Phytoplankton Community in the Pasak Jolasid Reservoir, Lop Buri Province

Apiradee Hanpongkittikul and Ladda Wongrat*

*Department of Fishery Biology, Faculty of Fisheries,
Kasetsart University, Bangkok 10900, Thailand

ABSTRACT

Qualitative aspect of the phytoplankton of Pasak Jolasid reservoir was studied during 2002. A total of 159 species and 81 varieties was recorded. Phytoplankton samples were collected by towing plankton nets of three mesh sizes 22, 40 and 100 μm at 29 stations. Green algae (Class Chlorophyceae) comprised the majority of species number with 54%, and followed by euglenoids (Class Euglenophyceae) with 17%. Other groups in decreasing number were Class Cyanophyceae, Class Bacillariophyceae, Class Dinophyceae, Class Xanthophyceae and Class Chrysophyceae. Important genera were *Scenedesmus, Pediastrum, Crucigenia, Closterium, Tetraedron, Coelastrum, Trachelomonas* and *Phacus*. Temporal and spatial variation in species numbers were not significantly different ($P<0.05$) in this study.

Key Words: phytoplankton, species composition, Pasak Jolasid reservoir, Thailand, tropical region

INTRODUCTION

Phytoplankton is the crucial part of aquatic food chain. As the primary producer, phytoplankton converts inorganic matters into organic compounds through photosynthesis, enabling transfers of energy and nutrients to zooplankton and other aquatic animals in the food chain. Each species of phytoplankton inhabits in different environments. Some live in areas with high concentration of organic matters, others are found in reservoirs with moderate concentration of organic matter while a number of species thrive in environment with little organic matter. Some phytoplankton species can thus be used as water quality index (Round, 1973), particularly for pollution caused by organic matters. Most plankton has short life cycle and can quickly respond to changing environment, such as in the case of water pollution.

Pasak Jolasid dam is a part of His Majesty's initiative on development of Pasak River basin. The earth dam is located in Pattana Nikom district, Lop Buri province and has effectively created a large reservoir, Pasak Jolasid reservoir, with maximum storage capacity of 960 million cubic meters. The dam itself was constructed to mitigate flooding in Pasak River basin and Lower Chao Praya river basin, which includes Bangkok and adjacent provinces. In addition, the dam was aimed to be used to tackle the problem of water shortage in agriculture, to provide water storage for consumption and industry, to enable introduction of new technologies for water management in irrigation projects as well as accommodate breeding of commercial fish species and large-scale fishing activities in the area (Royal Irrigation Department, 1999). Being a newly built reservoir, very little information on plankton in Pasak Jolasid has been made available. There were also few studies on plankton in Pasak river prior to the construction of the dam. These studies include environmental impact assessment of

the dam project by the Royal Irrigation Department, impact assessments on constructions of factories along Pasak river in Saraburi province (Royal Irrigation Department, 1997, 1998) and study by Jinowat (2000) on plankton distribution in a section of Pasak river located in Phra Nakhon Si Ayutthaya province, further south of the dam. These studies are not particularly relevant in understanding plankton distribution in the reservoir. Therefore, new investigation is thus needed.

Dam construction can bring about several changes to natural reservoirs, including their aquatic ecosystems. Studies on ecosystems, biodiversity and fishery resources after the constructions are essential in understanding these changes in enabling effective reservoir management and efficient use of their natural resources. As a newly built reservoir, carrying out such study in Pasak Jolasid reservoir is important. This study is a part of the project entitled "Strategies for Sustainable Management of Fishery Resources in the Pasak Jolasid Reservoir, Thailand through Ecological and Socioeconomic (SUMAFISH)" which aimed to investigate fishery resources in the reservoir for sustainable management of fishery. The purposes of this study are to investigate the species composition of phytoplankton in the reservoir, and whether there are temporal and spatial variation of phytoplankton community in the study area. Results of this study can be used as baseline information for future diversity and ecological studies of phytoplankton in reservoirs of Thailand.

MATERIALS AND METHODS

Study sites

Pasak Jolasid reservoir is located in Pasak river at latitude 14° 50' 32" N and longitude 101° 05' 00" E, linking Nong Bua village, Nong Bua Sub-district, Pattana Nikom district, Lop Buri province on one side with Kum Pran village, Kum Pran Sub-district, Wang Moung district, Saraburi province on the other. The dam receives most of water from Pasak river, which is originated from Phetchabun mountain range located in Dan Sai district, south of Loei province. The dam has been operational since September 1999 with maximum storage capacity of to 960 cubic meters at 45 meters above the sea level. At normal storage, the reservoir covers approximately 149 square kilometers (21,680 ha). The study of the reservoir covered from the dam itself (latitude 14° 50' N) to upstream area around Tadindum village, Chaibadan district, Lop Buri province (latitude 15° 11' N). Twenty-nine sampling stations were used in the study to ensure proper coverage of the whole reservoir. These stations were located in 4 separated areas divided by different latitudes. (Figure 1).

Sampling methods

Samples were collected 6 times every 2 months during 2002. Plankton nets with mesh size 22, 40 and 100 μm were used in collecting samples with oblique tow technique. Phytoplankton samples were preserved with 4% formaldehyde solution. Olympus CK30 microscopes and Sedgwick-Rafter slides were used in studying species identification. Species classification of the samples was mainly based on Desikachary (1959), Prescott (1962), West and West (1904, 1905, and 1908), Wongrat (1999), and Yamagishi (1992). Round (1973) and Smith (1950) were also used as complementary references for the classification. We followed the classification system recommended by Christensen (1962 cited by Wongrat, 1999).

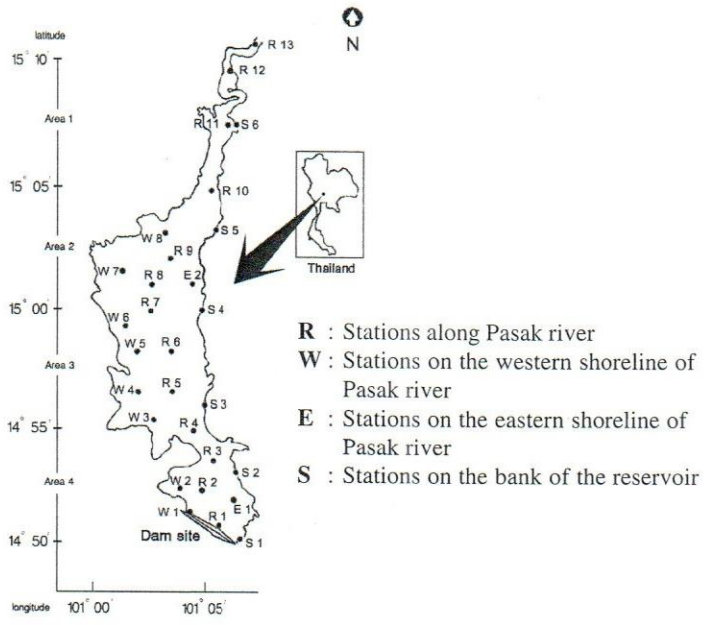


Figure 1 Sampling stations for phytoplankton in the Pasak Jolasid reservoir, Lop Buri province

RESULTS AND DISCUSSIONS

The study of phytoplankton community in Pasak Jolasid from February to December 2002 was conducted with 942 samples. We found 3 divisions of phytoplankton, 66 genera, 159 species and 18 varieties. Most of the species found belonged to Class Chlorophyceae (green algae), which had the highest number of species with 32 genera 87 species and 9 varieties (54%), followed by Class Euglenophyceae (euglenoids) with 5 genera 28 species 7 varieties (17%), Class Cyanophyceae (blue-green algae) with 10 genera 22 species (14%), Class Bacillariophyceae (diatoms) with 14 genera 16 species 2 varieties (10%), Class Dinophyceae (dinoflagellates) with 3 genera 4 species (3%), Class Xanthophyceae (yellow green algae) with 1 genera 2 species (1%) and Class Chrysophyceae (chrysophytes) with 1 genus 1 species (1%), respectively (Figure 2). The most diverse genus was *Scenedesmus* which was frequently occured throughout the study with 15 species followed by *Trachelomonas* 10 species, *Phacus* 9 species, *Pediastrum* 7 species, *Tetraedron* 6 species, *Crucigenia, Closterium* and *Coelastrum* 5 species, each. These 8 genera have been classified as cosmopolitan genera (Prescott, 1962; Wongrat, 1999).

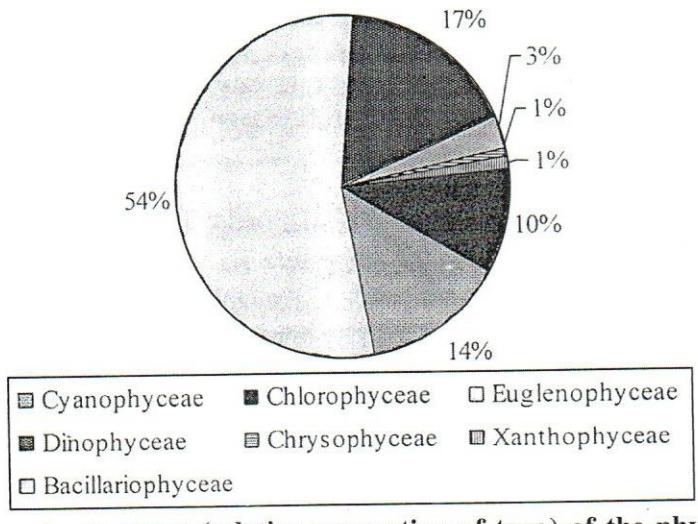


Figure 2 Taxonomic structure (relative proportion of taxa) of the phytoplankton in Pasak Jolasid reservoir

Table 1 gives a list of phytoplankton found in the reservoir. Additional photomicrographs are provided in Plates 1-3.

Table 1 List of phytoplankton found in the Pasak Jolasid reservoir (Feb.-Dec. 2002). The symbol * indicates figure presented in Plates 1-3.

Division Cyanophyta
Class Cyanophyce ae (Blue green algae; Cyanobacteria)
Family Chroococcaceae
Chroococcus minutus (Kützing) Naegeli*
C. turgidus (Kützing) Naegeli
Merismopedia convoluta Brébisson
M. minima Beck
M. punctata Meyen
M. tenuissima Lemmermann*
Microcystis aeruginosa Kützing*
Myxosarcina burmensis Skuja
Order Nostocales
Family Oscillatoriaceae
Lyngbya limnetica Lemmermann
Oscillatoria sp.1
Oscillatoria sp.2
O. limnetica Lemmermann*
O. tenuis C.A. Agardh
Phormidium mucicola Naumann & Huber-Pestalozzi
Spirulina sp.
S. major Kützing
S. platensis (Nordstedt) Geitler*
Family Nostocaceae
Anabaena affinis Lemmermann*
A. fertilissima Rao
A. spiroides Klebahn
Cylindrospermopsis raciborskii (Wołoszynska) Seenayya et Subba Raju*
C. phillipinensis (Taylor) Komárek
Division Chlorophyta
Class Chlorophyceae (Green algae)
Order Volvocales
Family Volvocaceea
Eudorina elegans Ehrenberg*
Gonium pectorale Müller*
Pandorina morum (Müller) Bory*
Volvox tertius A. Meyen*
Order Chlorococcales
Family Chlorococcaceae
Golenkinia radiata (Chodat) Wille
Family Hydrodictyaceae
Pediastrum sp.1
Pediastrum sp.2
P. duplex var. gracilimum West & West
P. obtusum Lucks
P. simplex (Meyen) Lemmermann
P. simplex var. *duodenarium* (Bailey) Rabenhorst*
P. simplex var. *echinulatum* Wittrock*
Family Coelastraceae
Coelastrum astroideum De Notaris*
C. cambricum Archer

Table 1 (Cont.)

Coelastrum microporum Naegeli
C. reticulatum (Dangeard) Senn
C. sphaericum Naegeli

Family Botryococcaceae

Botryococcus braunii Kützing*

Family Oocystaceae

Ankistrodesmus convolutus (Corda) Ralfs
A. falcatus (Corda) Ralfs
Chlorella vulgaris Bayerinck
Chodatella chodatii (Bernard) Ley
C. citriformis Snow
Dictyosphaerium ehrenbergianum Naegeli
D. pulchellum Wood*
Monoraphidium caribeum Hindak
Monoraphidium contortum (Thuret) Komarkova-Legnerova
M. griffithii (Berkeley) Komarkova-Legnerova
Nephrocytium limneticum (G.M. Smith) G.M. Smith
Oocystis elliptica W. West
O. parva West & West
Quadricoccus laevis Fott
Selenastrum westii G.M. Smith
Tetraedron caudatum (Corda) Hansgirg
T. gracile (Riensch) Hansgirg
T. minimum (Braun) Hansgirg
T. minutissimum Korschikoff
T. regulare Kützing
T. trigonum (Naegeli) Hansgirg var. *gracile* (Reinsch) De Toni
Treubaria schmidlei (Schroeder) Fott & Kovacik

Family Scenedesmaceae

Actinastrum gracillimum G.M. Smith
A. hantzschii Lagerheim
Crucigenia crucifera (Wolle) Collins
C. lauterbornii Schmidle*
C. neglecta Fott & Ettl
C. tetrapedia (Kirchner) W.& G.S. West
C. rectangularis (A. Braun) Gay
Kirchneriella contorta (Schmidle) Bohlin var. *gracillima* (Bohlin) Chodat
K. dianae (Bohlin) Comas
K. lunaris (Kirchner) Moebius*
Micractinium sp.1
M. bornhemiense (Conrad) Korschikoff
M. pusillum Fresenius
M. quadrisetum (Lemmermann) G.M.Smith
Scenedesmus sp.
S. armatus (Chodat) G.M. Smith
S. acuminatus (Lagerheim) Chodat*
S. acutiformis Schroeder
S. bijuga (Turpin) Lagerheim
S. bernardii G.M. Smith
S. denticulatus Lagerheim
S. dimorphus (Turpin) Kützing
S. disciformis Chodat (Fott) & Komarek
S. javanensis Chodat
S. pannonicus Hortobagyi
S. producto-capitatus Schmula
S. protuberans Fristch & Rich
S. quadricauda (Turpin) Brébisson*
S. smithii Teiling
Tetrastrum heteracanthum (Nordstedt) Chodat
T. staurogeniforme (Schroeder) Lemmermann

Order Oedogoniales

Family Oedogoniaceae

Oedogonium sp.

Order Zygnematales

Family Zygnemataceae

Mougeotia scalaris Hassell
Spirogyra weberi Kützing

Family Desmidiaceae

Closterium acerosum (Schrank) Ehrenberg
C. acerosum (Schrank)Ehrenberg var. *elongatum* Brébisson
C. limneticum Lemmermann
C. moniliferum (Bory) Ehrenberg*
C. praelongum Brébisson
C. binum Nordstedt
C. contractum Kirchner
C. laeve Rabenhorst
C. punctulatum Brébisson
C. subprotumidum Nordstedt var. *gregorii* (Roy & Bisset) W.& G.S. West
Euastrum spinulosum Delponte
Staurastrum gracile Ralfs
S. limneticum Schmidle var. *burmense* West & West
S. octoverucosum Scott
S. sebaldi Reinsch var. *ornatum* Nordstedt*
Staurastrum tetracerum (Kützing) Ralf

Class Euglenophyceae (Euglenoids)

Order Euglenales

Family Euglenaceae

Euglena acus Ehrenberg
E. oxyuris Schmarda var. *charkowiensis* (Swirenko) Chu
E. proxima Dangeard
E. spirogyra Ehrenberg
Lepocinclis constrictus Matvienko
L. ovum (Ehrenberg) Lemmermann
Phacus angulatus Pochmann
P. hamatus Pochmann
P. helikoides Pochmann
P. longicauda (Ehrenberg) Dujardin var. *rotundus* (Pochmann) Huber-Pestalozzi
P. longicauda (Ehrenberg) Dujardin var. *insecta* Koezvara

Table 1 (Cont.)

Phacus myersi Skvortzow*
P. pleuronectes (O.F.Müller) Dujardin*
P. ranula Pochmann
P. tortus (Lemmermann) Skvortzow
Trachelomonas armata (Ehrenberg) Stein
f. *coronata* Deflandre
T. crebea Kellicott*
T. hispida (Perty) Stein*
T. intermedia Dangeard var. *papillifera* (Popova) Popova
T. lacustris Drezepolski
T. mirabilis Swirenko var. *affinis* Skvorzow
T. ovalis Playfair var. *minor* Playfair*
T. scabra Playfair
T. similis Stokes
T. volvocina Ehrenberg var. *minuta* Fritsch
Strombomonas sp.
S. fluviatilis (Lemmermann) Deflandre*
S. gibberosa (Playfair) Deflandre
Division Chromophyta
Class Bacillariophyceae (Diatoms)
Order Biddulphiales (Centric diatoms)
Family Thalassiosiraceae
Cyclotella meneghiniana Kützing
Family Aulacoseiraceae
Aulacoseira granulata (Ehrenberg) Simonsen*
Order Bacillariales (Pennate diatoms)
Suborder Fragiariineae
Family Fragilariaceae
Fragilaria sp.
F. ulna var. *acus* (Kützing) Lange
Synedra ulna (Nitzsch) Ehrenberg
Suborder Bacillariineae
Family Achnanthaceae
Achnanthes sp.
Family Cymbellaceae
Cymbella tumida (Brébisson) Van Heurck
Encyonema sp.
Gomphonema spp.
Family Naviculaceae
Gyrosigma spencerii (Quekett) Griffith & Henfrey
Navicula spp.
Family Bacillariaceae
Nitzschia spp.
Family Rhopalodiaceae
Rhopalodia sp.
Family Surirellaceae
Stenopterbia sp.
Surirella sp.
S. robusta Ehrenberg var. *splendida* van Heurck*
Class Chrysophyceae (Chrysophytes; Yellow algae)
Order Ochromonadales
Family Dinobryaceae
Dinobryon sertularia Ehrenberg*
Class Xanthophyceae (Yellow green algae)
Order Mischococcales
Family Scidiaceae
Centritractus belonophorus Lemmermann
C. brunneus Fott
Order Gonyolacales
Family Ceratiaceae
Ceratium brachyceros Daday*
Family Peridiniaceae
Peridinium cunningtonii (Lemmermann) Lemmermann*
P. inconspicuum Lemmermann
Family Glenodiniaceae
Glenodinium sp.

Oscillatoria limnetica, Cylindrospermopsis raciborskii and *Microcystis aeruginosa* were the most common species being found in all samples. This is consistent with Wetzel (1975) who stated that cyanobacteria, particularly *Oscillatoria* and *Microcystis,* can be found in nutrient rich environments. *Cylindrospermopsis raciborskii* is a phytoplankton with heterocyst capable of nitrogen fixation (Wongrat, 1987). *Aulacoseira granulata* was the dominant species being found at almost all sampling stations throughout this study. This species is a diatom with long chain and tough cell wall and has been known to block filters used in water treatment when its population expands rapidly (Pekkoh, 2002).

Number of phytoplankton species in Pasak Jolasid reservoir fluctuated between seasons. The highest species number was recorded in December (124 species) and the lowest level in April (102 species). There was not any difference in species compositions between sampling periods (Figure. 3) and no significantly different in number of phytoplankton species between sampling stations (Figure 4). Class Chlorophyceae was the most diverse group, followed by Class Euglenophyceae, Class Cyanophyceae, Class Bacillariophyceae, Class Dinophyceae, Class Xanthophyceae and Class Chrysophyceae, respectively. The highest

number of species was observed at station R5 located on the Pasak river, whereas stations S4 (located on the east bank of the reservoir) and R12 (located on the Pasak river) contained the same number of species (88). The phytoplankton species of the Pasak Jolasid reservoir started to increase in February. The number was relatively stable in April and increased again until reached the highest value in December.

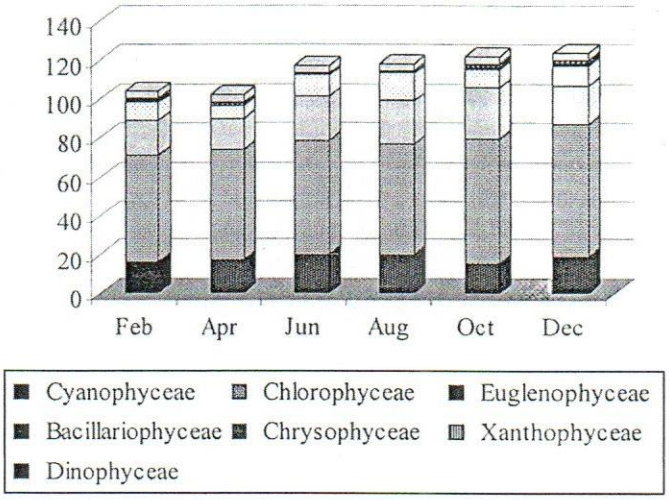


Figure 3 Temporal variation in species number of phytoplankton

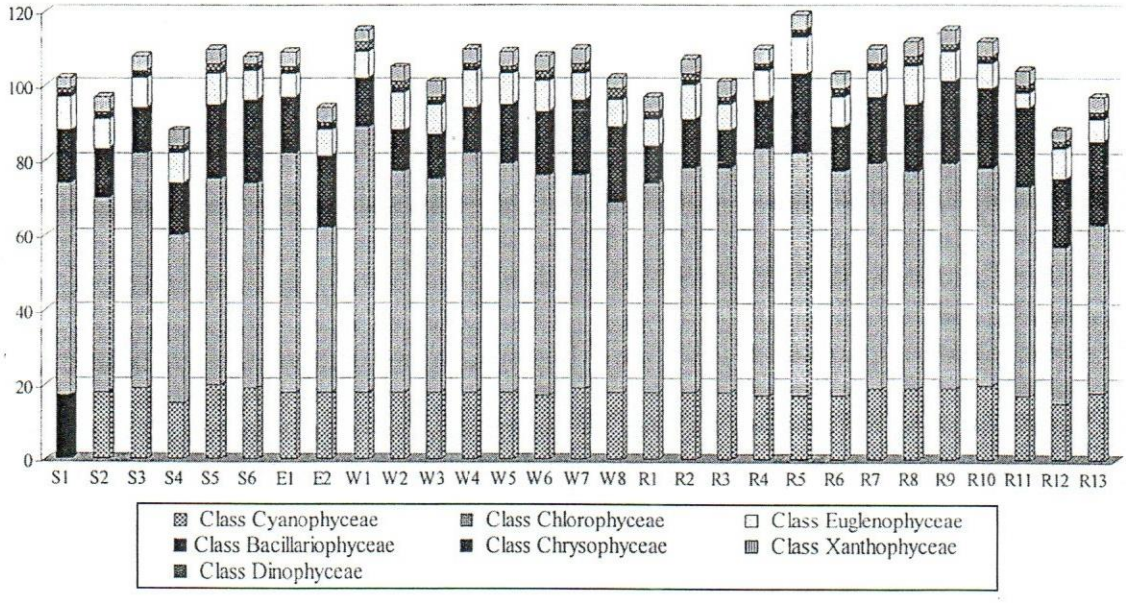


Figure 4 Spatial variation in species number of phytoplankton

This study found larger number of species of phytoplankton than those reported by environment impact assessment of the Pasak Jolasid dam conducted prior to the construction of the dam by Royal Irrigation Department (1993). The RID found only 35 phytoplankton species. Different sampling tool (three different mesh size of plankton nets) and the use of 29 sampling stations could contribute to the increase in the species number. However, physical change of the reservoir from riparian to static was likely to result in larger and more diverse populations of phytoplankton, by making available more nutrient and better overall water quality (Rukamatu, 2001). Three blooming species of phytoplankton, *Microcystis aeruginosa, Cylindrospermopsis raciborskii* and *Aulacoseira granulata,* were found in considerable numbers and could be used as indicating species of eutrophication in the reservoir. The first two species were regularly dominant throughout the water column, except the latter species was dominant at 10-20 meters in August and October. These cyanophyte-dominated communities are typical of a highly eutrophic, often well mixed and turbid environment (Reynolds, 1984).

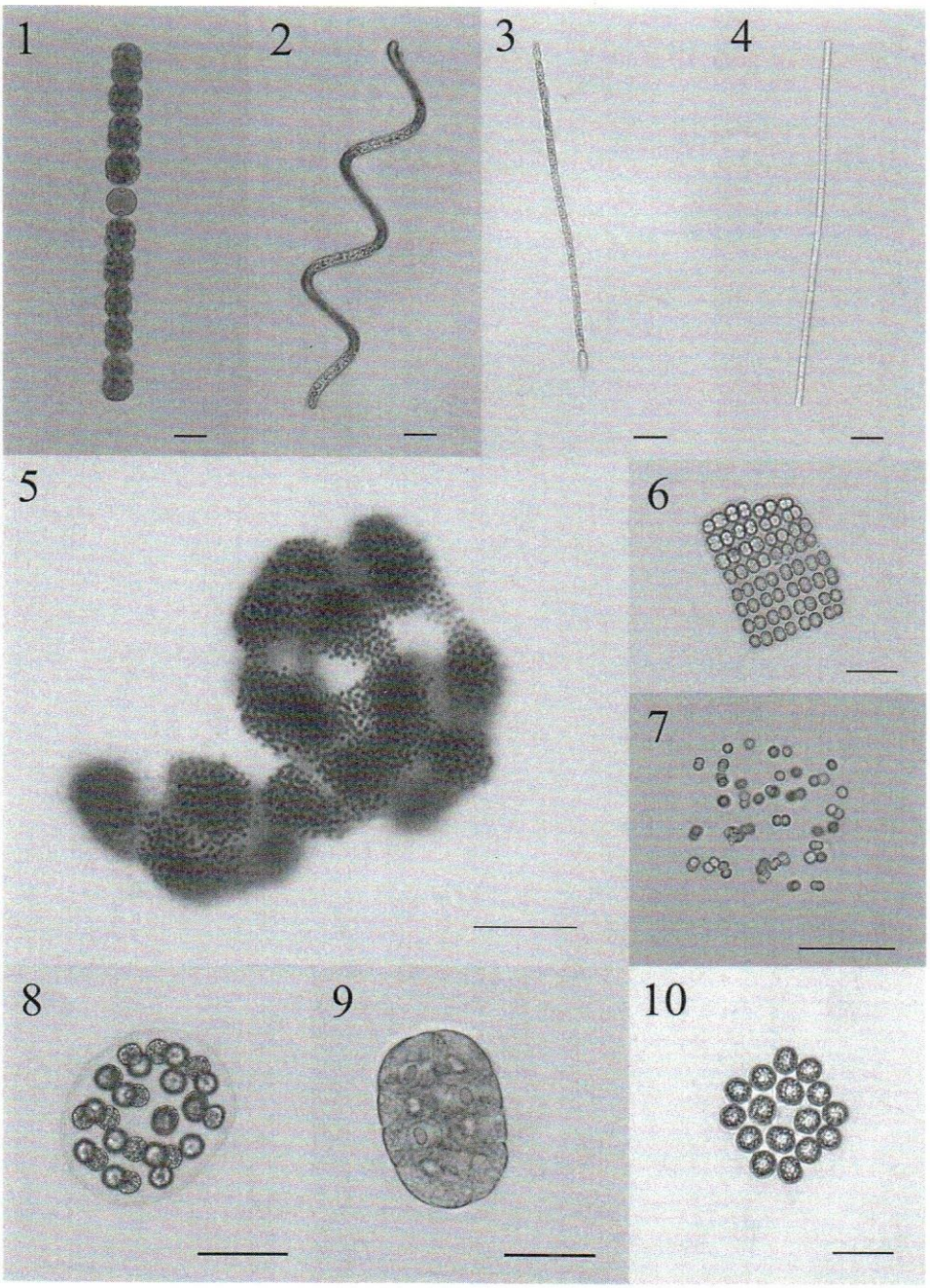
CONCLUSIONS

A phytoplankton taxon number of 159 species and 18 varieties was recorded in the Pasak Jolasid reservoir in 2002, with the following percentages : 54% Chlorophyceae, 17% Euglenophyceae, 14% Cyanophyceae, 10% Bacillariophyceae, and 5% other algae. There was not seasonal change in species composition throughout the study period. The largest number (124) and the lowest number (102) of species were recorded in December and April, respectively. However, no significant difference ($P<0.05$) in species number of the phytoplankton community of the reservoir was found. Common genera were *Scenedesnus, Pediastrum, Crucigenia, Closterium, Tetraedron, Coelastrum, Trachelomonas,* and *Phacus.* The dominance of *Cylindrospermopsis raciborskii* and *Microcystis aeruginosa* was regularly observed in the water column, while *Aulacoseira granulata* was occasionally dominant at the depths 10-20 m. in August and October. The results provide useful knowledge on phytoplankton community for further study phytoplankton in the Pasak Jolasid reservoir. To control eutrophication in the reservoir, detailed investigation on blooming of blue-green algae should be conducted in relation to physical and chemical qualities of water.

ACKNOWLEDGEMENTS

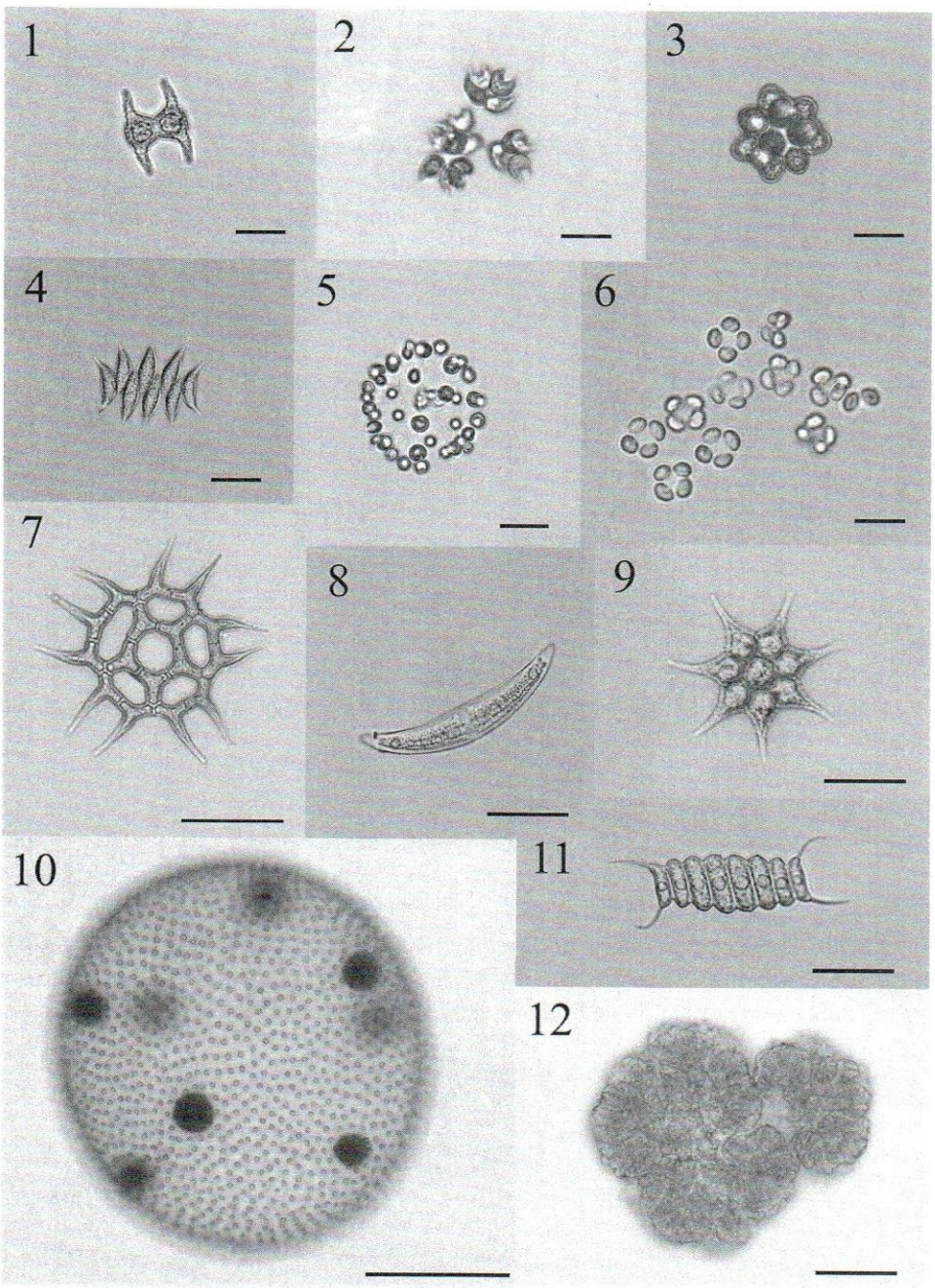
This study was funded by the Asean Regional Center for Biodiversity Conservation (ARCBC) and the European Commission. We thank the Freshwater Fishery Resource Conservation Unit of Pasak Jolasid Area and the Royal Irrigation Department (Pasak Jolasid Dam Unit) for their essential supports during our field trips.

PLATE 1



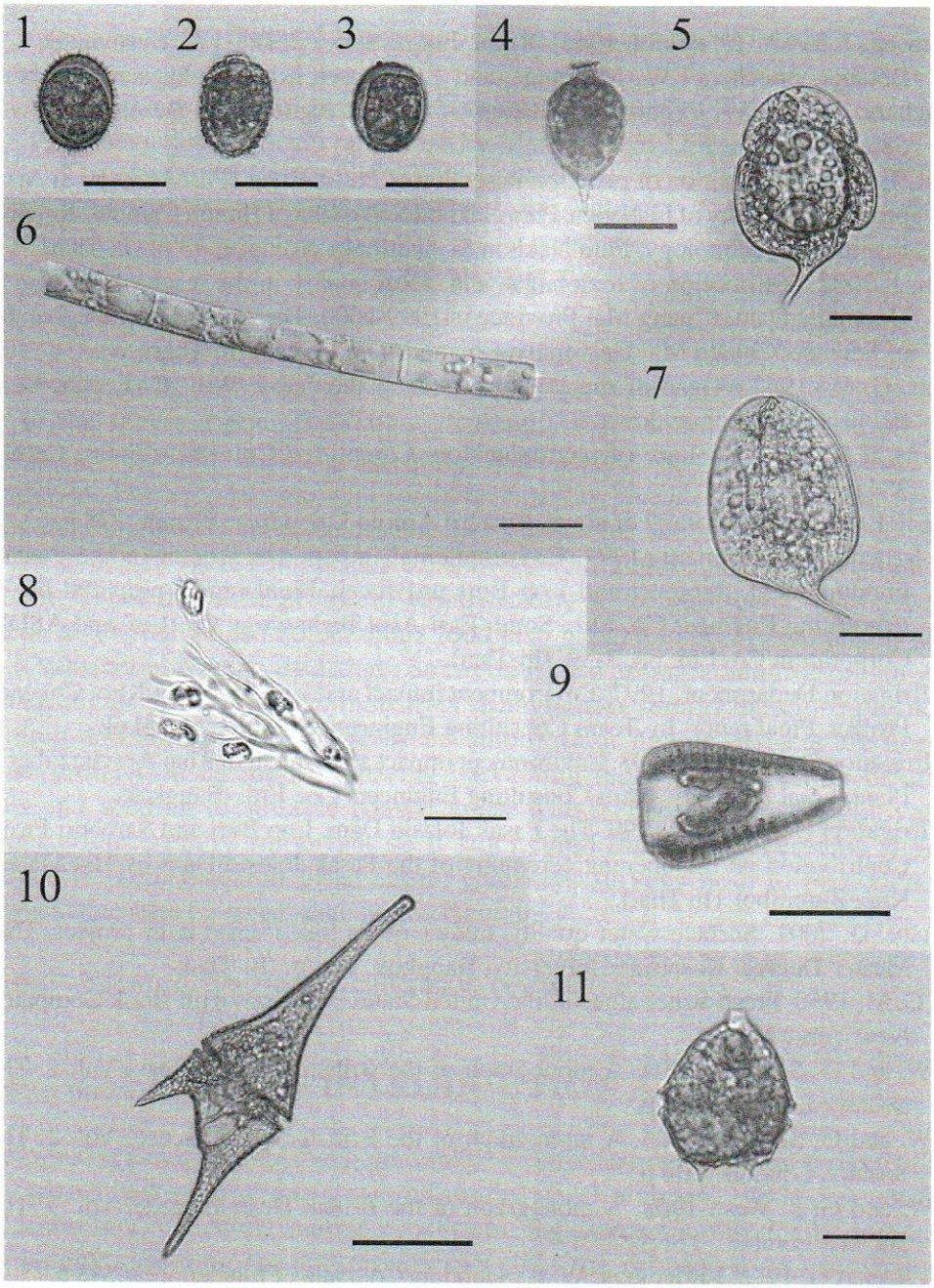
Phytoplankton in the Pasak Jolasid reservoir
(1) *Anabaena affinis;* (2) *Spirulina platensis;*
(3) *Cylindrospermopsis raciborski;* (4) *Oscillatoria limnetica;*
(5) *Microcystis aeruginosa;* (6) *Merismopedia tenuissima;*
(7) *Chroococcus minutus;* (8) *Eudorina elegans;*
(9) *Pandorina morum;* (10) *Gonium pectorale*
Scale bars of Figs. 1-4 10μm; Figs.6, 10 20 μm; Figs. 5, 7, 8, 9 50 μm

PLATE 2



Phytoplankton in the Pasak Jolasid reservoir (cont.)
(1) *Staurastrum sebaldi* var. *ornatum;* (2) *Kirchneriella lunaris;*
(3) *Coelastrum astroideum;* (4) *Scenedesmus acuminatus;*
(5) *Dictyosphaerium pulchellum;* (6) *Crucigenia lauterbornii;*
(7) *Pediastrum simplex* var. *duodenarium;* (8) *Closterium moniliferum;*
(9) *Pediastrum simplex* var. *echinulatum;* (10) *Volvox tertius;*
(11) *Scenedesmus quadricauda;* (12) *Botryococcus braunii*
Scale bars of Figs. 1-6 10μm; Figs.7-9, 11-12 50 μm; Figs. 10 50 μm

PLATE 3



Phytoplankton in the Pasak Jolasid reservoir (cont.)
(1) *Trachelomonas hispida;* (2) *Trachelomonas crebea;*
(3) *Trachelomonas ovalis* var. *minor;* (4) *Strombomonas fluviatilis;*
(5) *Phacus myersi;* (6) *Aulacoseira granulata;*
(7) *Phacus pleuronectes;* (8) *Dinobryon sertularia;*
(9) *Surirella robusta* var. *splendida;* (10) *Ceratium brachyceros;*
(11) *Peridinium cunningtonii*
Scale bars of Figs. 1-8, 11 20μm; Figs.9, 10 50 μm

REFERENCES

Christensen, T. 1962. (2nd edition 1966). Alger. In : *Botanik.*, 2(2):1-178. Systematik Botanik. Boecher, T.W., M. Lange, and T. Sorensen Eds. Munksgaard, Koebenhavn.

Desikachary, T. V. 1959. Cyanophyta. Indian Council of Agricultural Research, New Delhi. 686 p.

Jinowat, T. 2000. Distribution of plankton in section of Pasak River (Phra Nakhon Si Ayutthaya province). Faculty of Fisheries, Phra Nakhon Si Ayutthaya Huntra Campus, Rajamangala Institute of Technology, Phra Nakhon Si Ayutthaya province. 43 p. (In Thai).

Pekkoh, J. 2002. Distribution of toxic algae and water quality in the reservoir of Mae Kuang Udomtara Dam, Chiang Mai Province in 1999-2000. Thesis of Master Degree, Faculty of Science. Chiang Mai University, Chiang Mai province. (In Thai).

Prescott, G. W. 1962. Algae of the Western Great Lakes area. Wm. C. Brown Company Publishers, Dubuque, Iowa. 977 p.

Reynolds, C.S. 1984. Ecology of phytoplankton. Cambridge University Press, Cambridge. 384 p.

Round, F. E. 1973. The biology of algae. Edward Arnold Ltd., Great Britain. 278 p.

Royal Irrigation Department. 1993. Environmental impact assessment of the Pasak river impoundment, Saraburi and Lop Buri provinces. Final report prepared by TEAM Consulting Engineer Co. Ltd., South East Asia Technology Co. Ltd. and ASDECON Corporation Co. Ltd. pp. 3-39. (In Thai).

Royal Irrigation Department. 1997. Environment impact assessment Kaeng Khoi Cogeneration Project. Final report by Team Consulting Engineers Co., Ltd., Bangkok.

Royal Irrigation Department. 1998. Environment impact assessment of Thai Acrylic Fiber Power Plant. Final report by Team Consulting Engineers Co., Ltd., Bangkok.

Royal Irrigation Department. 1999. The Pasak Jolasid Dam, Lop Buri and Saraburi Provinces. Contribution on the opening ceremony of the Pasak Jolasid Dam by His Majesty the King Bhumibol. (In Thai).

Rukamatu, D. 2001. Surface water quality studies of Pa Sak Jolasid dam project. Thesis of Master Degree, Kasetsart University, Bangkok. 176 p. (In Thai).

Smith, G. M. 1950. Fresh-water algae of the United States. Mc Graw-Hill Book Company. Inc., New York. 719 p.

West, W. and G. S. West. 1904. A monograph of the British Desmidiaceae. Vol. 1. The Ray Society, London. 224 p.

West, W. and G. S. West. 1905. A monograph of the British Desmidiaceae. Vol. 2. The Ray Society, London. 204 p.

West, W. and G. S. West. 1908. A monograph of the British Desmidiaceae. Vol. 3. The Ray Society, London. 274 p.

Wetzel, Robert G. 1975. Limnology. W. B. Saunders Company, Philadenphia. 743 p.

Wongrat, L. 1987. Plankton. Department of Fishery Biology, Faculty of Fisheries, Kasetsart University, Bangkok. 259 p. (In Thai).

Wongrat, L. 1999. Phytoplankton. Kasetsart University Press, Bangkok. 851 p. (In Thai).

Yamagishi, T. 1992. Plankton algae in Taiwan (Formosa). Uchida Rokakuho Publishing Co., Ltd., Tokyo. 253 p.