than indicator species method because of the individual specie in the index list indicate the exactly score. And the diatoms species in the index are define into species category, different from the indicator list that given only in group of genus or family.

Biological indicators are extremely valuable in assessing water quality. It has long been recognized that many diatom taxa have distinct ecological requirements and tolerances in regard to a variety of water quality parameters. The development of applicable multivariate statistical techniques has the potential of diatoms as water quality indicators (Reid *et al.*, 1995).

Diatoms occupy a wide variety of habitat niches within the lotic environment. For the most part they are attached, living on rock surfaces, larger plants, other macroalgae, mud, silt and sand. In the lower reaches of streams it is possible to find a significant planktonic flora but this is rarely the case in the upper and middle reaches (Reid *et al.*, 1995). Besides the plankton, the benthic and epilithic diatoms are also important in lakes. In stream ecology, benthic algae are more important than planktonic algae. The benthic diatoms are those that live attached to hard substrates or live in and on fine sediments such as silt and fine sand.

Benthic diatom possess many attributes, but not in Thailand, that make them ideal organisms to employ in water quality monitoring investigations. Because benthic diatoms are sessile they cannot swim away from potential pollutants. They must either tolerate their surrounding abiotic environment or die. Benthic diatom communities are usually species-rich and each species, of course, has its own set of environmental tolerances and preferences. Thus, the entire assemblage represents as information rich system for environmental monitoring. The short life cycles of most benthic diatom species result in a rapid response to shift to environmental conditions. Extant benthic diatom communities are typically very representative of current environmental conditions. Identification is not exceedingly difficult. Taxonomy of benthic diatom is usually based on cell morphology easily discernible through the light microscope and is an excellent taxonomic key for identification of benthic diatom in most parts of the world (Lowe and Laliberte, 1996).

Diatoms have been extensively used as indicators of environmental changes e.g. eutrophication, acidification, metal contamination, salinification, thermal effluents, forest fires and land use changes. A variety of indices have been proposed to quantify some of these relationships (Dixit *et al.*, 1992). Routine biological monitoring is carried out in many countries (Europe and the United States) to complement or supplement chemical monitoring in order to assess pollution. But in Thailand, there is no publication concerned with the use of diatoms for monitoring rivers.

5.5 Comparative between Trophic indexes of van Dam, Saprobic index of Rott *et al.* and Mae Sa Index

The Trophic Diatom Index (TDI) of van Dam *et al.* (1997) and Saprobic Index (SI) of Rott *et al.* (1997) were applied in this research. By using both indices, the assessment of the water quality in the Mae Sa stream gave rather different results.

The trophic index of van Dam gave an over estimation of water qualities, although the water was assessed in mesotrophic status by physico-chemistry parameters but these indexes are assessed into the eutrophic status. Whilst saprobic index of Rott *et al.* classified water qualities in the Mae Sa stream as having good qualities.

The trophic index of van Dam published in 1997 is also used to classify the trophic state by using indicator weight evaluation. Their works were developed from the study of low land freshwater sites in the Netherlands. They classified the water quality level into 6 categories with scores ranging from 1.0- 6.0 (Table 3).

On the other hand, the methods of index and indicator weight of Rott *et al.* in 1997 were used in the saprobic water quality classification . Their works were developed from the study of streams and rivers in Austria. They classified the water quality with different levels (7 categories with scores ranging from 1.3-3.5: Table 4). Both indices are from temperate regions in which the endemism may occur with the index application. Reid *et al.* has suggested these problems are associated with the use of diatoms as water quality indicators. Although diatoms are generally cosmopolitan in their distribution, there is evidence to suggest that some taxa occurring in Australian waters may be endemic (Reid *et al.*, 1995).

There are different species given in each index which do not occur in lists and can not be scored in the calculation. For example Achcre, Achbre, Achinf, Achund, Amplib, Ampaeq, Cymtur, Dipobl, Dipova, Eunbil, Eunmin, Gomcle, Gomlin, Gyrsca, Navmed, Pinsub and Synlan are species which not occurred in van Dam index.

And Achbre, Achcre, Achexi, Eunsol, Frabic, Gomcle, Gomlin, Gyrsca, Navmed, Navcoh, Navlep, Pinmes, Surbis, Surten and Synuln species which not occurred in Rott et *al.* index. These contribute to errors in the assessment. The more species which are not in the list, the more errors occur. If the species that not in the list are dominant species (with a high number of relative abundance) they can result in more mistakes in the calculations. At present situation, diatomist attempt to develop universal index contain a plenty of diatom species in the list. These may be the way to solve an error problems.

For the method of index development, they should have standard method for the assessment of water qualities and standard statistical software to help us to extract indicator species. Terminology, sometime become the problem for limnologist. Because of each country define words "oligotrophic, mesotrophic and eutrophic" in different details.

5.6 The efficiency of the Mae Sa Index

Twenty-five species of diatoms were scored and listed in the Mae Sa Diatom Index and can be properly used to indicate the physico-chemical property of water quality. However, more indicator species should be compiled for the more efficient use of the Mae Sa Diatom Index. These can be checked with the data from the same stream at different times of sampling, coupled with the investigation of the water quality and may apply the Mae Sa Index to the nearby area (especially in the northern part of Thailand). The result from the application will be to show a good prediction, if it works. Anyway, the long-term investigation of diatoms in the Mae Sa Stream should be a cotinuous work to develop a better index for universal use. These may involved Thai researchers to do more research concern with diatom index. In addition to these attempts, research organizations in Thailand, particularly program for biodiversity and environmental monitoring should be supported to organized the further works.

Chapter 6

Conclusion and Recommendation

A study of the benthic diatom diversity and its application for use as indicator species to monitoring water quality in Mae Sa stream, Doi Suthep-Pui National Park, Chiang Mai was carried out from April 1998 to September 1999. Five sampling sites were located from upstream to downstream. Two hundred and seventy eight species of diatoms were found and could be classified into 2 orders, 3 suborders, 10 families and 34 genera, fifty one species of these have never been recorded in Thailand before and could be classified into 2 orders, 9 families, 23 genera and were described. The most abundant were diatoms in the Order Pennales. The majority of the species belonged to the diatom genera *Navicula* (47 species), *Nitzschia* (29 species), *Achnanthes* (29 species), *Pinnularia* (20 species), *Surirella* (19 species) and *Gomphonema* (18 species). The representatives, 278 taxa of investigated diatoms, among these 161 taxa could be classified into species category (58 %) and 117 taxa could be classified into genera category (42%).

The most abundance was *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, which indicate clean water, and presented in upstream. The species which indicated polluted water quality were *Nitzschia palea* Kützing, *Achnanthes lanceolata* (Brébisson) Grunow, *Gomphonema parvulum* Kützing, *Melosira varians* Agardh, *Gyrosigma scalproides* (Rabenhorst) Cleve and *Bacillaria paradoxa* Gmelin.

Sampling site 2 had a high value of diversity index and also had a number in maximum of species which was investigated. Sampling site 3 had a low value of diversity index.

The water quality in the Mae Sa Stream is moderate polluted by organic matters (ammonium, nitrate and SRP). The water quality of Mae Sa Stream could be classified into oligotrophic-mesotrophic to eutrophic depending on sampling site and seasonal changes. The concentration of nutrients, especially SRP and TP were quite high only in April–May 1998.

The maximum value of BOD_5 presented in site 3 (November 1998). By average site 3 had the significantly highest level of BOD_5 through the sampling period and could be classified into eutrophic status in some periods.

Multivariate analysis techniques using MVSP program (Multivariate Statistical Package version 3.1 for window) to examined the cell count data. Principal Correspondence Analysis (PCA) and Canonical Correspondence Analysis (CCA) were used to indicated the indicator species and dominant species for established the Mae Sa Index.

Twenty five diatom species were selected from CCA which are *Achnanthes crenulata* Grunow, *A. exigua* Grunow var. *exigua*, *A. lanceolata* (Brébisson) Grunow, *A. oblongella* Oestrup, *Amphora libyca* Ehrenberg, *Bacillaria paradoxa* Gmelin, *Cocconeis placentula* Ehrenberg, *Cymbella tumida* (Brébisson) Van Heurck, *C. turgidula* Grunow, *Eunotia minor* (Kützing) Grunow, *Fragilaria biceps* (Kützing) Lange-Bertalot, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Gomphonema clevei* Fricke, *G. parvulum* Kützing, *G. pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, *Gyrosigma scalproides* (Rabenhorst) Cleve, *Melosira varians* Agardh, *Navicula cryptotenella* Lange-Bertalot, *N. schroeterii* Meister, *N. viridula* (Kützing) Ehrenberg var. *viridula*, *Nitzschia palea* Kützing, *Pinnularia mesolepta* (Ehrenberg) W. Smith, *Sellaphora pupula* (Kützing) Mereschkowsky, *Stauroneis anceps* Ehrenberg and *Synedra lanceolata* Kützing.

Twenty five dominant species from CCA were computed for their relation to the physico-chemical parameters by the Pearson method and were plot in a scatter diagram for Mae Sa Index development.

The Trophic Diatom Index (TDI) of van Dam *et al.* (1997) and Saprobic Index (SI) of Rott *et al.* (1997) were applied in this research. And the comparison of both indices result were compared with Mae Sa Index application.

Recommendations

1. The influence of counting errors on estimations of the Trophic Diatom Index (TDI) cause by random and systematic error and mis-identifications of taxa (particularly dominants). And when the number of valves counted was increased from 200 to 400. The effect of counting errors on the calculation of TDI could be include an errors associated with the distribution of valves on the slide (variation due to a finite count of randomly distributed valves, variation due to clumping of valves on the slide and variation due to non-random distribution of valves on a coverslip) (Kelly, 1997).

To obtain the accuracy of Mae Sa Index, it is necessary to classify diatoms into species category and count in the number up to 300 valves. It is necessary to check the properly number for counting from scatter plot of number of presented species against with number of counting as the following graph.

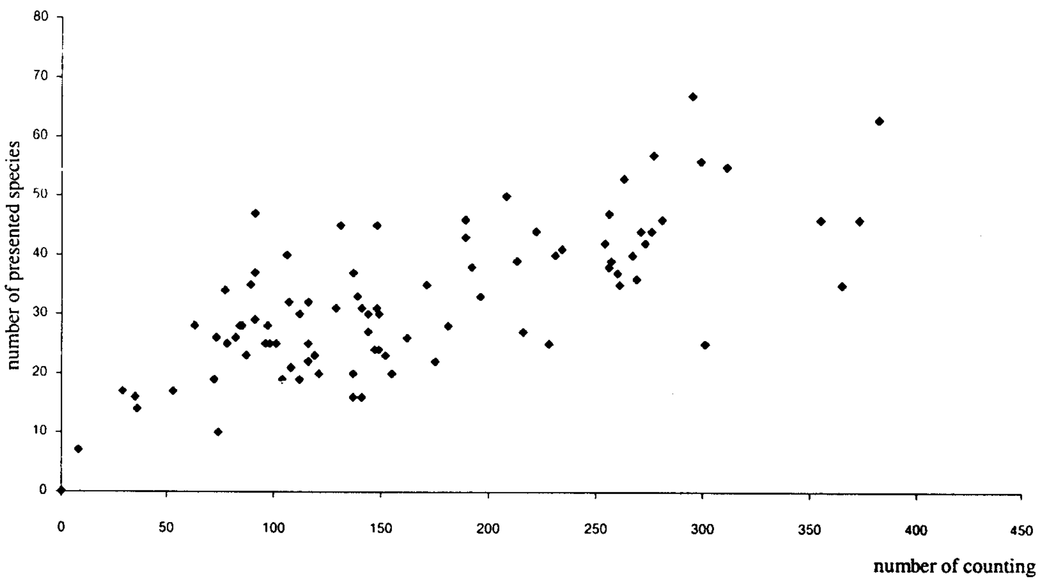


Figure 115 Scatter plots between number of counting and number of presented species

2. The standard classification of water quality in many countries are not the same standard. The evaluation of trophic status into categlory (oligotrophic, mesotrophic and eutrophic) are not the same ways, especially in Thailand, there are no complete standard table for water quality evaluation.

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APPENDICES

APPENDIX A

Publications

1. Fifty One New Record Species of Freshwater Diatoms in Thailand
2. Diversity of Phytoplankton and Benthic Algae in Mae Sa Stream, Doi Suthep–Pui National Park, Chiang Mai

Chiang Mai J. Sci. 2001; 28(2) : 97-112

Fifty One New Record Species of Freshwater Diatoms in Thailand

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ABSTRACT

Diversity of benthic diatoms in Mae Sa stream, Doi Suthep–Pui National Park, Chiang Mai was carried out from April 1998 to September 1999. Two hundred and twenty two species of benthic diatoms were found, fifty one species of these have never been recorded in Thailand before. They were classified into 9 families and 24 genera and were described. The species list of diatoms was compared with the checklist of freshwater algae in Thailand published in 1995.

Keywords: Diatom, Freshwater diatom, Bacillariophyta, Mae Sa Stream, Doi Suthep-Pui National Park

INTRODUCTION

Diatoms are microscopic unicellular algae which range in size from approximately 5 µm to 500 µm and live in any moist habitat, even on soils. The division Bacillariophyta belongs to the diatoms and is characterized by an exquisitely sculptured part of the cell wall composed of silica, which is highly resistant, usually remaining long after the death of the cell and decay of its organic contents [1].

Diatoms are interesting organisms, the first described of diatoms occurred in the latter half of the 18th century and given Latin binomials. The work of O. F. Müller is worth a special mention because it was one of his species *Vibrio paxillifer*, that served as the type of the first diatom genus *Bacillaria* Gmelin. To Müller, *V. paxillifer* and the other *Vibrio* species were animals; he called them animalcula infusoria. Along with ciliates, amoeba, *Volvox*, dinoflagellates and others [2]. The serious study of diatoms began early in the 19th century, with work by Ehrenberg (1838,1840), Ralfs (1843), Kützing (1833,1844) and William Smith (1853–1856), and was continued by numerous others, including Grunow (1860,1884), Cleve (1894), Schmidt (1873–1959), van Heurck (1880–1885) and Cleve-Euler (1934, 1951–1955) [1]. During the 20th century Hustedt published many works concerning freshwater diatom floras, mainly in German; only two of his publications are in English [3]. Foged has also produced numerous works identifying diatoms, including "Freshwater Diatoms in Thailand" in 1971 [4].

The diatom flora of Thailand has been investigated by foreign scientists for a hundred years from a checklist of algae in Thailand by Lewmanomont *et al.* in 1995 . The checklist of algae has been prepared through compilation of various publications include survey reports, scientific papers to results from the Environment Impact Assessment supported by Office of Environmental Policy and Planning (OEPP) and Danish Cooperation on Environment and Development (DANCED) [5].

The checklist of the Algae in Thailand compiled from 53 publications, lists 161 genera, 1001 species, 287 varieties and 63 forms. The checklist reported marine algae and freshwater algae separately. The diatom flora was reported in Division Chromophyta Class Bacillariophyceae. 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 in 1902 recorded 81 different diatoms from the island, Koh Chang in the Gulf of Thailand [6]. The material was collected by the Danish Expedition to Thailand during 1899–1900.

Ruth Patrick in 1936 reported a total of 185 diatom species in intestinal contents from tadpoles from Thailand and the Federal Malay States [7].

In 1961–1962 the material collected by the Joint Thai-Japanese Biological Expedition to Southeast Asia was identified by Hirano. In 1967, he published an account of 143 diatom species, 114 of them were found in the samples from Thailand. Most of these samples were collected in Chiang Mai area and the others from localities in central and southern part of Thailand [8].

In freshwater material collected by Foged in 1966 in central and northern parts of Thailand, about 378 taxa were published. Among these, 8 new species, 5 new varieties and 2 new forms were additional records for Thailand [4].

From 1971 to date, Thai scientists also worked on diatoms but not as intensively as before. Most work has been done on plankton and reported in "The status of phytoplankton diversity in Thailand" by Wongrat (1998) [9]. The material studied was collected from all parts of Thailand but mostly from the northern and northeastern parts of the country.

Further more, there are some works in Thai about the used of diatoms in aquaculture for feeding molluscs and crustacean, report by Powtongsook (2000) and published in the report submitted to the Thailand Research Fund in the title "Ultilisation of Algae: A Research and Development Potential in Thailand". They use *Chaetoceros muelleri* Lemmermann, *Chaetoceros calcitrans* Paulsen, *Skeletonema costatum* (Greville) Cleve, *Thalassiosira pseudonana* Hasle & Heimdal, many species of *Nitzschia* spp. and *Navicula* spp. to feed molluscs and crustacean [10].

Several ongoing projects on diversity of phytoplankton are presently underway in Thailand. Most projects are supported by Research Organizations in Thailand, particularly Program for Biodiversity Research & Training (BRT) financed by National Center for Engineering & Biotechnology. These research will extend the knowledge on diversity of freshwater algae in Thailand by Thai scientists.

Site Characteristic

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 [11].

Doi Suthep–Pui National Park is established in 1981 and has an area of 261 km^2. 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.

Five sites were studied once per month over 18 months from April 1998 to September 1999. The sites were selected along the Mae Sa stream (Figure 1). The name and details of each site are given in Table 1.

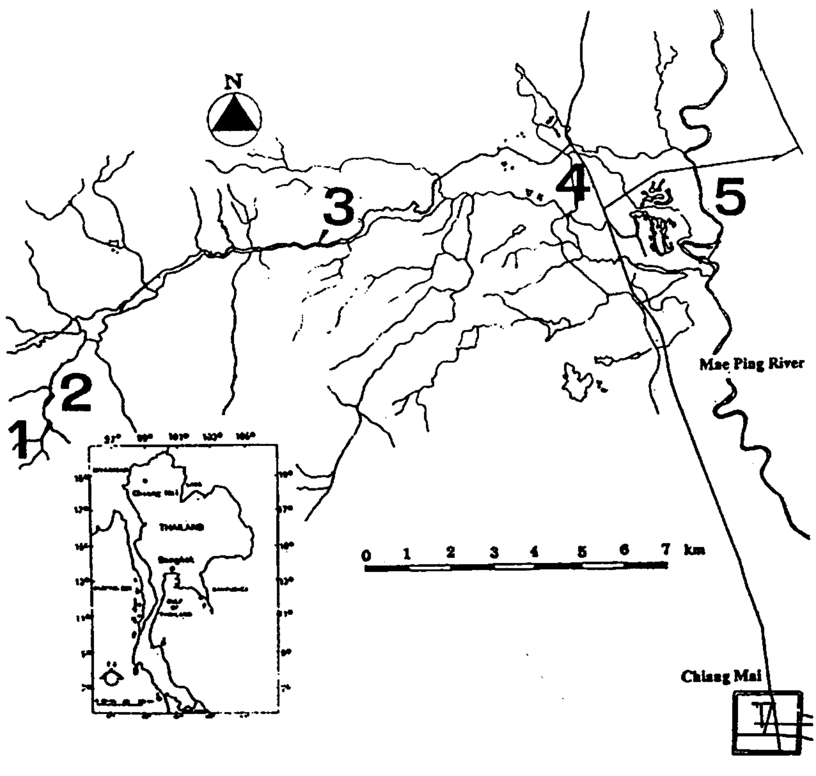

Figure 1. Map of the Mae Sa Stream showing the sampling sites (1–5).

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

Site name	Altitude (m)	Description
1. Kong Hae Village	1,075	agriculture and residental
2. entrance to Kong Hae Village	1,000	agriculture and residental
3. Mae Sa elephant camp	550	tourist attraction
4. Cholaprathan bridge	330	residental
5. Mae Sa Luang Village	340	agriculture and residental

MATERIALS AND METHODS

Diatoms Collection and Preparation

Epilithic diatom samples were scraped from 3–5 stones at each site. In the laboratory, the samples were centrifuged for separated diatom cells from gravel and sand. The diatom frustules were cleaned by boiling for 15–30 minutes in concentrated acid, HCl or HNO_3 and H_2O_2 Mounting agent, Naphrax and Dyrax, were used for mounting in permanent slide preparation. 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 (Kodak Verichromepan ISO 125).

Diatoms identification

The taxonomic classification system of the Süßwasserflora Mitteleuropa by Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b) [12-15], Krammer (1986, 1992, 1997a, 1997b) [16-19], Lange-Bertalot & Krammer (1989) [20], Lange-Bertalot (1993, 1995) [21-22] and Reichardt (1984) [23], Huber-Pestalozzi (1942) [24], Hustedt (1937) [3] were followed. In some cases, however, the relevant keys in the books or theses of some tropical studies such as Foged (1971,1974, 1975, 1976) [4,25-27], Podzorski & Hakansson (1987) [28], Vyverman (1991) [29] and Benavides (1994) [30] were used. Some small *Gomphonema* species were followed Reichardt (1997) [31]. Hand-drawings were followed Barber & Carter (1996) [32]. Fresh material of some species were investigate follow Cox (1996) [33]. The features of the diatom frustules were described in English follow Barber & Haworth (1981) [1] and Kelly (2000) [34]. Structural data presented such as diameter, length, width, striae, striae frequency in 10 µm and other features (raphe, puncta, areolae, fibulae, nodule, septa, costae, stigmata, rib, spine, wing and canals) were observed under light and scanning electron microscopes.

RESULTS AND DISCUSSION

Taxonomic Notes

The diatom description of each new record species was described. The diatom list was shown in table 2. The structural data are abbreviated as follows, D: Diameter, L: Length, W: Width, Str: Striae, Cs: Costae, Li: Lineolae, Pt: Puncta and Fb: Fibulae.

Order Centrales

Family Thalassiosiraceae

Cyclotella stelligera Cleve & Grunow (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 49: 1a–4,9). Figure 7:1

D: 9.3 µm, Cs: 10–14/10 µm. Valve circular, flat and with shallow mantle (seen in girdle view), valve margin without spines, valve face with outer zone of striae (alveoli) and central area unmarked. Distribution cosmopolitan.

Thalassiosira weissflogii (Grunow) Fryxell & Hasle (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 77: 3–4). Figure 6:1

D: 17 µm. Cells discoid, valve circular. Areolae polygonal, arranged in radial rows. Valve mantle with spine. Most species of this genus are marine, although *Thalassiosira weissflogii* has been recorded in freshwater it is described to be a halophile freshwater species. This is a genus where most of the morphology has been determined by electron microscopy.

Family Hemidiscaceae

Actinocyclus normanii (Gregory) Hustedt (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 81: 1–5; 82: 1–7). Figure 2:1

D: 68 µm. Centric form with shallow mantle, valve domed, mantle or margin of valve appearing striate (in valve view). Marginal tubules (strutted processes) visible, without spines. Small refractive area usually visible at or near the valve margin. Hexagonal areolae are equally spaced in straight rows of variable length. This is a freshwater species.

Order Pennales

Family Fragilariaceae

Diatoma ehrenbergii Kützing (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 97: 2). Figure 7:4

L: 52.3 µm, W: 8.1 µm, Cs: 9–10/10 µm. Cells elongate, rectangular in girdle view, valves narrowly linear with broadly rounded slightly capitate apices (truncated). Distribution cosmopolitan.

Diatoma moniliformis Kützing (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 96: 17). Figure 2:4

L: 26 µm, W: 5 µm, Cs: 8/10 µm. Valve isopolar, cells elongate, outline linear elliptic or linear without capitate ends.

Diatoma vulgaris Bory (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 93: 10). Figure 2:5

L: 28.2–72 µm, W: 7.9–12 µm, Cs:7/10 µm. Valve elliptic lanceolate with capitate ends. Isopolar and isobilateral. Thickened transapical costae, striae fine. Axial area (pseudoraphe) present on both valves.

Fragilaria biceps (Kützing) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 121: 1–5). Figure 2:2

L: 125 µm, W: 4 µm, Str: 16/10 µm. Shape needle-like, valve linear, isopolar, with rostrate ends. Striae parallel and absent from the central area. Distribution cosmopolitan especially in oligotrophic habitat.

Fragilaria bidens Heiberg (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 111: 20–21). Figure 7:2

L: 20.9 µm, W: 3.5 µm, Str: 15/10 µm. Valve linear, isopolar, with rostrate ends. Central area a wide rectangular, obviously swollen on both sides. Axial area narrow Distribution cosmopolitan.

Fragilaria elliptica Schumann (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 130: 31–32). Figure 7:3

L: 3–10 µm, W: 3–6 µm, Str: 11–16/10 µm. Valve round to linear elliptic with small spine on margin. Distribution cosmopolitan in freshwater and brackish.

Family Eunotiaceae

Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris* (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 137: 9). Figure 7:6

L: 23 µm, W: 6 µm, Str: 15/10 µm. Valve arcuate or crecentic with almost straight ventral margin, convex dorsal margin and slightly protected apices. End broadly rounded. Shortened raphe present on each mantle. Striae transapical, punctate.

Eunotia minor (Kützing) Grunow (Krammer, K. and H. Lange-Bertalot, 1991a, Figure 142: 8). Figure 2:6

L: 40 µm, W: 9.5 µm, Str: 7–9/10 µm . Valve crecentic with almost straight ventral margin, convex dorsal margin and slightly protected apices. End broadly rounded. Shortened raphe present on each mantle. Striae transapical, punctate.

Family Achnanthaceae

Achnanthes chlidanos Hohn & Hellermann (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 12: 25–26). Figure 7:7

L: 18 µm, W: 6 µm, Str: 22/10 µm. Valve linear elliptic, isopolar. Central area an acute-angled sub-fascia. Striae fine.

Achnanthes exigua Grunow var. *exigua* (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 23: 3–7). Figure 2:9

L: 12.8–15 µm, W: 4.6–7 µm, Str: 17–24/10 µm. Valve broadly linear elliptic with distinct broadly rostrate apices. Central area a wide transverse fascia.

Achnanthes helvetica (Hustedt) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1991b, Figure 10: 12–15). Figure 2:10

L: 7 µm, W: 7.3 µm, Str: 23/10 µm. Valve linear elliptic. Axial area linear. Central area an acute-angled fascia. Distribution cosmopolitan.

Achnanthes lanceolata var. *boyei* (Oestrup) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1993, Figure 41: 11–13). Figure 2:7–8

L: 20–22 µm, W: 8 µm, Str: 9–11/10 µm. Valve linear lanceolate with horse-shoe shape thickening in one side of rapheless valve. Valve with raphe, central area an acute-angled sub-fascia. Striae radiate throughout.

Achnanthes undata Meister (H. Lange-Bertalot, 1993, Figure 35: 8–10). Figure 3:11–13

L: 45–55 µm, W: 13–16 µm, Str: 9/10 µm. Pt: 10/10 µm. Valve lanceolate. Edge crenate, central area a narrow transverse fascia.

Cocconeis placentula var. *pseudolineata* Geitler (Krammer, K. and H. Lange-Bertalot, 1993, Figure 35: 4). Figure 6:2

L: 15 µm, W: 9 µm, Str: 22 /10 µm. Pt: 18/10 µm. Valve oval to elliptic lanceolate, isopolar and isobilateral. Apical axis straight, transapical axis bent (as seen in girdle view). Striae patterns radiate. Puncta coarse.

Distribution cosmopolitan. Forms attached to plants or rock material.

Family Naviculaceae

Amphora coffeaeformis (Agardh) Kützing var. *coffeaeformis* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 151: 2). Figure 7:8

L: 40 μm, W: 15 μm, Str: 22/10 μm. in end and Str: 20/10 μm. in central of dorsal side. Valve semicircular or crecentic in valve view. In girdle view they are wider on the dorsal side than the ventral one. Isopolar and dorsiventral (bilateral). Ends capitate. Raphe threadlike, slightly curved, lying close to the ventral edge. Axial area narrow.

Amphora dusenii Brun (Krammer, K. and H. Lange-Bertalot, 1986, Figure 152: 7–8). Figure 7:9

L: 20 μm, W: 8 μm, Str: 22/10 μm. in central of dorsal side. Valve semi lanceolate, isopolar and dorsiventral. Ends rostrate. Raphe threadlike, slightly curved, lying close to the ventral edge. Axial area narrow.

Amphora libyca Ehrenberg (Krammer, K. and H. Lange-Bertalot, 1986, Figure 149: 4,7). Figure 3:14

L: 25–32.4 μm, W: 6 μm, Str: 12–15/10 μ m. in central of dorsal side. Valve cresentic, isopolar and dorsiventral. Ends round. Raphe threadlike, slightly curved. Slightly finer striae interrupted at the centre on the dorsal side of the valve. Central area an acute-angled fascia. Distribution cosmopolitan.

Caloneis lauta Carter & Bailey-Watts (Krammer, K. and H. Lange-Bertalot, 1986, Figure 173: 2). Figure 3:15

L: 28.5 μm, W: 6.7 μm, Str: 20/10 μm. Valve lanceolate, isopolar and isobilateral. Ends rounded. Raphe straight, central and treadlike slit. Central area a wide transverse fascia. Striae fine and parallel throughout.

Caloneis silicula (Ehrenberg) Cleve (Krammer, K. and H. Lange-Bertalot, 1986, Figure 172: 7). Figure 7:17

L: 18 μm, W: 9 μm, Str: 20/10 μm. Valve linear elliptic, isopolar and isobilateral. Central area lanceolate. Striae fine and parallel throughout.

Cymbella amphicephala Naegeli (Krammer, K. and H. Lange-Bertalot, 1986, Figure 142: 7). Figure 3:16

L: 34.3 μm, W: 10 μm, Str: 10/10 μm in dorsal side and 16/10 μm in ventral side. Valve semilanceolate, isopolar and dorsiventral. Ends capitate.

Cymbella hustedtii Krasske (Krammer, K. and H. Lange-Bertalot, 1986, Figure 140: 15–17). Figure 3:17

L: 23.2 μm, W: 7.9 μm, Str: 12–14/10 μm in dorsal side and 14–15/10 μm in ventral side. Pt: 25/10 μm. Valve semi lanceolate, isopolar and dorsiventral, dorsal convex, ventral slightly convex. Distribution cosmopolitan. Present in oligotrophic habitat.

Cymbella turgidula Grunow (Krammer, K. and H. Lange-Bertalot, 1986, Figure 126: 4–7). Figure 3:21

L: 28–40 μm, W: 10.7–13 μm, Str: 7–13/10 μm. Pt: 22/10 μm. Valve dorsiventral, dorsal convex, ventral convex, elliptic lanceolate, ends cunate to rostrate.

Cymbellopsis cf. *lanceolata* Krammer (Krammer, K., 1997b, Figure 195: 10, 197: 9–13). Figure 6:3–4

L: 13–19 μm, W: 4–5 μm, Str: 14–19/10 μ m. Valve semicircular, isopolar and dorsiventral, dorsal convex, with the outline raphe structure, near the ventral margin, straight and threadlike. Ends of the raphe curve to ventral side (opposite to *Cymbella*).

Encyonema silesiacum (Bleisch) D.G. Mann (Krammer, K., 1997a, Figure 4: 11–12, Round, F.E., R.M. Crawford and D.G. Mann, 1990, Page 490-491). Figure 3:18–19

L: 19–23 μm, W: 6 μm, Str: 14–18/10 μm in dorsal side and 15–19/10 μm in ventral side. Pt: 25/10 μm. Valve strongly dorsiventral. Raphe parallel to ventral margin. *Encyonema* are small group recognised by Krammer (1982) [2] as a subgenus within *Cymbella,* were prefer to separated at the generic level. Live cells are easily identified because of the ventral plastid and dorsal nucleus. The whole cell interior and the orientation of the raphe system are opposite in *Encynema* and *Cymbella* relative to the dorsiventrality of the cell.

Frustulia weinholdii Hustedt (Krammer, K. and H. Lange-Bertalot, 1986, Figure 97: 12–14). Figure 4:22

L: 32–60 μm, W: 6.5–10 μm, Str: 30/10 μ m. Shape narrow elliptic, isopolar and isobilateral. Ends rounded. Raphe central, straight and treadlike, set on a thickened ridge differentiated from the narrow axial area which is produced at the apices. Striae parallel and fine.

Gomphonema affine Kützing (Krammer, K. and H. Lange-Bertalot, 1986, Figure 161:1–3). Figure 7:10

L: 52 µm, W: 8 µm, Str: 12/10 µm. Valve heteropolar, clavate to rhombic but isobilateral. Raphe central, central area one-side with one stigma. Distribution in trophic-subtrophic region.

Gomphonema augur var. *turris* (Ehrenberg) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 158: 6). Figure 7:11

L: 32 µm, W: 11 µm, Str: 13/10 µm. Valves markedly heteropolar, tapering evenly to the rather acute foot pole, broadening towards the head pole which often bears a bluntly rounded apical projection.

Gomphonema minutum (Agardh) Agardh (Krammer, K. and H. Lange-Bertalot, 1986, Figure 159: 5). Figure 7:16

L: 15–20 µm, W: 5–6 µm, Str: 10–15/10 µ m. Valves narrowly heteropolar with bluntly rounded apices, foot pole only slightly narrower than head pole. Striae more widely spaced at centre of valve. Stigma on one-side.

Gomphonema pumilum var. *rigidum* E. Reichardt et Lange-Bertalot (Reichardt, E.,1997, Figure 1:7, 3:1–41, 4: 24–25). Figure 4:23

L: 21 µm, W: 4.2 µm, Str: 12/10 µm. Valve linear to linear lanceolate. Central area a wide transverse fascia with one stigma separated from the central nodule. Typically with broadly lanceolate axial area. Striae transapical, slightly radiate.

Navicula cohnii (Hilse) Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 63: 1). Figure 4:24

L: 22.6 µm, W: 7.8 µm, Str: 20/10 µm. Pt: 15/10 µm. Valve broad elliptic to linear elliptic. Central area an acute-angled fascia with central pore. Distribution cosmopolitan.

Navicula concentrica Carter (Krammer, K. and H. Lange-Bertalot, 1986, Figure 36: 10–12). Figure 7:13

L: 45 µm, W: 10 µm, Str: 9/10 µm. Valve lanceolate with sharp ends, isopolar, isobilateral. Axial area narrow. Striae radiate. Raphe line a little lateral.

Navicula cryptotenella Lange-Bertalot (Krammer, K. and H. Lange-Bertalot, 1986, Figure 33: 9–11). Figure 4:25, Figure 6:6

L: 26.7–34.3 µm, W: 5.8–7 µm, Str: 14–15/10 µm. Valve lanceolate to rhombic lanceolate, tapering to acutely rounded apices which are only very slightly drawn out. Striae radiating in the central part, parallel at the poles. Distribution cosmopolitan.

Navicula elginensis (Gregory) Ralfs var. *elginensis* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 35:5). Figure 6:5

L: 20 µm, W: 8 µm, Str: 20/10 µm. Pt: 60/10 µm. Valve broad linear to broad elliptic. Ends stump. Striae radiate.

Navicula jaagii Meister (Krammer, K. and H. Lange-Bertalot, 1986, Figure 79: 18–21). Figure 6:12

L: 25 µm, W: 5 µm, Str: 32/10 µm. Valve broad linear to linear elliptic. Ends capitate to rounded. Axial area narrow linear, central area elliptic to rhombic. Striae fine.

Navicula laevissima Kützing var. *laevissima* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 67: 6–10). Figure 4:26

L: 20 µm, W: 6.7 µm, Str: 21/10 µm. Valve linear, isopolar, isobilateral. End broadly rounded. Axial area narrow, central area rhombic. Striae fine and curved around the central area.

Navicula mutica Kützing var. *mutica* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 61: 1). Figure 4:27

L: 19–20 µm, W: 7.3–7.8 µm, Str: 18–21/10 µm. Pt: 15/10 µm. Valve rhombic elliptic to broad elliptic. Axial area linear. Central area an acute-angled fascia. Striae radiate.

Navicula subplacentula Hustedt (Krammer, K. and H. Lange-Bertalot, 1986, Figure 50: 5–8). Figure 4:28

L: 23.8–25.9 µm, W: 9.6 µm, Str: 9–12/10 µ m. Valve elliptic lanceolate. Ends stump. Axial area linear, central area elliptic. Striae radiate. Distribution Africa, Europe and Asia.

Neidium ampliatum (Ehrenberg) Krammer (Krammer, K. and H. Lange-Bertalot, 1986, Figure 105: 2). Figure 4:29

L: 127 µm, W: 24 µm, Pt: 16–24/10 µm. Valve broadly linear with bluntly cuneate to broadly rostrate apices more than one-third valve width. Striae fine parallel. Ends stump. Central area elliptic. Distribution cosmopolitan.

Reimeria sinuata (Gregory) Kociolek & Stoermer (Krammer, K. and H. Lange-Bertalot, 1986, Figure 148:10–17, Round, F.E., R.M. Crawford and D.G. Mann, 1990, Page 500-501). Figure 3:20

L: 15 μm, W: 5 μm, Str: 12/10 μm. Pt: 45/10 μm. Valve slightly dosiventral with a slight unilateral expansion. Dorsal convex, ventral slightly convex. Valve linear to linear-lanceolate, subcapitate asymetrical about the apical axis. Striae distant biseriate, absent from the ventral swelling, opening internally between prominent ribs. Between the central raphe endings, or slightly to the dorsal side of them, is a single isolated pore (stigma), which is unoccluded both internally and externally. This recently erected genus differs from *Cymbella* in the unusual shape of the valve and the ventrally displaced apical pore field. The simple stigma, central internal raphe endings and pore field are also very reminiscent of many *Gomphonema* species. This described species was trasfer from *Cymbella sinuata* Gregory [2]. Distribution cosmopolitan, fresh-water, associated with stone surfaces particularly in rivers.

Sellaphora pupula (Kützing) Mereschkowsky (Krammer, K. and H. Lange-Bertalot, 1986, Figure 68: 1–21). Figure 4:30

L: 27 μm, W: 8 μm, Str: 20–22/10 μm. Valve linear elliptic to lanceolate, usually with bluntly rounded or capitate poles. Valve face flat, curveing fairly gently into shallow or moderately deep mantles; often grooved near the raphe externally. Striae uniseriate, containing small round poroids occluded near their internal apertures by hymenes. Raphe system central, straight. A large genus, containing many of the small naviculoid diatoms placed by Hustedt (1927-1966) in *Navicula* sect. *Bacillares* and *Minusculae*. Examples of species transferred to *Sellaphora* are *S. pupula*, *S. bacillum*, *S. laevissima*, *S. seminulum*, *S. disjuncta*. Plastid structure must be examined before a species can be reliably allocated using light microscope to this genus, or indeed to the other genera we have split from *Navicula*. *Sellaphora* is easily separated from *Navicula sensu stricto* by the plastid, areola and raphe structure. Plastid and cell division have been described in detail by Mann (1984a, 1985) [2].

Family Epithemiaceae

Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba* (Krammer, K. and H. Lange-Bertalot, 1986, Figure 111: 1–13). Figure 4:31–32

L: 60–74 μm, W: 18–22 μm, Str: 9/10 μm. Valve linear with crescentic cunate ends. Isopolar and dorsiventral with dorsal edge slightly gibbous. Raphe system situated along the dorsal margin of the valve. External central raphe endings expanded, sometimes deflected slightly towards the ventral side, internal endings simple. Axial area very narrow, central area absent. Transapical costae present.

Family Bacillariaceae

Hantzschia distinctepunctata (Hustedt) Hustedt (Krammer, K. and H. Lange-Bertalot, 1988, Figure 88: 8–10). Figure 4:33

L: 45 μm, W: 6 μm, Str: 12/10 μm. Valve slightly asymmetrical with respect to the apical plan, valves are either dorsiventral or slightly arc shaped. Striae fine and parallel. Raphe on ventral concave margin of valve supported by prominent fibulae. Distribution cosmopolitan.

Nitzschia brevissima Grunow (Krammer, K. and H. Lange-Bertalot, 1988, Figure 22: 1–6). Figure 7:14

L: 37.5 μm, W: 5 μm, Str: 32/10 μm, Fb: 10/10 μm. Valve broad linear, slightly sigmoid. Striae fine and parallel along the transapical axis. Distribution cosmopolitan.

Nitzschia coarctata Grunow (Krammer, K. and H. Lange-Bertalot, 1988, Figure 38: 14–15). Figure 7:15

L: 50 μm, W: 12 μm, Str: 10/10 μm, Pt: 15/10 μm. Fb: 6/10 μm. Valve panduriform, isopolar, isobilateral with cunate ends. Striae coarse in central area and slightly curve in the ends. Distribution cosmopolitan.

Nitzschia hantzschiana Rabenhorst (Krammer, K. and H. Lange-Bertalot, 1988, Figure 73: 18). Figure 5:34

L: 17 μm, W: 3 μm, Str: 20/10 μm, Fb: 7/10 μm. Valve elliptic linear lanceolate, isopolar. Ends stump. Distribution cosmopolitan.

Family Surirellaceae

Cymatopleura salea var. *apiculata* (W. Smith) Ralfs (Krammer, K. and H. Lange-Bertalot, 1988, Figure 118:4 –8). Figure 5:35

L: 62–67.5 μm, W: 22.5–27.5 μm, Fb: 9/10 μm. Valve linear, often constricted about the central portion, isopolar and isobilateral. Ends apiculate. Valve surface undulate. Raphe system on peripheral wing (ala) developed from the valve margin and supported by ribs. Striae very finely punctate, the patterns sometime varying from apical to transapical in direction, corresponding to the undulations.

Surirella roba Leclercq (Krammer, K. and H. Lange-Bertalot, 1988, Figure 148:8). Figure 5:36

L: 37 μm, W: 9 μm, Fb: 50/100 μm. Valve linear lanceolate, isopolar. Ends stump.

Surirella spiraloides Hustedt (Huber-Pestalozzi, G.,1942, Figure 617). Figure 5:37

L: 60–62 μm, W: 25–27 μm, Fb: 15/100 μm. Valve spirally twisted, heteropolar. Raphe system peripheral on a wing (ala) extension of the valve margin, supported by rib-like undulations. Striae fine, difficult to resolve.

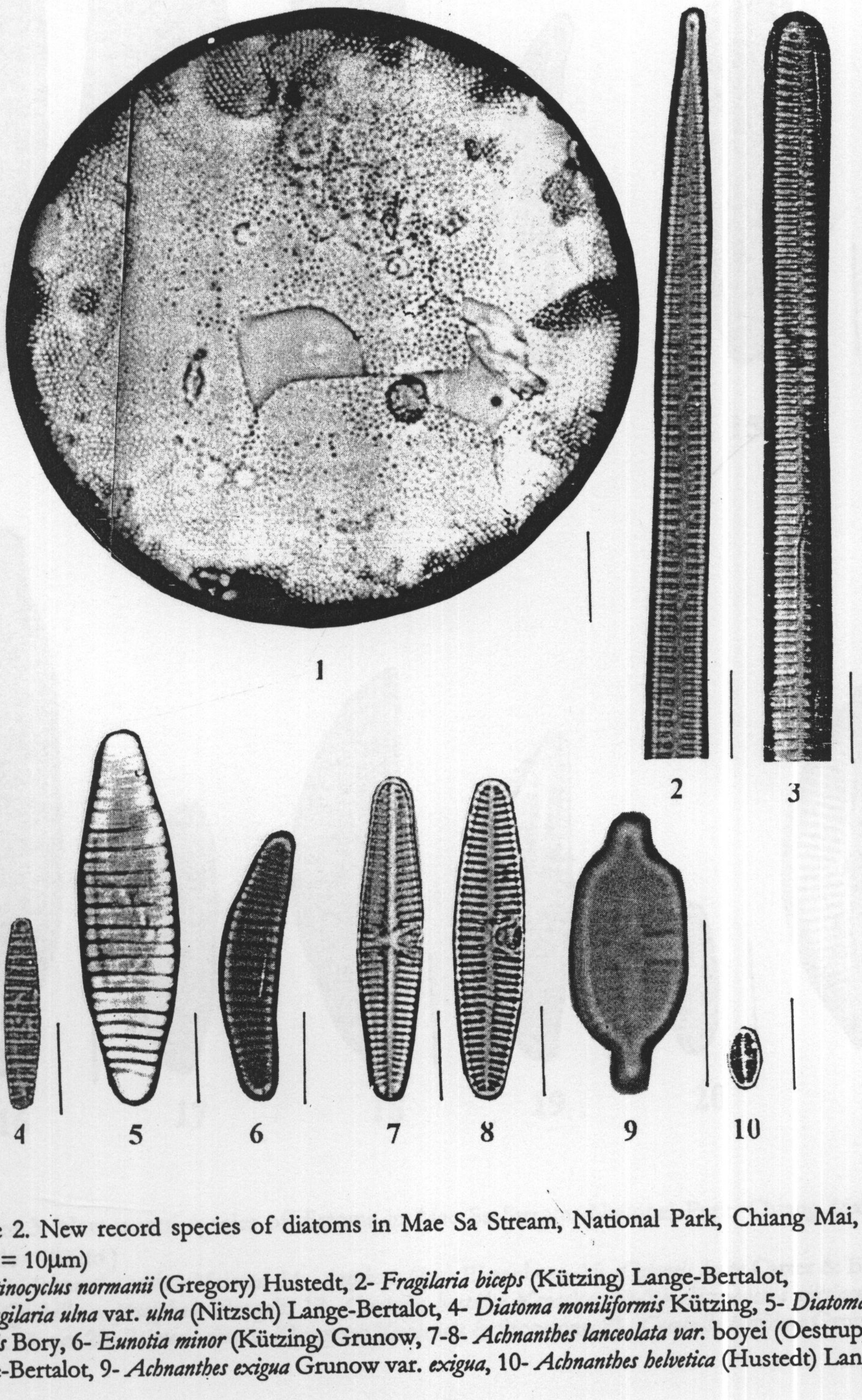

Figure 2. New record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand. (scale = 10μm)
1- *Actinocyclus normanii* (Gregory) Hustedt, 2- *Fragilaria biceps* (Kützing) Lange-Bertalot, 3- *Fragilaria ulna* var. *ulna* (Nitzsch) Lange-Bertalot, 4- *Diatoma moniliformis* Kützing, 5- *Diatoma vulgaris* Bory, 6- *Eunotia minor* (Kützing) Grunow, 7-8- *Achnanthes lanceolata var.* boyei (Oestrup) Lange-Bertalot, 9- *Achnanthes exigua* Grunow var. *exigua*, 10- *Achnanthes helvetica* (Hustedt) Lange-Bertalot

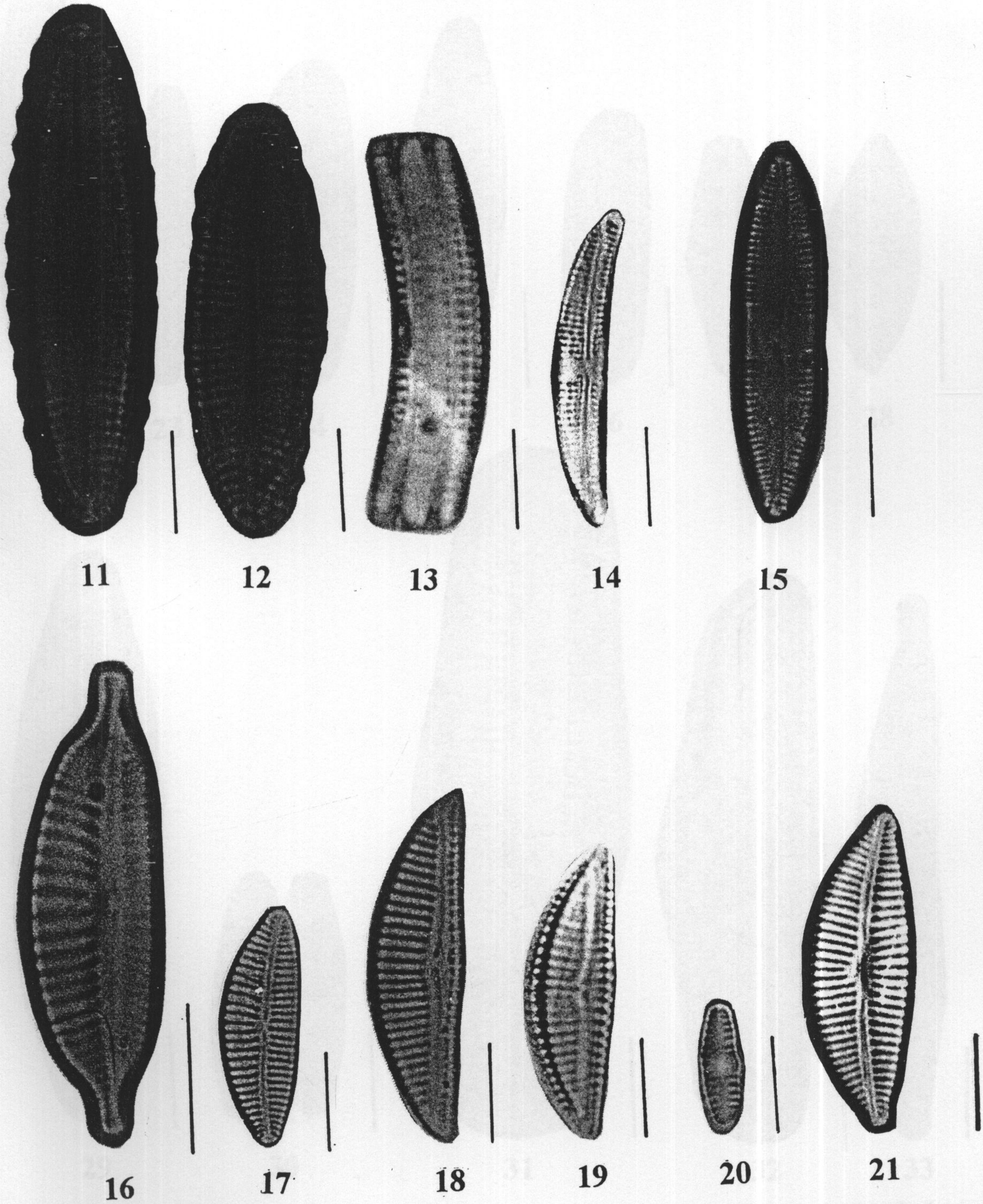

Figure 3. New record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand. (scale = 10µm)
11-13-*Achnanthes undata* Meister, 14- *Amphora libyca* Ehrenberg, 15- *Caloneis lauta* Carter & Bailey-Watts, 16- *Cymbella amphicephala* Naegeli, 17- *Cymbella hustedtii* Krasske, 18-19- *Encyonema silesiacum* (Bleisch) D.G. Mann, 20- *Reimeria sinuata* (Gregory) Kociolek & Stoermer, 21- *Cymbella turgidula* Grunow

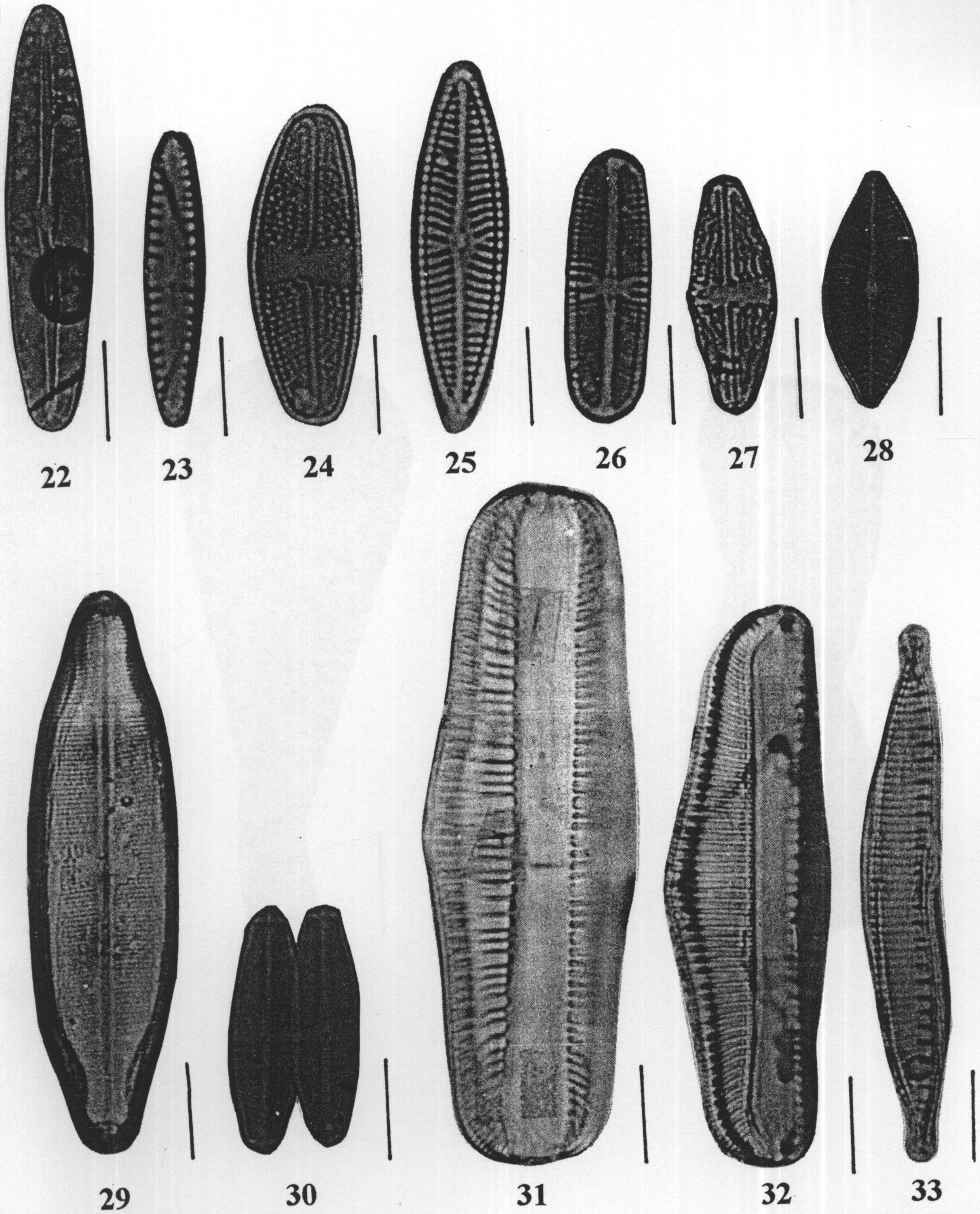

Figure 4. New record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand. (scale = 10μm)
22- *Frustulia weinholdii* Hustedt, 23- *Gomphonema pumilum* var. *rigidum* E. Reichardt et Lange-Bertalot, 24- *Navicula cohnii* (Hilse) Lange-Bertalot, 25- *Navicula cryptotenella* Lange-Bertalot, 26- *Navicula laevissima* Kützing var. *laevissima*, 27- *Navicula mutica* Kützing var. *mutica*, 28- *Navicula subplacentula* Hustedt, 29- *Neidium ampliatum* (Ehrenberg) Krammer, 30- *Sellaphora pupula* (Kützing) Mereschkowsky, 31-32-*Rhopalodia gibba* (Ehrenberg) O. Müller var. *gibba*, 33- *Hantzschia distinctepunctata* (Hustedt) Hustedt

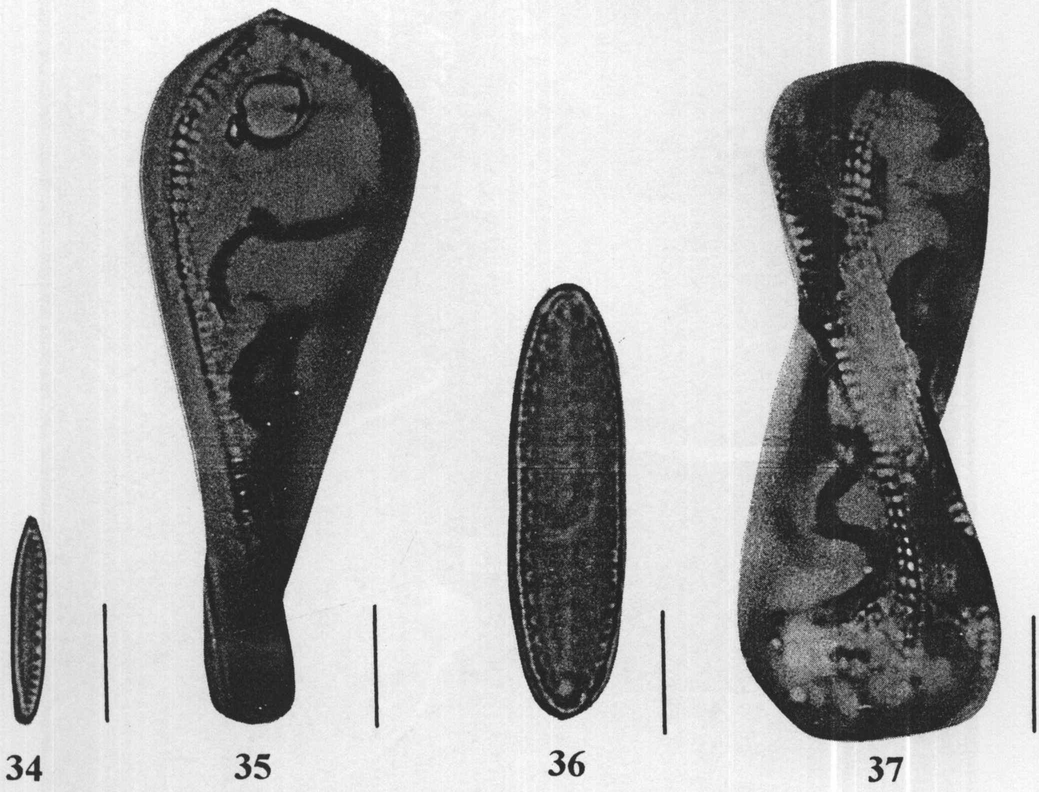

Figure 5. New record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand. (scale = 10μm)

34- *Nitzschia hantzschiana* Rabenhorst, 35- *Cymatopleura solea* var. *apiculata* (W.Smith) Ralfs,
36- *Surirella roba* Leclercq, 37- *Surirella spiraloides* Hustedt

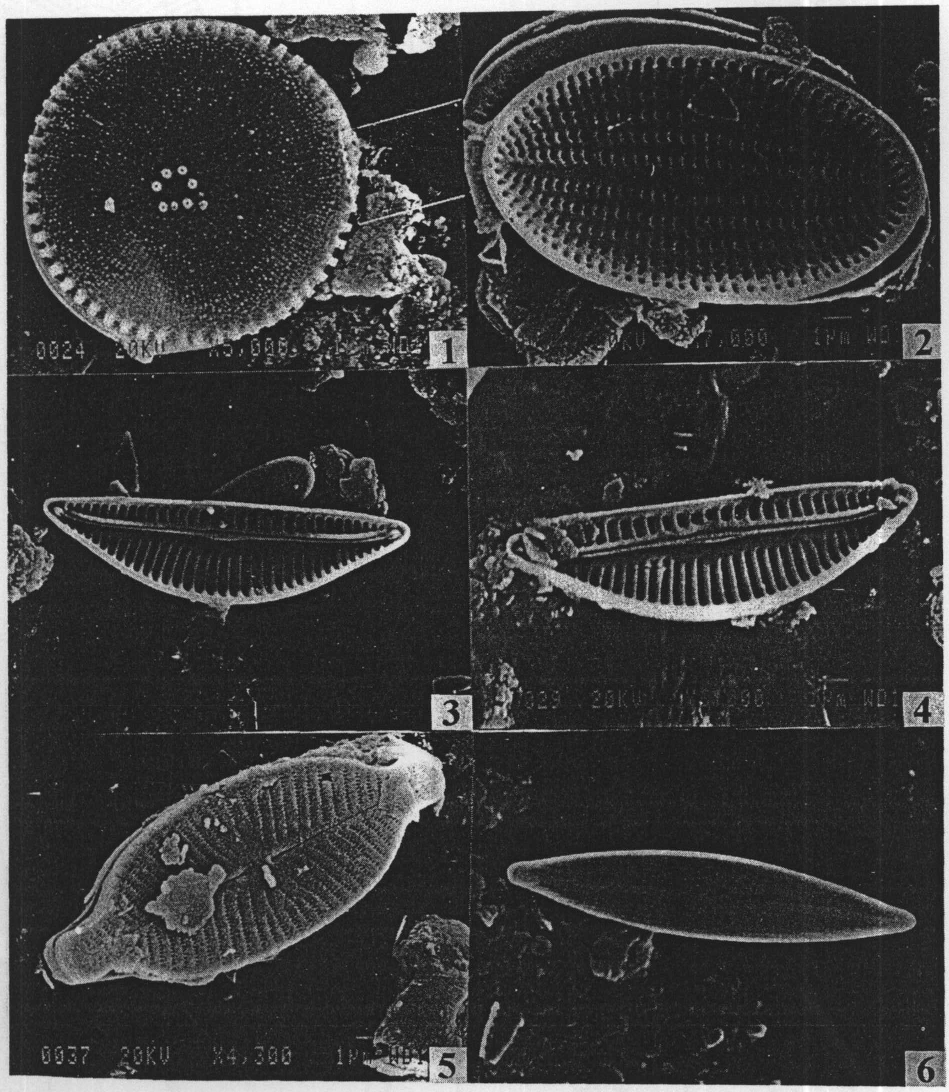

Figure 6. Scanning Electron Micrograph (SEM) of new record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand.
1- *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle, *2- Cocconeis placentula* var. *pseudolineata* Geitler,
3-4- *Cymbellopsis* cf. *lanceolata* Krammer, 5- *Navicula elginensis* (Gregory) Ralfs var. *elginensis*,
6- *Navicula cryptotenella* Lange-Bertalot

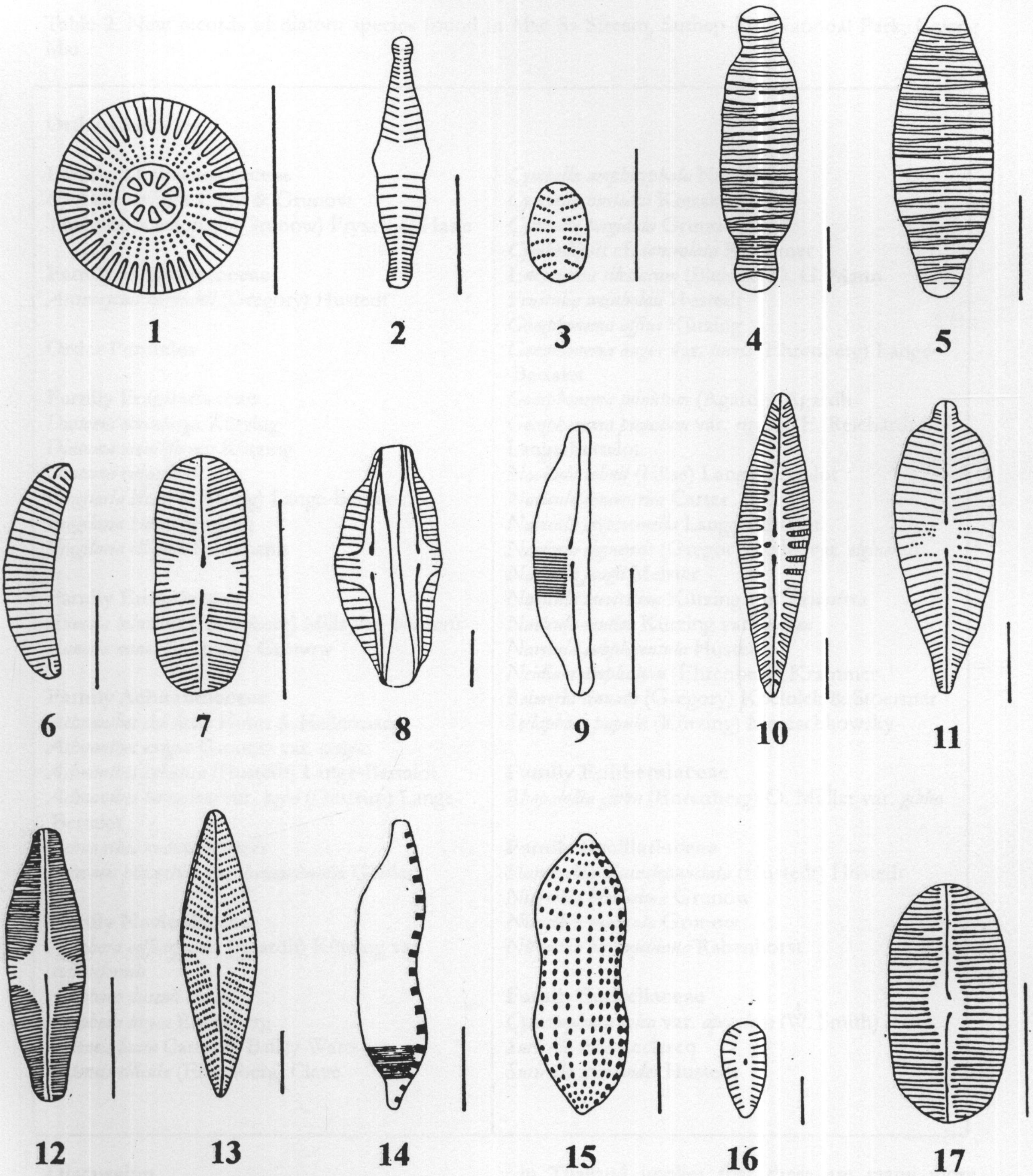

Figure 7. Hand-drawing of new record species of diatoms in Mae Sa Stream, National Park, Chiang Mai, Thailand. (scale = 10μm)
1- *Cyclotella stelligera* Cleve & Grunow, 2- *Fragilaria bidens* Heiberg, 3- *Fragilaria elliptica* Schumann,
4- *Diatoma ehrenbergii* Kützing, 5- *Diatoma vulgaris* Bory, 6- *Eunotia bilunaris* (Ehrenberg) Mills var. *bilunaris*,
7- *Achnanthes chlidanos* Hohn & Hellermann, 8- *Amphora coffeaeformis* (Agardh) Kützing var. *coffeaeformis*,
9- *Amphora dusenii* Brun, 10- *Gomphonema affine* Kützing,
11- *Gomphonema augur* var. *turris* (Ehrenberg) Lange-Bertalot, 12- *Navicula jaagii* Meister,
13- *Navicula concentrica* Carter, 14- *Nitzschia brevissima* Grunow, 15- *Nitzschia coarctata* Grunow,
16- *Gomphonema minutum* (Agardh) Agardh, 17- *Caloneis silicula* (Ehrenberg) Cleve

Table 2. New records of diatom species found in Mae Sa Stream, Suthep-Pui National Park, Chiang Mai .

Order Centrales

Family Thalassiosiraceae
Cyclotella stelligera Cleve & Grunow
Thalassiosira weissflogii (Grunow) Fryxell & Hasle

Family Hemidiscaceae
Actinocyclus normanii (Gregory) Hustedt

Order Pennales

Family Fragilariaceae
Diatoma ehrenbergii Kützing
Diatoma moniliformis Kützing
Diatoma vulgaris Bory
Fragilaria biceps (Kützing) Lange-Bertalot
Fragilaria bidens Heiberg
Fragilaria elliptica Schumann

Family Eunotiaceae
Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris*
Eunotia minor (Kützing) Grunow

Family Achnanthaceae
Achnanthes chlidanos Hohn & Hellermann
Achnanthes exigua Grunow var. *exigua*
Achnanthes helvetica (Hustedt) Lange-Bertalot
Achnanthes lanceolata var. *boyei* (Oestrup) Lange-Bertalot
Achnanthes undata Meister
Cocconeis placentula var. *pseudolineata* Geitler

Family Naviculaceae
Amphora coffeaeformis (Agardh) Kützing var. *coffeaeformis*
Amphora dusenii Brun
Amphora libyca Ehrenberg
Caloneis lauta Carter & Bailey-Watts
Caloneis silicula (Ehrenberg) Cleve
Cymbella amphicephala Naegeli
Cymbella hustedtii Krasske
Cymbella turgidula Grunow
Cymbellopsis cf. *lanceolata* Krammer
Encyonema silesiacum (Bleisch) D. G. Mann
Frustulia weinholdii Hustedt
Gomphonema affine Kützing
Gomphonema augur var. *turris* (Ehrenberg) Lange-Bertalot
Gomphonema minutum (Agardh) Agardh
Gomphonema pumilum var. *rigidum* E. Reichardt et Lange-Bertalot
Navicula cohnii (Hilse) Lange-Bertalot
Navicula concentrica Carter
Navicula cryptotenella Lange-Bertalot
Navicula elginensis (Gregory) Ralfs var. *elginensis*
Navicula jaagii Meister
Navicula laevissima Kützing var. *laevissima*
Navicula mutica Kützing var. *mutica*
Navicula subplacentula Hustedt
Neidium ampliatum (Ehrenberg) Krammer
Reimeria sinuata (Gregory) Kociolek & Stoermer
Sellaphora pupula (Kützing) Mereschkowsky

Family Epithemiaceae
Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba*

Family Bacillariaceae
Hantzschia distinctepunctata (Hustedt) Hustedt
Nitzschia brevissima Grunow
Nitzschia coarctata Grunow
Nitzschia hantzschiana Rabenhorst

Family Surirellaceae
Cymatopleura solea var. *apiculata* (W. Smith) Ralfs
Surirella roba Leclercq
Surirella spiraloides Hustedt

Discussion

The survey reported in this publication extends our knowledge of biodiversity in Thailand, with regard to freshwater diatoms as valuable natural resources. Additional studies to the freshwater algae that have been done by Thai scientists.

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

Studies of the diatoms in Thailand have started since the latest year of the nineteenth century. Most of early taxonomic studies were done by foreign scientists. The checklist reported about the papers of diatom flora published by foreign scientists such as Östrup (1902), Patrick (1936), Hirano (1967) and Foged (1971). Among the additional records for Thailand from 1971 to date, works on diatoms have been carried out by Thai scientists in various universities and institutions, but not deep in details. Most works are the studies on planktonic diatoms.

The results from the study of diversity of benthic diatoms in Mae Sa stream, Suthep-Pui National Park, Chiang Mai, gives a total of 222 diatom taxa. Of these fifty one species have never been recorded in Thailand before. According to the reports, it is obvious that Thailand has slow progress in the studies of freshwater algae biodiversity and include marine algae. If we consider the aquatic environment more intimately, we will see that the most important producers are algae either planktonic or benthic forms. Therefore, extensive biodiversity of freshwater algae is urgently needed as supporting knowledge for all biological sciences and for the development of the country as well.

Diatoms especially benthic diatoms possess a number of attributes which contribute to their suitability as biological indicators in the running water because of the highly sensitive to water chemistry changes, abundant in aquatic environments, largely cosmopolitan in distribution and have a well-studied taxonomy and ecology. Application of the use of benthic diatoms have to intend in taxonomic study along with the ecological studies. Measurements of physical and chemical parameters should have been investigated to assess the water quality. Furthermore to looking for relationships between benthic diatoms and quality of the water are necessary.

About the situation of environmental risk crisis for extinction species. The Convention on Biological Diversity (CDB) has encouraged governments to focus attention on the conservation of biodiversity. Currently more than 127 countries have ratified the convention. Although Thailand is preparing to ratify the convention, it has not yet done so. Preparation for eventual ratification of the CDB, however, has encouraged the government of Thailand to establish several institutions to implement biodiversity conservation, including monitoring programmes of phytoplankton, although progress has been slow. Such programmes include the Biodiversity Research and Training Program (BRT), financed by the National Center for Genetic Engineering and Biotechnology, which has supported several projects to monitor phytoplankton. The Biodibersity Research and Training Program was established joinly by the Thailand Research Fund (TRF) and BIOTEC. The aim is to provide support and funding for research into and management of Thailand's biodiversity resources. This work was also supported from BRT grant. The results from this work may be expand our knowledge, at least to record the discovered species in the checklist.

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

Yuwadee Peerapornpisal, Trai Pekthong, Prasert Waiyaka and Sakorn Promkutkaew[1]

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 19th century, the present state of knowledge is unsatisfactory. According to available literature, green algae (Chlorophyceae) have been throughly 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^2. 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.

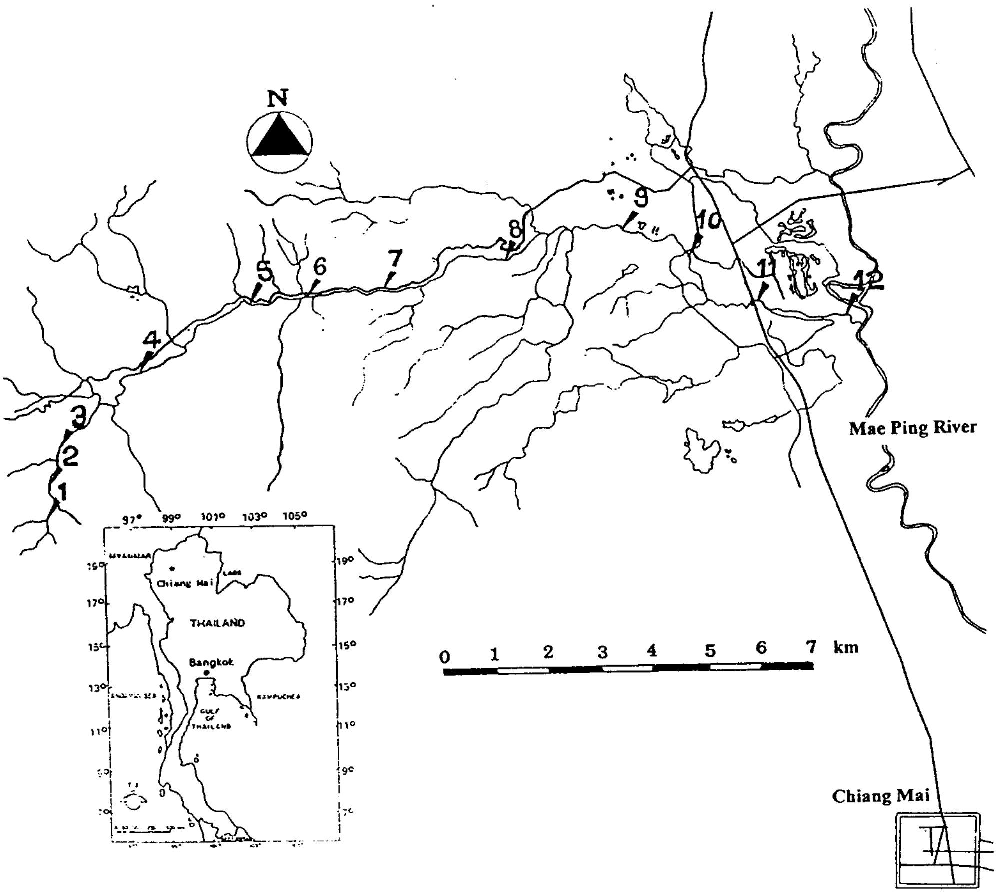

Figure 1. Map of the Mae Sa Stream showing the 12 sampling sites.

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 µm. 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_3 and H_2O_2. 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 Süβwasserflora 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 µm) 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
CYANOBACTERIA		
Order Oscillatoriales, Family Oscillatoriaceae		
Lyngbya circumcreta West, G. S.	P	5,12
Oscillartoria acuminata Gomont	B	1,2,7,10
Oscillartoria spp.	P, B	2,3,6,7,8,9,10,11,12
Planktolyngbya limnetica Lemm.	P	10,11,12
Spirulina major (Gomont) Kützing	P	12
Order Nostocales, Family Nostocaceae		
Anabaena sp.	P	1,3,4,5,6,7,8,10,12
Cylindrospermopsis raciborskii (Wolosz.) Seenayya & Subba	P	10
Nostoc spp.	B	1,2,10,12
Nostochopsis sp.	B	1
Pseudanabaena sp.	P	1,2,4,6,8,10,12
Family Rivulariaceae		
Gleotrichia sp.	P	2
CHLOROPHYTA		
Order Volvocales, Family Volvocaceae		
Gonium sp.	P	2
Order Tetrasporales, Family Tetrasporceae		
Tetraspora sp.	P	11
Order Chlorosphaerales, Family Oocystaceae		
Ankistrodesmus sp.	P	3,4,5,7,10
Monoraphidium sp.	P	11
Family Scenedesmaceae		
Coelastrum sp.	P	7,8
Scenedesmus javanensis Chod.	P	5,7
Scenedesmus spp.	P	1,4,7,9
Tetrastrum sp.	P	12
Family Hydrodictyaceae		
Hydrodictyon reticulatum (Linn.) Lagerheim	B	2
Pediastrum duplex Meyen	P	1,8,9
Pediastrum simplex Meyen	P	1,9,12
Pediastrum sp.	P	10

Table 2. (continued).

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

Table 2. (continued).

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

Table 2. (continued).

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

Table 2. (continued).

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

Table 2. (continued).

Phytoplankton and benthic algae	Form	Site distribution
Gomphonema parvulum (Kützing) Kützing	B	1,2,3,4,5,6,12
Gonphonema pumilum var. *rigidum*	B	7,12
Gomphonema subclavatum Grunow	B	3,5
Gonphonema spp.	P,B	1–12
Family Bacillariaceae		
Bacillaria paradoxa Gmelin	P,B	6,8,10,11,12
Family Epithemiaceae		
Epithemia sp.	P	1,2,3,4,5
Rhoicosphenia sp.	P	1,3,5,6
Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba*	B	2,10
Rhopalodia sp.	P,B	2,9,10,11,12
Family Surirellaceae		
Cymatopleura salea var. epicolata (W. Smith) Ralfs	P,B	9,10,12
Surirella angusta Kützing	B	11
Surirella bifrons Ehrenberg	B	11
Surirella biseriata Brébisson	B	2,11,12
Surirella capronii Brébisson	P,B	1.2,3,4,5,6,7,10,12
Surirella elegans Ehrenberg	B	12
Surirella spiralis Kützing	B	7,10
Surirella tenera Gregory	B	2
Surirella 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

Family Thalassiosiraceae

Cyclotella stelligera Cleve & Grunow

Stephanodiscus sp.

Thalassiosira weissflogii (Grunow) Fryxell & Hasle

Family Hemidiscaceae

Actinocyclus normanii (Gregory) Hustedt

ORDER PENNALES

Family Fragilariaceae

Diatoma ehrenbergii Kützing

Diatoma moniliformis Kützing

Diatoma vulgaris Bory

Fragilaria biceps (Kützing) Lange-Bertalot

Fragilaria bidens Heiberg

Fragilaria elliptica Schumann

Fragilaria ulna (Nitzsch) Lange-Bertalot

Family Eunotiaceae

Eunotia bilunaris (Ehrenberg) Mills var. *bilunaris*

Eunotia minor (Kützing) Grunow

Family Achnanthaceae

Achnanthes chlidanos Hohn & Hellermann

Achnanthes exigua Grunow var. *exigua*

Achnanthes helvetica (Hustedt) Lange-Bertalot

Achnanthes lanceolata ssp. *lanceolata* (Brébisson) Grunow var. *haynaldii* (Schaarschmidt) Cleve

Achnanthes undata Meister

Cocconeis placentula var. *pseudolineata* Geitler

Family Naviculaceae

Amphora coffeaeformis (Agardh) Kützing

Amphora dusenii Brun

Amphora libyca Ehrenberg

Frustulia weinholdii Hustedt

Gomphonema affine Kützing

Gomphonema augur var. *turris* (Ehrenberg) Lange-Bertalot

Gomphonema minutum (Agardh) Agardh

Gonphonema pumilum var. *rigidum*

Navicula amphibola Cleve

Navicula cohnii (Hilse) Lange-Bertalot

Navicula concentrica Carter

Navicula cryptotenella Lange-Bertalot

Navicula elginensis (Gregory) Ralfs var. *elginensis*

Navicula jaagii Meister

Navicula laevissima Kützing var. *laevissima*

Navicula mutica Kützing var. *mutica*

Navicula subplacentula Hustedt

Navicula tripunctata (O. F. Müller) Bory

Navicula trivialis Lange-Bertalot

Neidium ampliatum (Ehrenberg) Krammer

Pinnularia subgibba Krammer

Pinnularia viridiformis Krammer

Sellaphora pupula (Kützing) Mereschkowsky

Stauroneis producta Grunow

Family Epithemiaceae

Rhopalodia gibba (Ehrenberg) O. Müller var. *gibba*

Family Bacillariaceae

Hantzschia distinctepunctata (Hustedt) Hustedt

Nitzschia acula Hantzsch

Nitzschia angustatula Lange-Bertalot

Nitzschia bremensis Hustedt

Nitzschia brevissima Grunow

Nitzschia coarctata Grunow

Nitzschia dubia W.Smith

Nitzschia granulata Grunow

Table 3. (continued).

Caloneis lauta Carter & Bailey-Watts	*Nitzschia literalis* Grunow
Caloneis silicula (Ehrenberg) Cleve	*Nitzschia palustris* Hustedt
Cymbella amphicephala Naegeli	*Nitzschia subacicularis* Hustedt
Cymbella hustedtii Krasske	Family Surirellaceae
Cymbella silesiaca Bleisch	*Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs
Cymbella sinuata Gregory	*Surirella bifrons* Ehrenberg
Cymbella turgidula Grunow	*Surirella spiraloides* Hustedt
Cymbellopsis sp.	*Surirella splendida* (Ehrenberg) Kützing
Nitzschia fonticola 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^{th} 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
Phyrrophyta	1,100	300	600

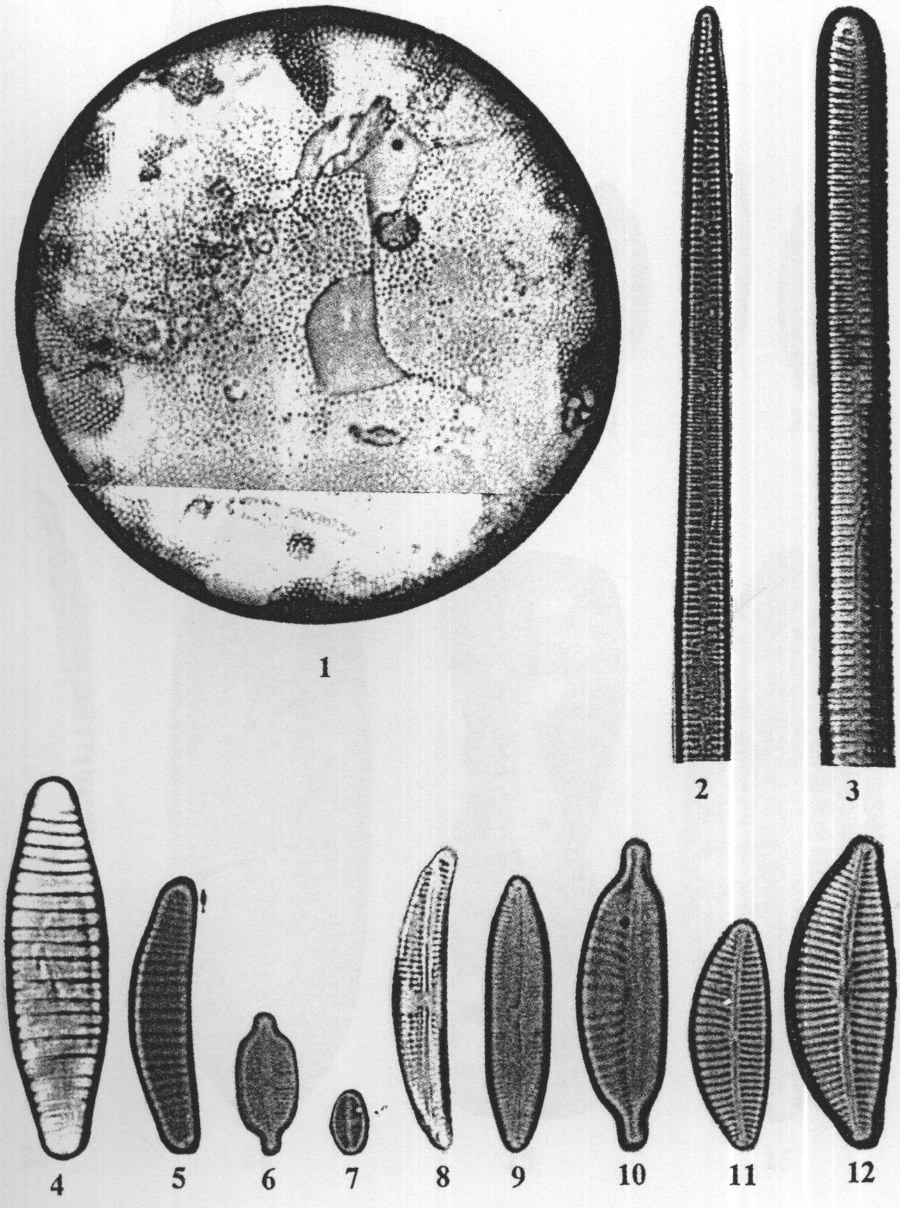

Figure 2. Light micrographs showing some newly recorded species of diatoms in Mae Sa Stream, Suthep–Pui National Park, Chiang Mai (scale bar = 10 µ).
1, *Actinocyclus normanii* (Gregory) Hustedt; 2, *Fragilaria biceps* (Kützing) Lange-Bertalot; 3, *Fragilaria ulna* (Nitzsch) Lange-Bertalot; 4, *Diatoma vulgaris* Bory; 5, *Eunotia minor* (Kützing) Grunow; 6, *Achnanthes exigua* Grunow var. *exigua*; 7, *Achnanthes 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

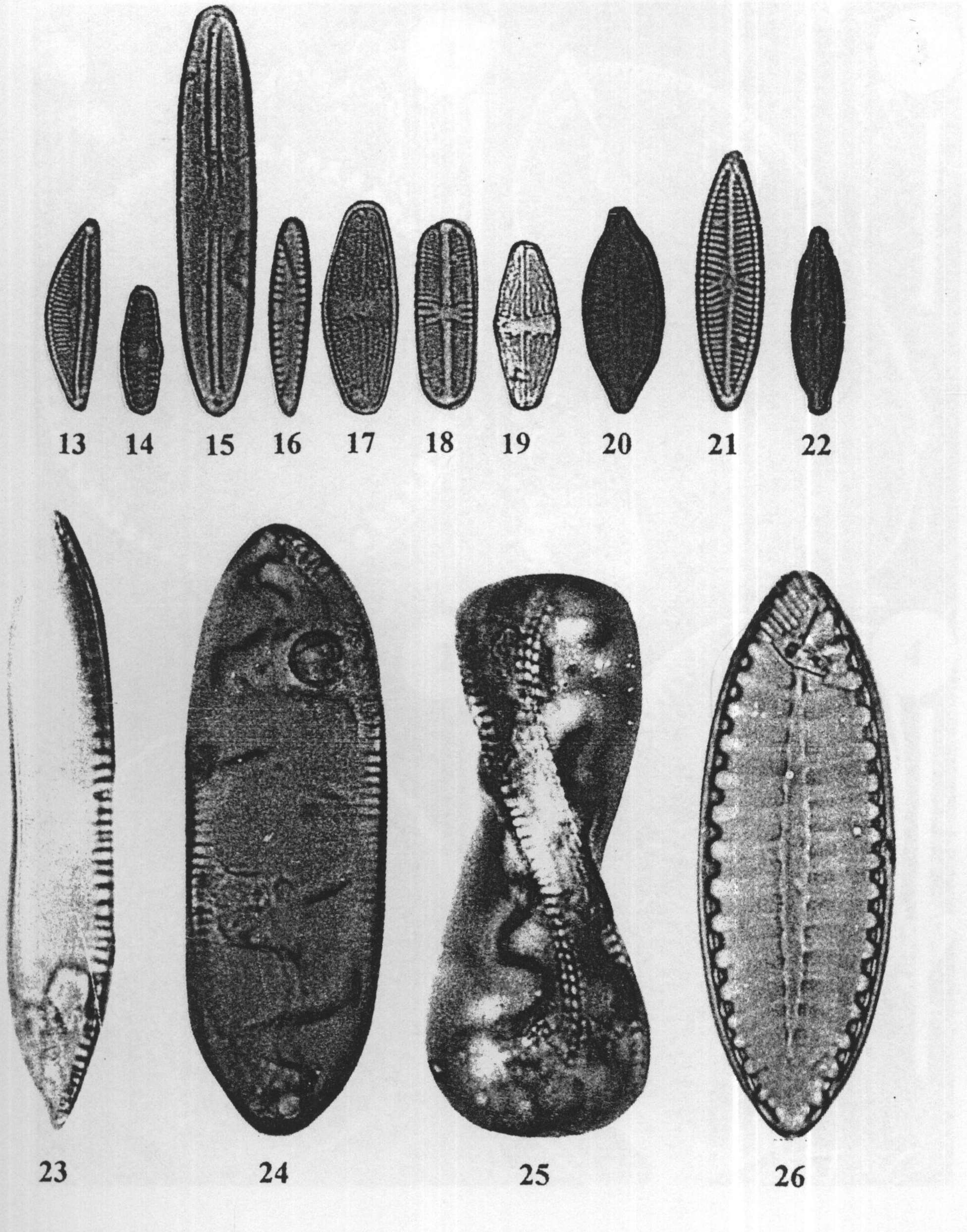

Figure 3. Light micrographs show some newly recorded species of diatom in Mae Sa Stream, Suthep–Pui National Park, Chiang Mai (scale bar = 10 μ).
13, *Cymbella silesiaca* Bleisch; 14, *Cymbella sinuata* Gregory; 15, *Frustulia weinholdii* Hustedt; 16, *Gonphonema pumilum* var. *rigidum*; 17, *Navicula 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 spiraloides* Ehrenberg; 26, *Surirella splendida* (Ehrenberg) Kützing

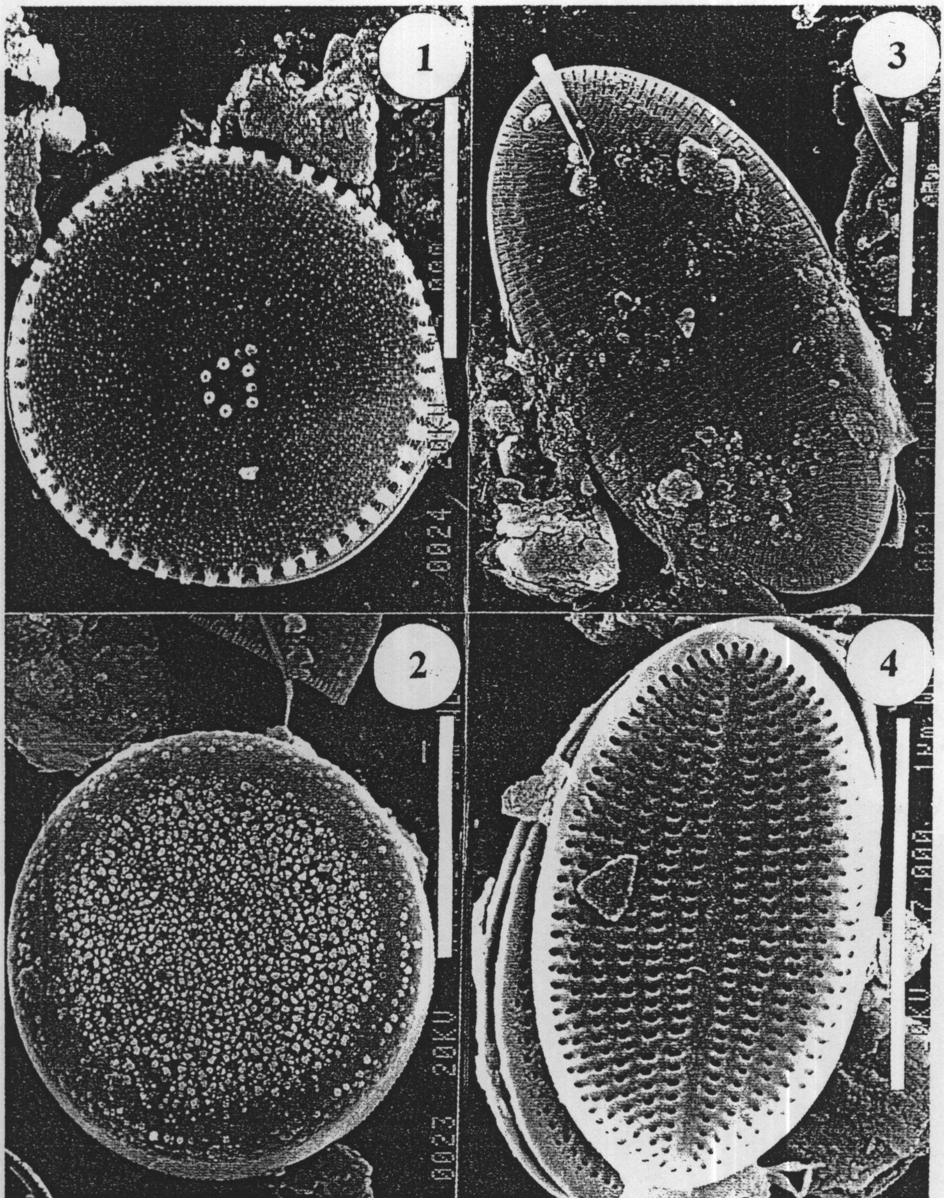

Figure 4. SEM Micrographs (scale bars = 10 µ)
1, *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle; 2, *Melosira varians* Agardh (valve view); 3, *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow; 4, *Cocconeis placentula* var. *pseudolineata* Geitler

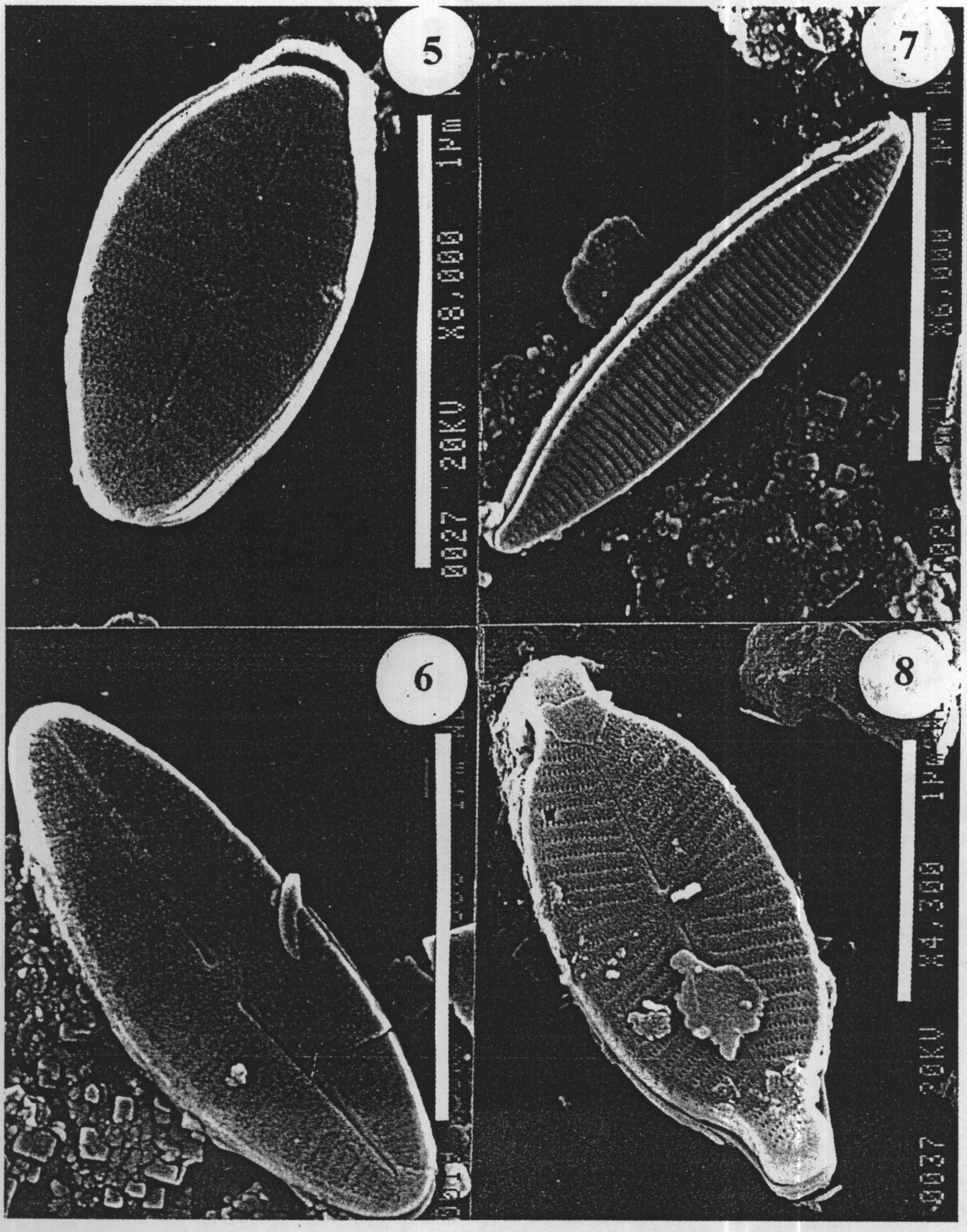

Figure 5 SEM Micrographs (scale bars = 10 μ)
5, *Achnanthes lanceolata* (Brébisson) Grunow? (rapheless valve); 6, *Achnanthes lanceolata* (Brébisson) Grunow (raphae valve); 7, *Nitzschia* sp.; 8, *Navicula elginensis* (Gregory) Ralfs var. *elginensis*

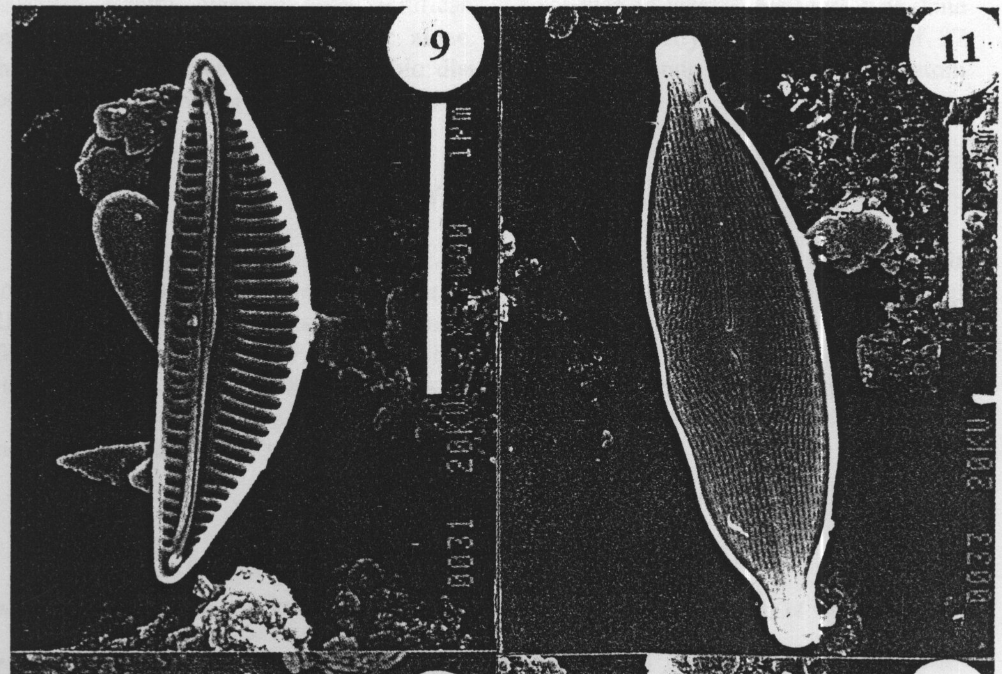

Figure 6. SEM Micrographs (scale bars = 10 μ)
9–10, *Cymbellopsis* sp.; 11, *Navicula* sp.: 12, *Surirella* sp.

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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