APPENDICES

APPENDIX A

WATER QUALITY ASSESSMENT

Classification of water quality

Classification of trophic level by using water characteristic and dominant phytoplankton according to the criteria of Lorraine and Vollenweider (1981), Wetzel (2001) (Tables 1-3), and Peerapornpisal *et al*. (2007).

Table 1 Assessment of water quality by considering amount of total phosphorus, nitrogen, chlorophyll a and secchi depth (Lorraine and Vollenweider, 1981)

Variable (Annual Mean Values)		Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total phosphorus	mean	8.0	26.7	84.4	
$mg.m^{-3}$	$x \pm 1$ s.d.	4.85 – 13.3	14.5 – 49	38 – 189	
	$x \pm 2$ s.d.	2.9 – 22.1	7.9 – 90.8	16.8 – 424	
	Range	3.0 – 17.7	10.9 – 95.6	16.2 – 386	750 – 1200
	n	21	19 (21)	71 (72)	2
Total nitrogen	mean	661	753	1875	
$mg.m^{-3}$	$x \pm 1$ s.d.	371 – 1180	485 – 1170	861 – 4081	
	$x \pm 2$ s.d.	208 – 2103	313 – 1816	395 – 8913	
	Range	307 – 1630	361 – 1387	393 – 6100	100 – 150
	n	11	8	37 (38)	2
Chlorophyll a	mean	4.2	16.1	42.6	
$mg.m^{-3}$	$x \pm 1$ s.d.	2.6 – 7.6	8.9 – 29	16.9 – 107	
	$x \pm 2$ s.d.	1.5 – 13	4.9 – 52.5	6.7 – 270	
	Range	1.3 – 10.6	4.9 – 19.5	9.5 – 275	
	n	1.3 – 10.6	4.9 – 49.5	9.5 – 275	
Secchi Depth	mean	9.9	4.2	2.45	
m.	$x \pm 1$ s.d.	5.9 – 16.5	2.7 – 7.4	1.5 – 4.0	
	$x \pm 2$ s.d.	3.6 – 27.5	14 – 13	0.9 – 6.7	
	Range	5.4 – 28.3	1.5 – 8.1	0.8 – 7.0	0.4-0.5
	n	13	20	70 (72)	2

Table 2 Classification of trophic level by using water characteristic and dominant phytoplankton (Wetzel, 2001)

General Lake Trophy	Water Characteristics	Dominant Algae	Other Commonly Occurring Algae
Oligotrophic	Slightly acidic; very salnity	Desmids *Staurodesmus, Staurastrum*	*Sphaerocystis, Gloeocystis, Rhizosolenia, Tabellaria*
Oligotrophic	Neutral to slightly alkaline; Nutrient-poor lakes	Diatoms, especially, *Cymbella* and *Tabellaria*	Some *Asterionella* spp., some *Melosira* spp., *Dinobryon*
Oligotrophic	Neutral to slight alkaline; nutrient-poor lakes or more productive lakes at seasons of nutrient reduction	Chrysophycean algae, especially *Dinobryon*. Some *Mallomonas*	Other Chrysophyceans, e.g. *Synura, Uroglena*: diatom *Tabellaria*
Oligotrophic	Neutral to slight alkaline; nutrient-poor lakes	Chlorococcal *Oocystis* or Chrysophycean *Botryococcus*	Oligotrophic diatoms
Oligotrophic	Neutral to slight alkaline; generally nutrient poor; common in shallow Arctic lakes	Dinoflagellates, especially some *Peridinium* and *Ceratium* spp.	Small chrysophytes cryptophytes, and diatoms
Mesotrophic or Eutrophic	Neutral to slightly alkaline; annual dominants or in eutrophic lakes at certain seasons	Dinoflagellates, some *Peridinium* and *Ceratium* spp.	*Glenodinium* and many other algae
Eutrophic	Usually alkaline lakes with nutrient enrichment	Diatoms much of year, especially *Asterionella* spp., *Fragilaria crotonensis, Synedra, Ctephanodiscus,* and *Melosira granulata*	Many other algae, especially green and blue-greens during warmer periods of year; desmids of dissolved organic matter is fairly high
Eutrophic	Usually alkaline; nutrient enriched; common in warmer periods of temperature lakes or perennially in enriched tropical lakes	Blue-green algae, especially *Anacystis* (= *Microcystis*), *Aphanizomenon, Anabaena*	Other blue-green; euglenophytes if organically enriched or polluted

Table 3. Surface water quality standards of Thailand

Surface Water Quality Standards

Parameter[1/]	Units	Statistics	Standard Value for Class[2/]					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
1. Colour,Odour and Taste	-	-	n	n'	n'	n'	-	-
2. Temperature	C°	-	n	n'	n'	n'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
4. Dissolved Oxygen (DO)[2/]	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
5. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C , 5 days
6. Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
7. Fecal Coliform Bateria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
8. NO_3 -N	mg/l	-	n		5.0		-	Cadmium Reduction
9. NH_3 -N	mg/l	-	n		0.5		-	Distillation Nesslerization
10.Phenols	mg/l	-	n		0.005		-	Distillation,4-Amino antipyrene
11.Copper (Cu)	mg/l	-	n		0.1		-	Atomic Absorption - Direct Aspiration
12.Nickle (Ni)	mg/l	-	n		0.1		-	Atomic Absorption - Direct Aspiration
13.Manganese (Mn)	mg/l	-	n		1.0		-	Atomic Absorption - Direct Aspiration
14.Zinc (Zn)	mg/l	-	n		1.0		-	Atomic Absorption - Direct Aspiration
15.Cadmium (Cd)	mg/l	-	n		0.005* 0.05**		-	Atomic Absorption - Direct Aspiration
16.Chromium Hexavalent	mg/l	-	n		0.05		-	Atomic Absorption - Direct Aspiration
17.Lead (Pb)	mg/l	-	n		0.05		-	Atomic Absorption - Direct Aspiration
18.Total Mercury (Total Hg)	mg/l	-	n		0.002		-	Atomic Absorption- Cold Vapour Technique
19.Arsenic (As)	mg/l	-	n		0.01		-	Atomic Absorption - Direct Aspiration
20.Cyanide (Cyanide)	mg/l	-	n		0.005		-	Pyridine-Barbituric Acid
21.Radioactivity - Alpha - Beta	Becqurel/l	-	n		0.1 1.0		-	Gas-Chromatography
22.Total Organochlorine Pesticides	mg/l	-	n		0.05		-	Gas-Chromatography

23.DDT	µg/l	-	n	1.0	-	Gas-Chromatography
24.Alpha-BHC	µg/l	-	n	0.02	-	Gas-Chromatography
25.Dieldrin	µg/l	-	n	0.1	-	Gas-Chromatography
26.Aldrin	µg/l	-	n	0.1	-	Gas-Chromatography
27.Heptachlor & Heptachlorepoxide	µg/l	-	n	0.2	-	Gas-Chromatography
28.Endrin	µg/l	-	n	None	-	Gas-Chromatography

Classification and Objectives	
Classification	**Objectives/Condition and Beneficial Usage**
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment process before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process before using (2) industry
Class 5	The sources which are not classification in class 1-4 and used for navigation.

Remark : [1/]Guideline value for Class 2-4
[2/] Minimum value of DO
P Percentile value
n naturally
n' naturally but changing not more than 3°C
* when water hardness not more than 100 mg/l as $CaCO_3$
** when water hardness more than 100 mg/l as $CaCO_3$
Based on Standard Methods for the Examination of Water and Wastewater recommended by APHA : American Public Health Association, AWWA : American Water Works Association and WPCF : Water Pollution Control Federation

Source : Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

การประเมินคุณภาพน้ำในแหล่งน้ำนิ่งโดยใช้แพลงก์ตอนพืชชนิดเด่นด้วย AARL – PP Score

ยุวดี พีรพรพิศาล[1] จีรพร เพกเกาะ[1] ดวงกมล โพธิ์หวังประสิทธิ์[1] ธนพล ทนคำดี[1] อดินุช หงษ์สิริชาติ[1] และ ทัตพร คุณประดิษฐ์[2]

Assessment of Water Quality in Standing Water by Using Dominant Phytoplankton (AARL- PP Score)

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บทคัดย่อ

ห้องปฏิบัติการวิจัยสาหร่ายประยุกต์ (Applied Algal Research Laboratory: AARL) ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยเชียงใหม่ ได้วิจัยเกี่ยวกับคุณภาพน้ำและความหลากหลายของแพลงก์ตอนพืช 35 เรื่อง ในเวลา 15 ปีที่ผ่านมา ซึ่งนำไปสู่การศึกษาคุณภาพน้ำในแหล่งน้ำนิ่งได้อย่างง่าย โดยใช้แพลงก์ตอนพืช เป็นวิธีการที่ไม่ใช้สารเคมี และยังบ่งชี้คุณภาพน้ำในอดีตได้ด้วย การประเมินคุณภาพน้ำด้วยวิธีนี้เรียกว่า AARL-PP Score ซึ่งประกอบด้วยคะแนนจาก 2 ส่วน ส่วนที่ 1 เป็นการสร้างคะแนนมาตรฐานคุณภาพน้ำโดยอิงระดับสารอาหาร ด้วยการแบ่งออกเป็น 6 ระดับ คือ คุณภาพดี (oligotrophic status), ดีถึงปานกลาง (oligotrophic - mesotrophic status), ปานกลาง (mesotrophic status), ปานกลางถึงไม่ดี (mesotrophic - eutrophic status),ไม่ดี (eutrophic status), และไม่ดีมาก (hypereutrophic status) โดยใช้คะแนน 1-10 แบ่งแต่ละระดับโดยใช้ประสบการณ์ที่มีมาก่อน ส่วนที่ 2 เป็นการให้คะแนนแพลงก์ตอนพืชชนิดเด่นที่ปรากฏในแหล่งน้ำซึ่งมีคุณภาพต่างกัน โดยให้คะแนน 1-10 คะแนนน้อยจะบ่งชี้คุณภาพน้ำดี ส่วนคะแนนมากจะบ่งชี้คุณภาพน้ำไม่ดี การศึกษาคุณภาพน้ำในแหล่งน้ำที่ศึกษา ทำได้โดย รวบรวมแพลงก์ตอนพืชมาวินิจฉัยและหาความมากน้อยของแต่ละจีนัส นำจีนัสเด่นซึ่งเรียงตามลำดับความมากน้อย 3-5 จีนัส ให้คะแนนระดับคุณภาพน้ำจากส่วนที่ 2 หาค่าเฉลี่ยแล้วนำ ไปเปรียบเทียบกับคะแนนมาตรฐานคุณภาพน้ำในส่วนที่ 1 จะสามารถหาคุณภาพน้ำได้ ได้มีการทดลองใช้ Score นี้ ในแหล่งน้ำ 50 แห่งในภาคเหนือ ส่วนภาคตะวันออกเฉียงเหนือ และภาคใต้ ภาคละ 20 แห่ง ผลปรากฏว่าให้ความถูกต้องมากกว่า 95% เมื่อเปรียบเทียบกับคุณภาพน้ำทางด้านกายภาพและเคมี

Abstract

The Applied Algal Research Laboratory (AARL), Department of Biology, Faculty of Science, Chiang Mai University, had done 35 research topics on the quality of water and phytoplankton diversity in the past 15 years. The new knowledge leading to the simplicity of standing water quality study. Besides, the chemical reagents are not required and could be used to indicate the water quality in its past history.

This water quality assessment is called “AARL- PP Score”. It is composed of 2 parts scoring system. The first part is the standard score of water quality base on trophic level status. The water quality was categorized into 6 status using 1-10 scores. Each status was divided by former research experience, i.e. clean (oligotrophic status), clean to moderate (oligotrophic-mesotrophic status), moderate (mesotrophic status), moderate to polluted (mesotrophic-eutrophic status), polluted (eutrophic status), and very polluted (hypereutrophic status). In the second part, the dominant genera of phytoplankton from different water quality resources were given 1-10 scores. The lower scores indicated clean water whereas the higher scores indicated polluted water. During the assessment of water quality, the phytoplankton were collected, identified and the quantity of each genus was determined. Three to five dominant genera of the phytoplankton were selected in accordance with their respective amount. The score of each genus following the water quality in the second part was averaged and compared with the standard score of water quality in the first part. The AARL-PP Score had been tested in 50 water resources in the North and 20 water resources each in Northeastern and Southern parts of Thailand, with more than 95% in agreement with physical and chemical water quality.

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Introduction

The study of standing water quality, generally use physical and chemical methods. Most of them involved the examination of the colour, odor and taste of the water, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), electric conductivity (EC), chlorophyll *a* contents, the amount of nitrite, nitrate, ammonia and phosphate; the amount of total and fecal coliform bacteria including heavy metals and some insecticides.

These methods require the use of some expensive instruments and chemical reagents, the residues will be pollutants in the environments. Besides, the water quality base on physical and chemical analysis will only show the quality on the measuring day (Wetzel, 1983),it can not predict the water quality in the past. Some aquatic entomologists, protozoologists, phycologists, limnologists and hydrologists have tried to creat bioindicators to assess water quality in some water resources. In the case of standing water quality, phytoplanktons were suitably used as bioindicator to assess the water quality. Applied Algal Research Laboratory (AARL), Microbiology Section, Department of Biology, Faculty of Science, Chiang Mai University, Thailand have carried out the research concerning the use of phytoplankton (PP) as bioindicator to assess standing water quality for more than 15 years. At present, members of AARL have been used "AARL-PP Score" to assess the standing water quality all over Thailand. The researchers hope that this score will be useful for students, local people and those who are interested in standing water quality.

Materials and Methods

AARL-PP Score is composed of 2 parts scoring system. The first part is the standard score of water quality base on trophic level. The water quality was categorized into 6 status using 1-10 score. Each status was divided by the data from the past survey (Table1).

Table 1 Water quality scores followed trophic level and general water quality

Score	Water quality by trophic level	General water quality
1.0-2.0	Oligotrophic status	Clean
2.1-3.5	Oligo-mesotrophic status	Clean- moderate
3.6-5.5	Mesotrophic status	Moderate
5.6-7.5	Meso-eutrophic status	Moderate- polluted
7.6-9.0	Eutrophic status	Polluted
9.1-10.0	Hypereutrophic status	Very polluted

The second part of AARL-PP Score is the dominant genera of phytoplankton score, it was given in 1-10. The lower score indicated clean water whereas the higher score indicated polluted water (Table 2). Morphological characters of phytoplankton genera used in AARL – PP Score were showed in Figure 1.

During the assessment of water quality, the phytoplankton were collected, identified to genera and the quantity of each genus determined (John *et al.* ,2002 ; Peerapornpisal , 2005). Three to five dominant genera of the phytoplankton were selected according to their irrespective amount. The score of each selected genus following the water quality in the second part (Table 2) was averaged and compared with the standard water quality score in the first part (Table1).

Table 2 Dominant genus scores

Genus	Score	Genus	Score
Actinastrum	5	*Gymnodinium*	6
Acanthoceras	5	*Gyrosigma*	7
Amphora	6	*Isthmochloron*	5
Anabaena	8	*Kirchneriella*	5
Ankistrodesmus	7	*Melosiera*	5
Aphanocapsa	5	*Merismopedia*	9
Aphanothece	5	*Micractinium*	7
Aulacoseira	6	*Micrasterias*	2
Bacillaria	7	*Microcystis*	8
Botryococcus	4	*Monoraphidium*	7
Centritractus	4	*Navicula*	5
Ceratium	4	*Nephrocytium*	5
Chlamydomonas	6	*Nitzschia*	9
Chlorella	6	*Oocystis*	6
Chroococcus	6	*Oscillatoria*	9
Closterium	6	*Pandorina*	6
Cocconeis	6	*Pediastrum*	7
Coelastrum	7	*Peridiniopsis*	6
Cosmarium	2	*Peridinium*	6
Crucigenia	7	*Phacus*	8
Crucigeniella	7	*Phormidium*	9
Cryptomonas	8	*Pinnularia*	5
Cyclotella	2	*Planktolyngbya*	7
Cylindrospermopsis	7	*Pseudanabaena*	7
Cymbella	5	*Rhizosolenia*	6
Dictyosphaerium	7	*Rhodomonas*	8
Dimorphococcus	7	*Rhopalodia*	5
Dinobryon	1	*Scenedesmus*	8
Encyonema	6	*Staurastrum*	3
Epithemia	6	*Staurodesmus*	3
Euastrum	3	*Stauroneis*	5
Eudorina	6	*Strombomonas*	8
Euglena	10	*Surirella*	6
Eunotia	2	*Synedra*	6
Fragilaria	5	*Synura*	8
Golenkinia	5	*Tetraedron*	6
Gomphonema	6	*Trachelomonas*	8
Gonium	6	*Volvox*	6

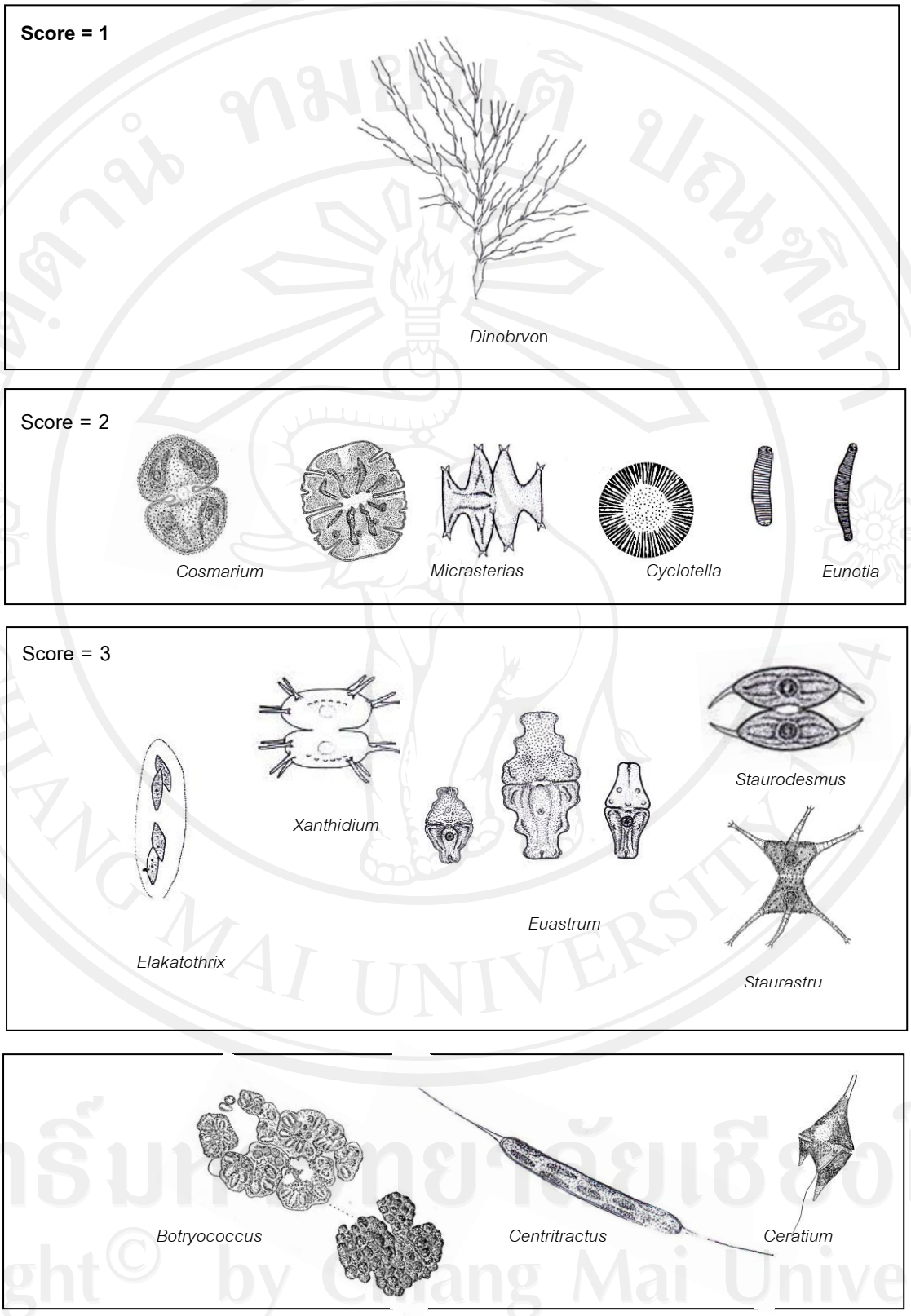
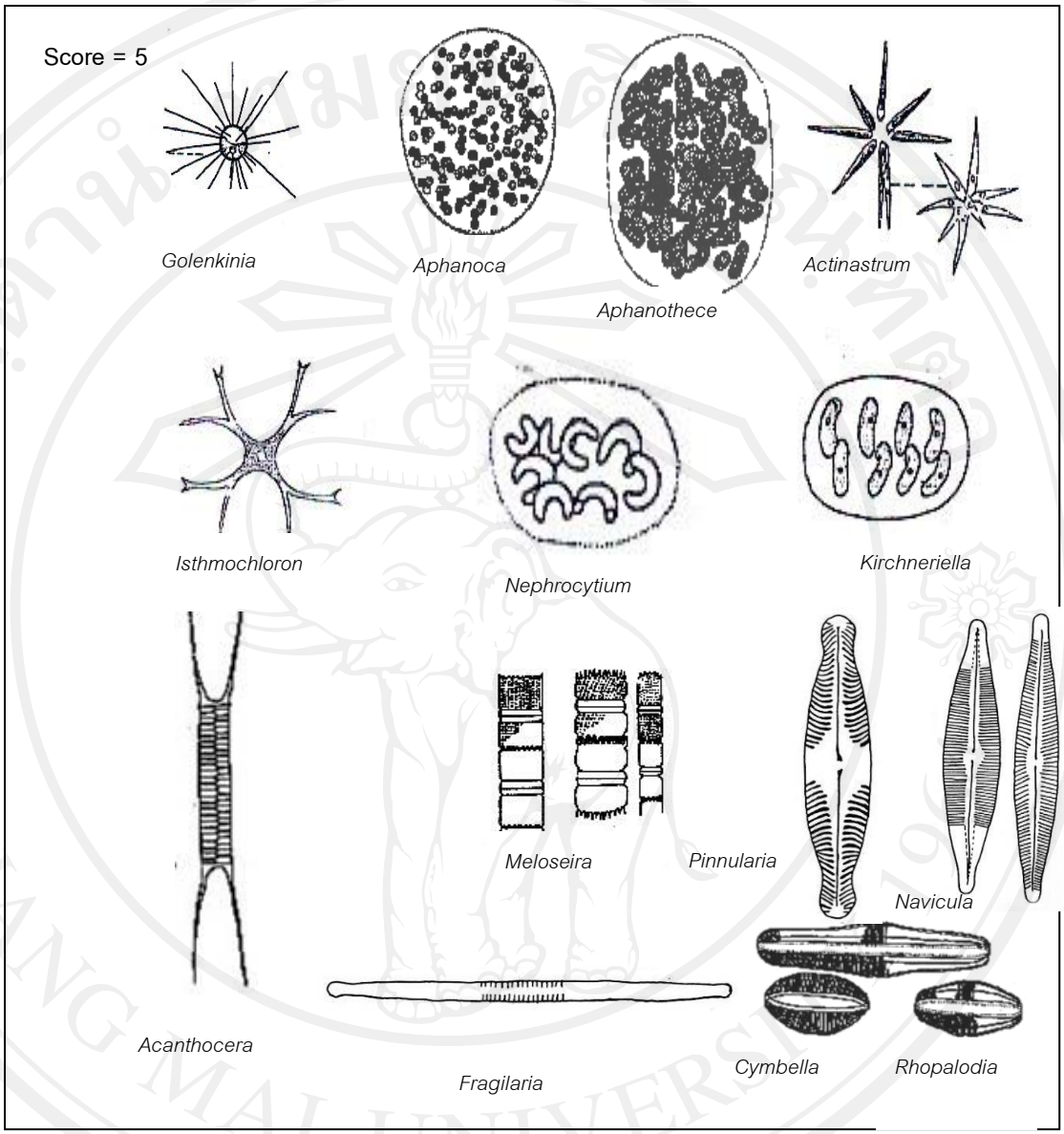


Figure 1 Dominant phytoplankton genus with the indicated score



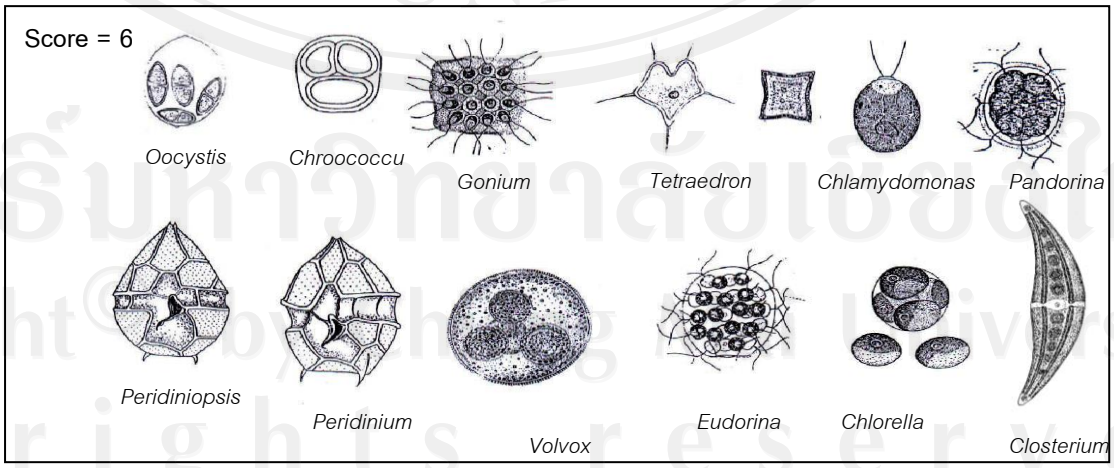
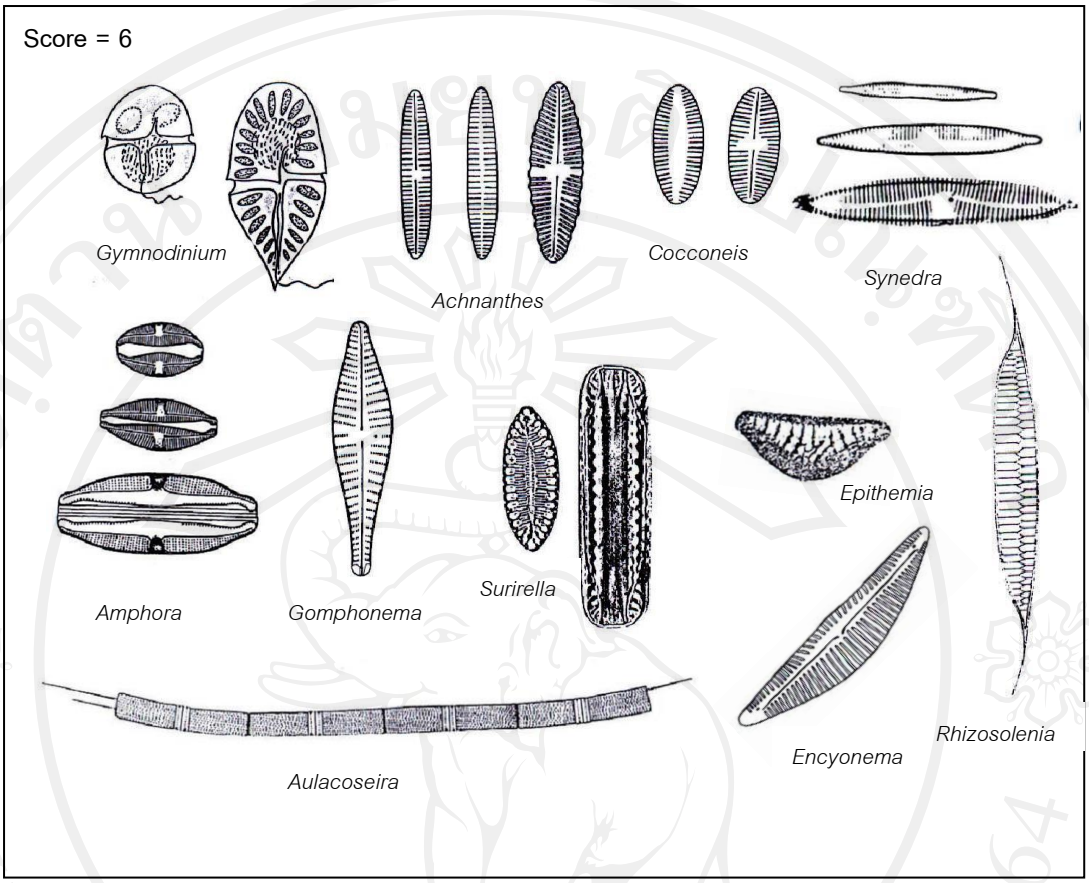
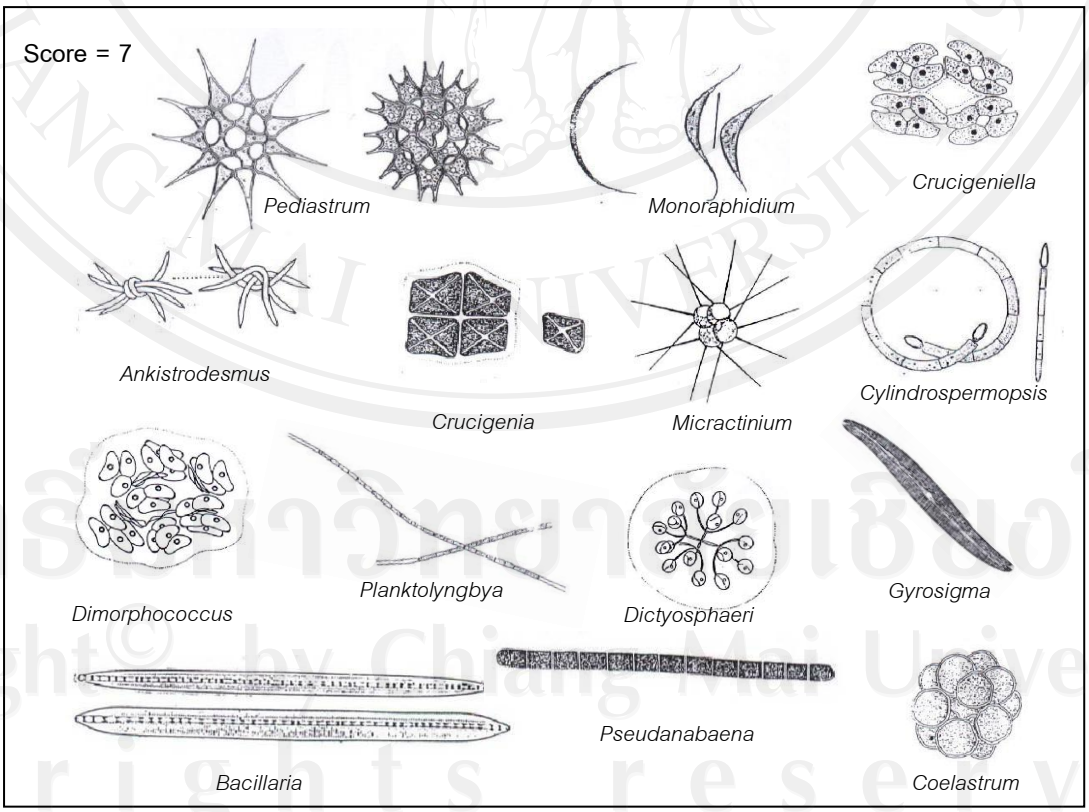


Figure 1 (continued)





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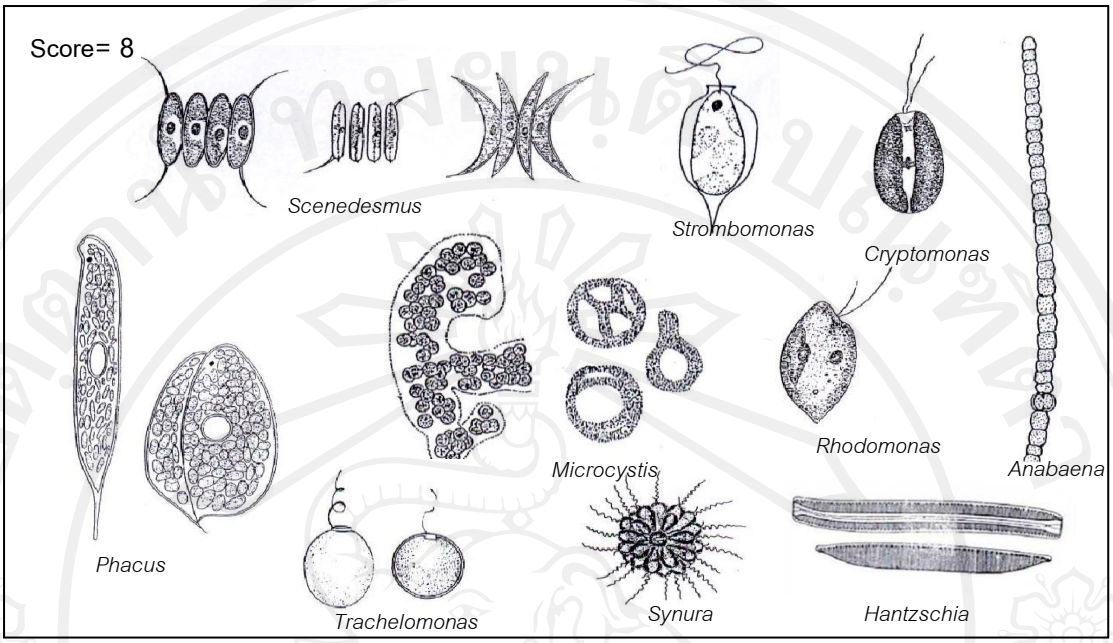

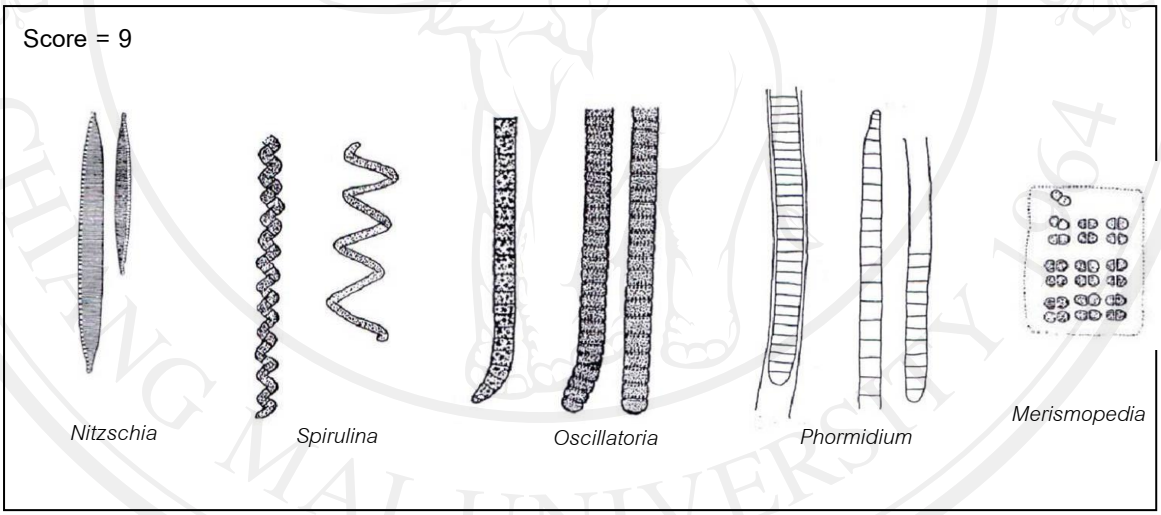

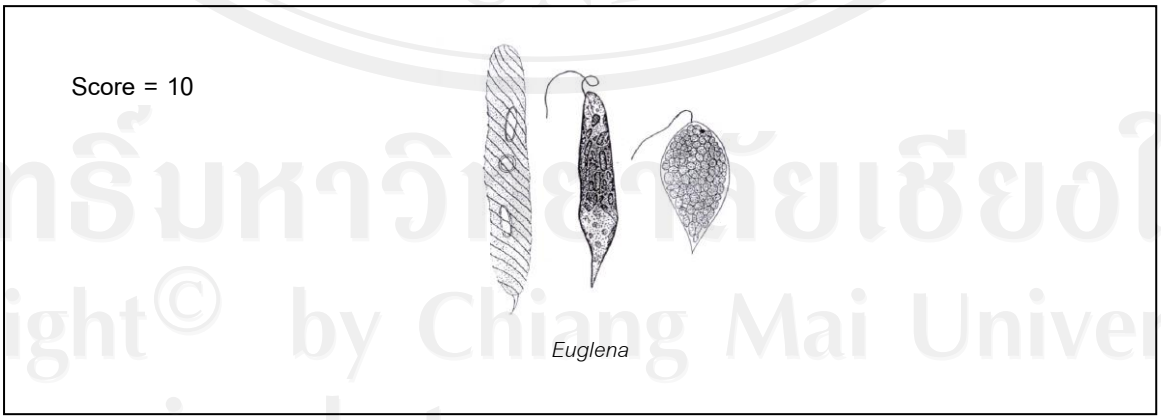

Figure 1 (continued)

In the present study, the physical and chemical properties of water i.e. colour and oder of water, pH, DO, BOD, EC, chlorophyll a contents, amount of nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorous were also investigated (APHA, 1996). The physical and chemical properties of water were used in combination to evaluate the water quality (Lorraine and Vollenweider, 1981; Peerapornpisal *et al*., 2004). The results of water quality using AARL – PP Score will be compared with those obtained from physical and chemical methods.

Example

In Chiang Mai Moat, Chiang Mai, Thailand

3 genera were dominant : *Euglena* sp., *Trachelomonas* sp.and *Navicula* sp.

From Table 2: Scores of selected genera are:-

Euglena sp.	= 10	*Trachelomonas* sp.	= 8
Navicula sp.	= 5		
Total score	= 10+8+5	= 23	
Average score	= 23/3	= 7.6	

From Table 1: Score 7.6 is in **Eutrophic status** or **Polluted water quality** The water quality in Chiang Mai Moat is **Polluted**

Results and Discussion

The authors believe that AARL – PP Score can be used to assess the water quality in Thailand and tropical areas. However, the water quality scores followed tropic level and dominant genus scores of phytoplankton should be investigated in temperate and other regions before the application of AARL – PP Score as the value of water quality in each level and the species composition of phytoplankton may be different in different region (Lorraine and Vollenweider 1981; Wetzel,1983).

The AARL-PP Score had been done in 50 water resources in the North, 40 water resources in the Northeastern and Southern parts of Thailand with more than 95 % in agreement with physical and chemical water quality. The water quality of some water resources in Thailand using AARL – PP Score were showed in Table 3.

Table 3 The water quality of some water resources in Thailand using AARL – PP Score

Water resources	Dominant phytoplankton	Phytoplankton score	Trophic level	General water quality
Mae Jok LuangReservoir, Chiang Mai (North)	*Dinobryon* *Staurodesmus* *Stauratrum*	1.66	Oligotrophic status	Clean
Maekuang Udomtara Reservoir , Chiang Mai (North)	*Staurodesmus* *Staurastrum* *Cosmarium*	2.66	Oligo-mesotrophic status	Clean-moderate
Ang Kaew Reservoir Chiang Mai University Chiang Mai (North)	*Peridinium* *Aulacoseira* *Ceratium*	5.66	Meso-eutrophic status	Moderate-polluted
Fish pond in Wat Umong Chiang Mai (North)	*Phacus* *Oscillatoria* *Pediastrum*	8	Eutrophic status	Polluted
Chiang Mai Moat Chiang Mai (North)	*Euglena* *Trachelomonas* *Phacus*	8.6	Eutrophic - status	Polluted
Bang Wad Reservoir Phuket (South)	*Cosmarium* *Staurastrum* *Dinobryon*	2	Oligotrophic status	Clean
Chiew Lan Reservoir Surat tani (South)	*Staurastrum* *Cosmarium* *Peridinium*	3.66	Mesotrophic status	Moderate
Talay Noi Phatthalung (South)	*Dictyosphaerium* *Pandorina* *Microcystis*	7	Meso-eutrophic status	Moderate-polluted
Lamtakhong Reservoir Nakhon Ratchasima (Northeast)	*Aulacoseira* *Fragilaria* *Staurastrum*	4.66	Mesotrophic status	Moderate
Ubonrath Reservoir Khon Kaen (Northeast)	*Aulacoserra* *Eudorina* *Fragilaria*	5.66	Meso-eutrophic status	Moderate-polluted

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APPENDIX B

Research data

Distribution of *Microcystis aeruginosa* and microcystins in prawn and fish ponds.

1. Data of some physico-chemical parameters in prawn and fish farms in Chiang Rai and Chiang Mai province during April 2006 – February 2007 were shown in Tables 1B-4B

Table 1B Some physico-chemical parameters of sampling sites in April 2006.

Sampling site / Parameter	P1	T1	T2	T3	T4
Temperature (°C)	27.0	26.9	28.0	27.5	27.1
pH	6.91	6.90	7.22	6.94	6.96
Conductivity ($\mu s.cm^{-1}$)	212	439	451	596	519
Turbidity (NTU)	35	45	54	31	22
Dissolved oxygen ($mg.l^{-1}$)	5.2	5.0	4.0	-	2.0
BOD ($mg.l^{-1}$)	5.0	4.5	3.8	3.7	-
Nitrate nitrogen ($mg.l^{-1}$)	0.6	1.0	0.8	0.8	0.9
Soluble reactive phosphorus ($mg.l^{-1}$)	0.25	0.30	0.28	0.42	0.14
Ammonium nitrogen ($mg.l^{-1}$)	0.16	0.22	0.18	0.25	0.32

- = not studied

Table 2B Some physico-chemical parameters of sampling sites in July 2006.

Sampling site / Parameter	P1	P2	P3	P4	T1	T2	T3	T4
Temperature (°C)	30.6	30.4	31.1	30.7	31.4	31.5	31.3	31.1
pH	8.26	7.94	7.80	7.64	7.14	8.11	8.26	7.28
Conductivity ($\mu s.cm^{-1}$)	196	173	230	161	270	366	360	375
Turbidity (NTU)	135	110	129	124	143	133	176	128
Dissolved oxygen ($mg.l^{-1}$)	7.4	5.6	6.0	4.8	7.8	7.2	8.0	3.6
BOD ($mg.l^{-1}$)	3.0	1.2	1.0	1.8	5.0	6.4	6.4	3.8
Nitrate nitrogen ($mg.l^{-1}$)	N.D.	N.D.	N.D.	N.D.	1.1	0.2	0.4	0.3
Soluble reactive phosphorus ($mg.l^{-1}$)	0.10	0.10	0.04	0.01	0.04	0.01	0.01	0.03
Ammonium nitrogen ($mg.l^{-1}$)	0.07	0.20	0.04	0.04	0.53	0.17	0.22	0.14

Table 3B Some physico-chemical parameters of sampling sites in October 2006.

Parameter \ Sampling site	P1	P2	P3	P4	T1	T2	T3	T4
Temperature (°C)	30.1	29.5	30.6	29.6	31.0	30.9	31.2	30.6
pH	6.82	7.06	6.97	7.11	8.17	8.02	8.81	8.37
Conductivity ($\mu s.cm^{-1}$)	129	194	106	154	326	173	312	250
Turbidity (NTU)	90	48	58	33	120	124	187	110
Dissolved oxygen ($mg.l^{-1}$)	6.2	5.7	6.1	6.0	5.8	6.2	6.0	6.1
BOD ($mg.l^{-1}$)	5.0	4.2	4.3	5.7	5.0	5.8	5.5	5.2
Nitrate nitrogen ($mg.l^{-1}$)	1.0	0.8	0.9	1.0	1.2	0.9	2.2	1.1
Soluble reactive phosphorus ($mg.l^{-1}$)	0.03	0.07	0.06	0.08	0.16	0.13	0.80	0.13
Ammonium nitrogen ($mg.l^{-1}$)	0.20	0.15	0.16	0.37	0.62	0.15	0.38	0.29

Table 4B Some physico-chemical parameters of sampling sites in February 2007.

Parameter \ Sampling site	P1	P2	P3	P4	T5	T6
Temperature (°C)	21.8	22.2	22.7	22.9	24.6	24.8
pH	7.20	7.32	7.41	7.22	7.01	7.55
Conductivity ($\mu s.cm^{-1}$)	276	241	230	263	141	302
Turbidity (NTU)	32	189	53	62	94	161
Dissolved oxygen ($mg.l^{-1}$)	5.4	5.0	6.2	7.0	4.8	7.0
BOD ($mg.l^{-1}$)	4.6	4.7	3.0	5.0	4.4	5.0
Nitrate nitrogen ($mg.l^{-1}$)	1.0	0.8	0.9	1.0	1.2	0.9
Soluble reactive phosphorus ($mg.l^{-1}$)	0.03	0.07	0.06	0.08	0.16	0.13
Ammonium nitrogen ($mg.l^{-1}$)	0.20	0.15	0.16	0.37	0.62	0.15

2. Data of species composition in prawn and fish ponds in Chiang Rai and Chiang Mai province during July 2006 – February 2007 were shown in Tables 5B-7B

Table 5B Diversity of phytoplankton in prawn and fish ponds in July 2006

sampling site / Species	P1	P2	P3	P4	T1	T2	T3	T4
	(cells/colony/filaments per liter)							
Division Chlorophyta								
Botryococcus braunii Kützing		9,558	4,500	3,300				
Chlorogonium tetragamum Bohlin					766			
Chlorella sp.		6,372		3,300	53,620	73,580	111,600	116,220
Coelastrum astroideum De Notaris	2,587					1,132		
Cosmarium sp.		1,593			4,596			17,880
Crucigenia tetrapedia (Kirchner) West et West			2,250		766			
Crucigeniella crucifera (Wolle) Komarek		1,593	2,250	1,650	1,532	1,132		13,410
Dictyosphaerium sp.					766	2,264		
Kirchneriella irregularis (G.M. Smith) Korshikov						1,132		
Monoraphidium convolutum (Corda) Komrkova-legnerova					12,256			
Monoraphidium contortum (Thuret) Komrkova-legnerova					19,150	3,396		
Monoraphidium tortile (West et West) Komarek		1,593			3,064	2,264		
Nephrocytium lunatum West					3,830	2,264		
Oocystis sp.			1,125					
Pandorina sp.						1,132		
Pediastrum biradiatum Meyen	862			1,650		5,660	13,950	49,170
Pediastrum simplex Meyen	3,450	12,744	3,375			1,132		
Scenedesmus acuminatus var. tetradesmoides Smith				1,650	7,660	6,792		53,640
Scenedesmus armatus var. *bicaudatus* (Guglielmetti) Chodat					9,192	11,320	9,300	
Scenedesmus semipulcher Hortobágyi					766			
Staurastrum sp. 1	2,587	1,593						
Staurastrum sp. 2					766			
Tetraedron minimum (A. Braun) Hansgirg		1,593						
Tetraedron regulare Kützing					1,532			
Tetrastrum komarekii						1,132		

Table 5B (continued)

Species \ sampling site	P1	P2	P3	P4	T1	T2	T3	T4
	(cells/colony/filaments per liter)							
Division Cyanophyta								
Anabaena sp.								49,170
Cylindrospermopsis curvispora M. Watanabe								397,830
Merismopedia sp. (colony)					15,320	4,528		17,880
Microcystis aeruginosa Kützing	$45x10^6$	97,173	$1.2 x10^6$	597,300			4,650	983,400
Microcystis wesenbergii Komarek	$3.5 x10^6$	108,324	$2.3 x10^6$					
Microcystis ichtyoblabe Komarek	2,587							
Oscillatoria limosa (C. Agardh) Gomont	8,625	12,744		138,600				
Pseudanabaena sp.					766			
Spirulina sp.					766		9,300	4,470
Division Bacillriophyta								
Aulacoseira granulata (Ehrenberg) Simonsen		1,593						134,100
Cyclotella sp.								31,290
Division Euglenophyta								
Euglena acus Ehrenberg	3,450		1,125		1,532			4,470
Euglena texta (Dujardin) K. Hübner	11,212	3,186		4,950	5,362			98,340
Euglena sp.						4,528		
Phacus caudatus K. Hübner	6,037		3,375	4,950		3,396		
Phacus orbicularis K. Hübner		1,593		1,650				62,580
Phacus sp.					6,128			
Strombomonas sp.				11,550				
Trachelomonas sp.	1,725	1,593		8,250	766			
Division Pyrrhophyta								
Ceratium sp.	3,450			796,950				
Peridinium bipes F. Stein	27,600	11,151	82,500	8,250				22,350
Peridinium sp.			9,000					

Table 6B Diversity of phytoplankton in prawn and fish ponds in October 2006

sampling site / Species	P1	P2	P3	P4	T1	T2	T3	T4
	(cells/colony/filaments per liter)							
sampling site / Species	P1	P2	P3	P4	T1	T2	T3	T4
Division Chlorophyta								
Botryococcus braunii Kützing	2,100	12,960	900	11,340				173
Chlorella sp.	100					1,628		173
Closterium sp.	500							
Coelastrum astroideum De Notaris	900		60	158		1,395		518
C. reticulatum (Dangeard) Senn				158				
Cosmarium depressum var. *planctonicum* Reverd.				158				
Cosmarium sp.		480						
Crucigenia tetrapedia (Kirchner) West et West				473	225	1,860		
Crucigeniella pulchra (W. et G.S. West) Kom.							218	345
Dictyosphaerium sp.		320						
Eudorina sp.						233		
Euastrum sp.								345
Kirchneriella irregularis (G.M. Smith) Korshikov								
Monoraphidium griffithii (Berkeley) Komarkoma-Legnerova		480			225			
Nephrocytium lunatum West			120					
Oocystis sp.		160						345
Pediastrum duplex Meyen	100	640	120		4,050	9,068	1,305	690
P. duplex var. *subgranulatum* Raciborskii					450			
P. simplex Meyen	700	2,880	240		225		218	
P. tetras (Ehrenberg) Ralfs						698		
Scenedesmus abundans (Kirchner) Chodat						4,650	1,740	2,070
S. communis E.H. Hegewald					2,925		1,523	
S. denticulatus Lagerheim							1,305	

Table 6B (continued)

Species \ sampling site	P1	P2	P3	P4	T1	T2	T3	T4
	(cells/colony/filaments per liter)							
S. falcatus Chodat						8,138	1,740	1,035
S. opoliensis P.G. Richter		160						
S. subspicatus Chodat		160			1,125	2,325		
S. semipulcher Hortobágyi								2,070
Staurastrum tetracerum (Kutzing) Ralfs								
Staurastrum sp. 1		160	240	158				
Staurastrum sp. 2			300	630				
Tetraedron caudatum (Corda) Hangsirg								
T. regulare Kützing		160						
Division Cyanophyta								
Anabaena sp.		160						
Merismopedia sp. (colony)					450			
Microcystis aeruginosa Kützing	539,900	399,200	764,880	3,135,658		7,905		518
M. ichtyoblabe Komarek	45,000							
M. flos-aquae Komarek		73,440	145,560					
M. wesenbergii Komarek				27,090				
Oscillatoria limosa (C. Agardh) Gomont		320	240	158	225	3,023		
Division Bacillriophyta								
Achnanthes sp.								
Aulacoseira granulata (Ehrenberg) Simonsen	200	160	240			6,278	218	173
Cyclotella sp.						3,023		173
Cymbella sp.		160						
Nitszchia sp.				158				
Division Chysophyta								
Dinobryon sp.		2,080	180	2,363				
Mallomanas sp.	100							

Table 6B (continued)

sampling site / Species	P1	P2	P3	P4	T1	T2	T3	T4
	(cells/colony/filaments per liter)							
Division Cryptophyta								
Cryptomonas sp.		960						
Division Euglenophyta								
Euglena acus Ehrenberg				158	225			
E. oxyuris Schmarda					225			
Phacus acuminatus A. Stokes				158				
P. circumflexus Pochmann					900		218	
P. orbicularis K. Hübner				315				
P. tortus (Lemmermann) Skvortsov				158				
P. trigueter (Ehrenberg) Dujardin						465		
Phacus sp.					225			
Strombomonas deflandrei (Y.V.Roll) Deflandre					675			
Trachelomonas caudata fo. *caudata* (Ehrenberg) Stein				158				
Trachelomonas sp. 1	4,300	2,880	1,020			1,860		
Division Pyrrhophyta								
Ceratium furcoides (Levender) Laghans	500		600				653	
Peridiopsis cunningtonii (Lemmermann) popvksy et Pfiester		12,000	17,200	23,460		2,093		
Peridinium sp. 1	600		120	1,733			653	

Table 7B Diversity of phytoplankton in prawn and fish ponds in February 2007

sampling site / Species	P1	P2	P3	P4	T1	T2
	(cells/colony/filaments per liter)					
Division Chlorophyta						
Monoraphidium tortile (West et West) Komarek				1,593	3,064	2,264
Nephrocytium lunatum West					3,830	2,264
Pediastrum biradiatum Meyen	13,950	49,170	862			
Pediastrum simplex Meyen			3,450	12,744		1,132

Table 7B (continued)

Species \ sampling site	P1	P2	P3	P4	T1	T2
	(cells/colony/filaments per liter)					
Pediastrum tetras (Ehrenberg) Ralfs						
Scenedesmus acuminatus (Lagerheim) Chodat		53,640			7,660	6,792
Scenedesmus armatus var. *bicaudatus* (Guglielmetti) Chodat	9,300				9,192	11,320
Scenedesmus semipulcher Hortobágyi					766	
Staurastrum sp. 1			2,587	1,593		
Tetraedron minimum (A. Braun) Hansgirg				1,593		
Tetraedron regulare Kützing					1,532	
Tetrastrum komarekii						1,132
Division Cyanophyta						
Merismopedia tenuissima Lemmermann (colony)		17,880			15,320	4,528
Microcystis aeruginosa Kützing	4,650	983,400	30,000	97,173		
Microcystis wesenbergii Komarek			90,000	2.5×10^6		
Microcystis ichtyoblabe Komarek			2,587			
Oscillatoria sp.			8,625	12,744		
Division Bacillriophyta						
Aulacoseira granulata (Ehrenberg) Simonsen		134,100		1,593	634,100	
Cyclotella sp.		31,290				
Fragilaria sp.	134,500	134,100				
Division Euglenophyta						
Euglena acus Ehrenberg		4,470	3,450		1,532	
Euglena texta (Dujardin) K. Hübner		98,340	11,212	3,186	5,362	
Euglena limnophila Lemmermann						4,528
Euglena sp.			6,037			3,396
Phacus caudatus K. Hübner		62,580		1,593		
Phacus orbicularis K. Hübner					6,128	
Phacus sp.						
Strombomonas australica (Playf.) Defl.			1,725	1,593	766	
Trachelomonas sp.						

Table 7B (continued)

Species	sampling site	P1	P2	P3	P4	T1	T2
			(cells/colony/filaments per liter)				
Division Pyrrhophyta							
Ceratium furcoides (Levender) Laghans				3,450		97,600	
Peridiopsis canningtonii (Lemmermann) popvsky et Pfiester							
Peridinium bipes F. Stein			22,350	27,600	11,151		
Peridinium sp.							

3. Statistical analysis: correlation between cyanobacterial species and some physico chemical parameters

	Anab	C.cur	M.aeru	M.wese	M.ich	M.flos	Osci	Temp.	pH	conduct.	Turbid	DO	BOD	nitrate	phosphate	ammonia
Anab	1.0000	0.9995	-0.0345	-0.0599	-0.0705	-0.0671	-0.0567	0.1227	0.3055	0.0339	-0.0041	0.0026	0.1217	0.1380	0.0332	0.0596
C.cur	0.9995	1.0000	-0.0343	-0.0597	-0.0703	-0.0651	-0.0565	0.1223	0.3050	0.0345	-0.0041	0.0029	0.1232	0.1390	0.0332	0.0599
M.aeru	-0.0345	-0.0343	1.0000	0.0805	-0.0379	-0.0579	0.0122	0.1023	-0.3210	-0.3355	-0.0966	0.0024	0.0591	0.0694	-0.1190	-0.0679
M.wese	-0.0599	-0.0597	0.0805	1.0000	-0.0797	-0.0816	-0.0609	-0.3384	-0.2245	-0.0010	-0.2671	0.2019	0.1093	0.1125	-0.0585	0.1450
M.ich	-0.0705	-0.0703	-0.0379	-0.0797	1.0000	-0.0962	-0.0810	-0.2237	0.0875	-0.1016	-0.1517	0.1981	-0.2858	-0.1554	-0.0601	0.1458
M.flos	-0.0671	-0.0651	-0.0579	-0.0816	-0.0962	1.0000	-0.0745	0.1904	0.1291	-0.1017	0.0760	-0.0643	-0.6643	-0.4403	-0.0866	-0.0744
Osci	-0.0567	-0.0565	0.0122	-0.0609	-0.0810	-0.0745	1.0000	0.0747	-0.2387	-0.2569	-0.3981	-0.0194	0.2054	0.0980	-0.0503	0.1486
Temp.	0.1227	0.1223	0.1023	-0.3384	-0.2237	0.1904	0.0747	1.0000	0.4282	0.0420	0.2845	0.1595	-0.0077	-0.2235	0.1107	-0.0831
pH	0.3055	0.3050	-0.3210	-0.2245	0.0875	0.1291	-0.2387	0.4282	1.0000	0.4477	0.5866	0.2744	0.0711	-0.0112	0.5112	0.1969
conduct.	0.0339	0.0345	-0.3355	-0.0010	-0.1016	-0.1017	-0.2569	0.0420	0.4477	1.0000	0.4700	0.1786	0.3547	0.0361	0.1396	-0.1559
Turbid	-0.0041	-0.0041	-0.0966	-0.2671	-0.1517	0.0760	-0.3981	0.2845	0.5866	0.4700	1.0000	0.1740	0.1040	-0.0540	0.3403	-0.1211
DO	0.0026	0.0029	0.0024	0.2019	0.1981	-0.0643	-0.0194	0.1595	0.2744	0.1786	0.1740	1.0000	0.3710	0.0154	-0.0397	-0.0335
BOD	0.1217	0.1232	0.0591	0.1093	-0.2858	-0.6643	0.2054	-0.0077	0.0711	0.3547	0.1040	0.3710	1.0000	0.5622	0.1825	0.0474
nitrate	0.1380	0.1390	0.0694	0.1125	-0.1554	-0.4403	0.0980	-0.2235	-0.0112	0.0361	-0.0540	0.0154	0.5622	1.0000	0.6783	0.3128
phosphate	0.0332	0.0332	-0.1190	-0.0585	-0.0601	-0.0866	-0.0503	0.1107	0.5112	0.1396	0.3403	-0.0397	0.1825	0.6783	1.0000	0.3597
ammonia	0.0596	0.0599	-0.0679	0.1450	0.1458	-0.0744	0.1486	-0.0831	0.1969	-0.1559	-0.1211	-0.0335	0.0474	0.3128	0.3597	1.0000

APPENDIX C
Research Data

The accumulation of microcystins in fish and prawn samples in demonstrated ponds

1. Data of some physico-chemical parameters in earthen pond at Maejo University during August 2007 – April 2008 were shown in Tables 1C

Table 1C. Some physico-chemical parameters of earthen pond in April 2008.

Parameters \ Treatment	1	2	3	4	5	6
pH	7.43	8.05	7.90	7.80	7.75	7.72
Conductivity ($\mu s.cm^{-1}$)	173	200	216	218	232	288
Dissolved oxygen ($mg.l^{-1}$)	5.5	7.1	6.7	5.8	5.1	4.9
BOD ($mg.l^{-1}$)	2.1	13.5	13.7	10.0	24.2	33.8
Nitrate nitrogen ($mg.l^{-1}$)	0.13	0.20	0.23	0.41	0.18	0.25
Soluble reactive phosphorus ($mg.l^{-1}$)	0.85	0.82	0.89	1.42	2.22	2.40
Ammonium nitrogen ($mg.l^{-1}$)	0.54	0.79	0.80	0.93	0.86	0.86

2. Data of species composition in earthen pond at Maejo University during August 2007 – April 2008 were shown in Tables 2C

Table 2C Diversity of phytoplankton in earthen pond in April 2008.

Phytoplankton \ Treatment	1	2	3	4	5	6
	(cells/colony/filaments per liter)					
Division Chlorophyta						
Actinastrum hantzchii Lagerheim			1,300			
Ankistrodesmus bibraianus (Reinsch) Kors.			2,000			750
Chlorella sp.					28,125	
Coelastrum sp.	2,350		100	125		
Crucigeniella crucifera (Wolle) Komarek		188	6,500	1,000	188	
Dictyosphaerium pulchellum Wood (colony)				250		1,500
Eudorina sp.					750	

Table 2C (continued)

Phytoplankton \ Treatment	1	2	3	4	5	6
	(cells/colony/filaments per liter)					
Monoraphidium acuatum (Korshikov) Hindak				375	376	
Nephrocytium sp. (colony)		188	500			
Pediastrum boryasnum					188	
Pediastrum duplex Meyen	150	813	2,000	1,250		
Pediastrum simplex Meyen	50	1,250	500	1,375		
Pediastrum tetras (Ehrenberg) Ralfs			500			
Scenedesmus acuminatus var. tetradesmoides Smith		313	2,000		1,125	2,250
Scenedesmus falcatus Chodat				3,125		
Selenastrum sp.			100			
Staurastrum sp.			100			750
Tetraedron caudatrum		125			938	
Tetraedron sp.					188	
Division Cyanophyta						
Anabaena catenula		63				
Anabaena spiroides						
Aphanocapsa	50		1600			
Coelosphaerium sp. (colony)						
Cylindrospermopsis raciborskii Wolosz.		1,813	500	8,625		
Cylindrospermopsis philippinensis Komarek			300			
Merismopedia tenuissima Lemmermann (colony)		438	600	375	2,063	
Microcystis aeruginosa Kützing	213	375	3,000	6,750	1,125	2,650
Microcystis wesenbergii Komarek			500			
Oscillatoria subbrevis Schmidle			200		30,000	7,500
Oscillatoria tenuis Gomont						1,500
Pseudanabaena sp.			200		1,500	
Division Bacillriophyta						
Achnanthes sp.		63				
Cyclotella sp.						
Fagilaria sp.		563	1,200			
Gomphonema sp.	100					

Table 2C (continued)

Phytoplankton	Treatment 1	2	3	4	5	6
	(cells/colony/filaments per liter)					
Navicula sp.		63				
Pinnularia sp.		63				
Surirella sp.		63				
Division Euglenophyta						
Euglena acus Ehrenberg				250		20,250
Euglena elastica	50		100	250	1,500	122,250
Euglena oxyuris fo. major Popova					24,750	
Euglena sp. 1						2,250
Euglena sp. 2						2,250
Phacus longicauda (Ehrenberg) Dujardin		250		375	188	78,000
Phacus sp.				250		10,500
Strombomonas acuminatus (Schmorda) Deflandre						3,750
Trachelomonas bulla Stein emend Deflandre			500		938	
Trachelomonas caudata (Ehrenberg) Stein				1,000		
Trachelomonas hispida Ehrenberg				257	188	
Trachelomonas volvocina Ehrenberg	100		1000		188	
Division Pyrrhophyta						
Peridinium sp.	250				564	750
Division Xanthophyta						
Istmochloron sp.		63	100			
Division Cryptophyta						
Chroomonas sp.					188	

3. Data of species composition in cement pond at Maejo University during July – August 2008 and May – June 2009 were shown in Tables 3C - 5C and 6C - 7C respectively.

Table 3C Diversity of phytoplankton in cement pond in July 2008.

Treatment	**Tr.1**	**Tr.2**	**Tr.3**	**Tr.1**	**Tr.2**	**Tr.3**
Phytoplankton	20/7/08	20/7/08	20/7/08	1/08/08	1/08/08	1/08/08
Division Chlorophyta						
Ankistrodesmus fusiformis Corda						
Chlorella sp.	2,550	15,300		1,188	9,275	
Coelastrum astroideum De Notaris	850	17,550		450		6,175
Coelastrum reticulatum (P.A.Dangeard) Senn						
Crucigeniella apiculata (Lemmermann) Komárek						
Dictyosphaerium pulchellum Wood (colony)		6,375		900		2,275
Kirchneriella irregularis (G.M.Smith) Korshikov		5,850				
Monoraphidium arcuatum (Korshikov) Hindak				3,125		5,850
Monoraphidium minutum (Nägeli) Komárková-legnerová		7,800				
Oocystis sp.				450		650
Pandorina sp.						
Pediastrum simplex Meyen				875	3,950	
Pediastrum duplex Meyen	2,550	6,375		850		
Pediastrum duplex var. *gracillimum* West & West						
Scenedesmus sp. 1	850	26,775	19,500	875	10,975	5,350
Scenedesmus sp. 2			175,500	450	17,013	31,600
Scenedesmus sp. 3		20,400	50,700	850		
Scenedesmus sp. 4		6,375				
Staurastrum sp.		850				
Tetraedron caudatum (Corda) Hansgirg	2,550					
Tetraedron sp.1		850	1,950			
Division Cyanophyta						
Microcystis aeruginosa Kützing		21,751,500	45,661,000		20,302,250	25,617,500
Microcystis wesenbergii Komarek						
Oscillatoria sp.				450	850	715
Division Bacillriophyta						
Aulocoseira granulata Simonsen		5,100			4,713	
Cyclotella sp.	750					
Fagilaria sp.						

Table 3C (continued)

Treatment	Tr.1	Tr.2	Tr.3	Tr.1	Tr.2	Tr.3
Phytoplankton	20/7/08	20/7/08	20/7/08	1/08/08	1/08/08	1/08/08
Gomphonema sp.		5,100	3,900			3900
Navicula sp. 1		850		425	850	5,200
Navicula sp. 2	750					
Nitzschia sp.		850				
Division Euglenophyta						
Euglena oxyuris fo. major Popova						
Euglena sp.				425		3,575
Lepocinclis						
Phacus sp. 1	1,700			450	425	
Trachelomonas caudata (Ehrenberg) Stein	850			450		
Trachelomonas hispida Ehrenberg						
Trachelomonas volvocina Ehrenberg						
Division Pyrrhophyta						
Peridinium sp. 1					425	715

Table 4C Diversity of phytoplankton in cement pond in August 2008.

Treatment	Tr.1	Tr.2	Tr.3	Tr.1	Tr.2	Tr.3
Phytoplankton	8/8/08	8/8/08	8/8/08	15/8/08	15/8/08	15/8/08
Division Chlorophyta						
Ankistrodesmus fusiformis Corda			2,925	17,450	650	
Chlorella sp.	943					
Coelastrum astroideum De Notaris	525	1,475	1,450	3,400	1,300	3,400
Coelastrum reticulatum (P.A.Dangeard) Senn						
Crucigeniella apiculata (Lemmermann) Komárek	1,360	2,200				2,550
Dictyosphaerium pulchellum Wood (colony)	4,080	2,200	3,000			2,550
Kirchneriella irregularis (G.M.Smith) Korshikov						
Monoraphidium arcuatum (Korshikov) Hindak	2,547	1,525	1,450	1,725	3,000	4,250
Oocystis sp.				850		1,700
Pandorina sp.	1,013					
Pediastrum simplex Meyen	6,944	600	1,075		2,600	5,100
Pediastrum duplex Meyen	2,720	600	750		1,300	
Pediastrum duplex var. *gracillimum* West & West						

Table 4C (continued)

Treatment	Tr.1	Tr.2	Tr.3	Tr.1	Tr.2	Tr.3
Phytoplankton	8/8/08	8/8/08	8/8/08	15/8/08	15/8/08	15/8/08
Scenedesmus sp. 1	525	5,125	1,800	850	3,900	12,750
Scenedesmus sp. 2	525	4,425	1,775	850	1,075	2,975
Scenedesmus sp. 3						
Staurastrum sp.	4,080					
Tetraedron caudatum (Corda) Hansgirg				850	650	
Division Cyanophyta						
Microcystis aeruginosa Kützing (เซลล์)		21,848,250	33,960,000		17,608,500	26,344,000
Microcystis wesenbergii Komarek						
Oscillatoria sp.	6,800	1,200				1,275
Division Bacillriophyta						
Aulocoseira granulata Simonsen	1,013					850
Cyclotella sp.	4,080					
Fagilaria sp.					650	
Gomphonema sp.	525					1,700
Navicula sp. 1		600			1,625	850
Navicula sp. 2						
Nitzschia sp.				850		
Division Euglenophyta						
Euglena oxyuris fo. major Popova						
Euglena sp.	525	1,300			1,625	
Lepocinclis						
Phacus sp. 1		550				
Trachelomonas caudata (Ehrenberg) Stein		1,150				1,700
Trachelomonas hispida Ehrenberg						
Division Pyrrhophyta						
Peridinium sp. 1	525	550			650	850

Table 5C Diversity of phytoplankton in cement pond in August 2008.

Treatment	Tr.1	Tr.2	Tr.3
Phytoplankton	21/8/08	21/8/08	21/8/08
Division Chlorophyta			
Ankistrodesmus fusiformis Corda	2,925		
Chlorella sp.		10,763	
Coelastrum astroideum De Notaris	1,450	1,388	

Table 5C (continued)

Treatment	Tr.1	Tr.2	Tr.3
Phytoplankton	21/8/08	21/8/08	21/8/08
Coelastrum reticulatum (P.A.Dangeard) Senn			15,600
Crucigeniella apiculata (Lemmermann) Komárek		1,275	4,875
Dictyosphaerium pulchellum Wood (โคโลนี)	3,000	6,188	
Kirchneriella irregularis (G.M.Smith) Korshikov			5,850
Monoraphidium arcuatum (Korshikov) Hindak	1,450		5,850
Oocystis sp.			
Pandorina sp.			
Pediastrum simplex Meyen	1,075	1,500	2,925
Pediastrum duplex Meyen	750	6,188	1,950
Pediastrum duplex var. *gracillimum* West & West			
Scenedesmus sp. 1	1,800	20,888	15,600
Scenedesmus sp. 2	1,775	21,450	54,600
Scenedesmus sp. 3		6,188	
Staurastrum sp.			
Tetraedron caudatum (Corda) Hansgirg			1,950
Division Cyanophyta			
Microcystis aeruginosa Kützing		19,012,500	35,109,750
Microcystis wesenbergii Komarek			
Oscillatoria sp.		3,938	
Division Bacillriophyta			
Aulocoseira granulata Simonsen		3,300	
Cyclotella sp.			
Fagilaria sp.			
Gomphonema sp.	1500		2,925
Navicula sp. 1	725	1,388	
Navicula sp. 2			
Nitzschia sp.	2,100		
Division Euglenophyta			
Euglena oxyuris fo. major Popova			1,950
Euglena sp.			
Lepocinclis			
Phacus sp. 1	1,500		
Trachelomonas caudata (Ehrenberg) Stein			
Trachelomonas hispida Ehrenberg	1,500		1,950
Division Pyrrhophyta			1,950
Peridinium sp. 1			1,950

Table 6C Diversity of phytoplankton in cement pond in May 2009.

Treatment	**Tr.1**	**Tr.2**	**Tr.3**	**Tr.1**	**Tr.2**	**Tr.3**
Phytoplankton	16/05/09	16/05/09	16/05/09	30/05/09	30/05/09	30/05/09
Division Chlorophyta						
Ankistrodesmus fusiformis Corda	24,050					
Chlorella sp.			1,950			
Coelastrum astroideum De Notaris	19,500	3,900				7,200
Coelastrum reticulatum (P.A.Dangeard) Senn				900		
Coelastrum sp.					900	
Crucigeniella apiculata (Lemmermann) Komárek		5,850				
Dictyosphaerium pulchellum Wood						
Kirchneriella irregularis (G.M.Smith) Korshikov						
Monoraphidium arcuatum (Korshikov) Hindak		7,800		1,350		900
Monoraphidium minutum (Nägeli) Komárková-legnerová						
Oocystis sp.						
Pandorina sp.						
Pediastrum simplex Meyen	5,200	1,300	2,925			
Pediastrum duplex Meyen				5,400	900	
Pediastrum duplex var. *gracillimum* West & West						
Scenedesmus sp. 1	19,500	39,000	5,850	1,400	2,250	1,800
Scenedesmus sp. 2	3,250	25,350	1,300		7,650	
Scenedesmus sp. 3				2,100		900
Scenedesmus sp. 4						
Staurastrum sp.			1,300			
Division Cyanophyta						
Microcystis aeruginosa Kützing		17,169,150	18,655,650		31,170,000	29,050,000
Microcystis wesenbergii Komarek						
Oscillatoria sp.						

Table 6C (continued)

Treatment	Tr.1	Tr.2	Tr.3	Tr.1	Tr.2	Tr.3
Phytoplankton	16/05/09	16/05/09	16/05/09	30/05/09	30/05/09	30/05/09
Tetraedron caudatum (Corda) Hansgirg						
Tetraedron sp.1						
Division Bacillriophyta						
Aulocoseira granulata Simonsen				2,100	450	
Cyclotella sp.						
Fagilaria sp.			1,300			
Gomphonema sp. 1	11,700	9,750				
Gomphonema sp. 2		3,900	650		900	
Navicula sp. 1	15,600		1,300		450	
Navicula sp. 2						
Nitzschia sp.					2,250	1,800
Division Euglenophyta						
Euglena acus Ehrenberg			650			
Euglena oxyuris fo. major Popova						900
Euglena sp.	3,250					
Lepocinclis						
Phacus sp. 1						900
Trachelomonas caudata (Ehrenberg) Stein						
Trachelomonas hispida Ehrenberg						
Trachelomonas volvocina Ehrenberg						
Division Pyrrhophyta						
Peridinium sp. 1		1,950				

Table. 7C Diversity of phytoplankton in cement pond in June 2009.

Treatment	Tr.1	Tr.2	Tr.3
Phytoplankton	10/6/09	10/6/09	10/6/09
Division Chlorophyta			
Ankistrodesmus fusiformis Corda			12,250
Chlorella sp.	13,050		
Coelastrum astroideum De Notaris			752
Crucigeniella apiculata (Lemmermann) Komárek		650	
Dictyosphaerium pulchellum Wood (โคโลนี)	1,350	650	

Table. 7C (continued)

Treatment	**Tr.1**	**Tr.2**	**Tr.3**
Phytoplankton	10/6/09	10/6/09	10/6/09
Kirchneriella irregularis (G.M.Smith) Korshikov		650	
Monoraphidium minutum (Nägeli) Komárková-legnerová			
Oocystis sp.	550		752
Pediastrum simplex Meyen			752
Pediastrum duplex Meyen	550		752
Pediastrum duplex var. *gracillimum* West & West		650	
Scenedesmus sp. 1	3,250	10,400	8,450
Scenedesmus sp. 2			
Scenedesmus sp. 3	450		
Scenedesmus sp. 4		3,250	
Staurastrum sp.		650	
Tetraedron caudatum (Corda) Hansgirg			8,450
Tetraedron sp.1		650	
Division Cyanophyta			
Microcystis aeruginosa Kützing (เซลล์)		18,404,100	15,219,750
Microcystis wesenbergii Komarek		292,500	
Oscillatoria sp.	450		1,250
Division Bacillriophyta			
Aulocoseira granulata Simonsen			
Cyclotella sp.			
Fagilaria sp.			750
Gomphonema sp.	3,270	1,300	
Navicula sp. 1	4,735	11,700	1,350
Navicula sp. 2			
Nitzschia sp.			
Division Euglenophyta			
Euglena oxyuris fo. major Popova			750
Lepocinclis		650	
Phacus sp. 1			750
Trachelomonas hispida Ehrenberg			
Trachelomonas volvocina Ehrenberg		650	
Division Pyrrhophyta			
Peridinium sp. 1			752

3. Data of species composition in cement pond at Maejo University during September - November 2009 were shown in Tables 8C - 9C.

Table 8C Diversity of phytoplankton in cement pond in September 2009.

Treatment / **Phytoplankton**	**Tr. 1** 4/09/09	**Tr. 2** 4/09/09	**Tr. 1** 19/09/09	**Tr. 2** 19/09/09
Division Chlorophyta				
Chlorella sp.	0	175	0	0
Closterium sp.	0	0	0	0
Coelastrum astroideum De Notaris	0	0	426	0
Coelastrum sp.	290	1,260	528	5,775
Dictyosphaerium pulchellum Wood (colonh)	0	6,293	0	8,587
Eudorina sp.	88	0	0	0
Kirchneriella irregularis (G.M.Smith) Korshikov	175	3,040	0	0
Monoraphidium arcuatum (Korshikov) Hindak	425	10,480	264	15,867
Pandorina sp.	203	0	0	0
Pediastrum simplex Meyen	88	0	2,200	0
Pediastrum duplex Meyen	230	3,420	330	9,683
Pediastrum duplex var. *gracillimum* West & West	0	7,093	0	0
Scenedesmus sp. 1	1,380	25,707	1,926	42,560
Scenedesmus sp. 2	0	21,907	426	7,467
Scenedesmus sp. 3	0	23,573	0	31,267
Staurastrum sp.	183	150	0	1,400
Tetraedron caudatum (Corda) Hansg.	115	0	0	0
Tetraedron sp.	0	0	0	0
Division Cyanophyta				
Microcystis aeruginosa Kützing	0	18,886,400	0	14,763,767
Oscillatoria sp.	0	4,227	426	5,880
	0	0	0	0
Division Bacillriophyta	0	0	0	0
Achnanthidium sp.	6,388	0	13,200	0
Aulocoseira granulata Simonsen	175	1,360	0	0
Cyclotella sp.	10,354	49,373	6,325	24,733
Gomphonema sp.	0	0	0	0
Navicula cryptotenelloides Lange-Bertalot	2,418	0	3,506	0
Navicula sp. 2	115	0	0	0
Nitzschia sp.	1,893	0	0	0

Table 8C (continued)

Treatment	**Tr. 1**	**Tr. 2**	**Tr. 1**	**Tr. 2**
Phytoplankton	4/09/09	4/09/09	19/09/09	19/09/09
Division Euglenophyta				
Euglena acus Ehrenberg	115	0	0	0
Euglena sp.	290	0	426	700
Phacus sp. 1	115	0	0	0
Trachelomonas hispida Ehrenberg	115	0	0	0
Division Pyrrhophyta				
Peridinium sp.	640	1,400	0	3,983

Table 9C Diversity of phytoplankton in cement pond in September 2009.

Treatment	**Tr. 1**	**Tr. 2**	**Tr. 1**	**Tr. 2**
Phytoplankton	1/11/09	1/11/09	24/11/09	24/11/09
Division Chlorophyta				
Chlorella sp.	533	0	0	400
Closterium sp.	0	0	0	533
Coelastrum astroideum De Notaris	135	0	200	225
Coelastrum sp.	0	0	0	400
Cosmarium sp.	0	0	495	0
Crucigeniella crucifera (Wolle) Komarek	0	0	0	400
Dictyosphaerium pulchellum Wood (colony)	0	7,867	83	0
Kirchneriella irregularis (G.M.Smith) Korshikov	0	1,887	0	0
Monoraphidium arcuatum (Korshikov) Hindak	0	76,267	0	0
Monoraphidium minutum (Näg.) Kom.-Leg.	675	35,583	330	12,880
Oocystis sp.	0	0	0	400
Pandorina sp.	0	0	300	0
Pediastrum simplex Meyen	0	4,940	0	400
Pediastrum duplex Meyen	0	2,200	330	0
Scenedesmus sp. 1	2,200	11,500	1,598	800
Scenedesmus sp. 2	900	15,600	700	0
Scenedesmus sp. 3	0	0	8,663	0
Staurastrum sp.	0	0	630	1,707
Tetraedron caudatum (Corda) Hansg.	0	0	83	0
Tetraedron sp.	133	0	0	0

Table 9C. (continued)

Treatment	**Tr. 1**	**Tr. 2**	**Tr. 1**	**Tr. 2**
Phytoplankton	1/11/09	1/11/09	24/11/09	24/11/09
Division Cyanophyta				
Microcystis aeruginosa Kützing	0	12,620,333	0	19,600,000
Oscillatoria sp.	0	1,433	0	0
Division Bacillriophyta				
Achnanthidium sp.	54,700	0	0	2,133
Cyclotella sp.	4,115	853	150	907
Fragilaria sp.	8,333	0	0	0
Gomphonema sp.	0	427	75	0
Luticula sp.	1,287	0	0	0
Meloseira sp. 1	0	0	233	36,333
Navicula cryptotenelloides Lange-Bertalot	2,700	0	0	800
Nitzschia sp.	2,085	400	0	194,133
Division Euglenophyta				
Euglena sp. 1	0	0	350	1,200
Trachelomonas hispida Ehrenberg	0	0	100	0
Trachelomonas volvocina Ehrenberg	467	467	0	0
Division Pyrrhophyta				
Peridinium sp. 1	135	0	375	1,400

3. Cell numbers of *Microcystis aeruginosa* in various concentration of Effective Microorganisms (EM) were shown in Tables 10C - 11C.

Table 10C. Amount of *Microcystis aeruginosa* in various concentration of EM1

EM1		I	II	III	mean	se
3-Mar-09	control	16,933,500	18,589,500	26,922,000	20,815,000	2523541
	EM1 (0.3)	26,266,000	19,425,000	18,910,000	21,533,667	1935777
	EM1 (0.5)	24,042,000	22,073,500	21,823,000	22,646,167	572897.2
	EM1 (1.0)	21,660,000	23,275,000	21,851,500	22,262,167	415943.8
7-Apr-09	control	2,680,000	1,800,000	1,792,500	2,090,833	240532.8
	EM1 (0.3)	2,040,000	2,701,300	1,550,000	2,097,100	272363.4
	EM1 (0.5)	1,837,500	1,756,300	1,674,200	1,756,000	38490.37
	EM1 (1.0)	2,040,100	1,219,750	1,919,750	1,726,533	208829

Table 11C. Amount of *Microcystis aeruginosa* in various concentration of EM2

EM2		I	II	III	mean	se
3-Mar-09	control	16,754,100	18,665,100	15,929,750	17,116,317	661469
	EM2 (0.3)	17,159,150	17,232,150	18,645,650	17,678,983	395014.9
	EM2 (0.5)	17,574,625	22,870,000	21,170,000	20,538,208	1274504
	EM2 (1.0)	22,585,000	20,050,000	19,771,000	20,802,000	730871.2
7-Apr-09	control	2,660,150	1,850,000	1,750,000	2,086,717	235286.7
	EM2 (0.3)	1,837,500	3,851,700	1,854,600	2,514,600	545883.7
	EM2 (0.5)	2,753,000	2,437,500	1,348,250	2,179,583	347441.9
	EM2 (1.0)	1,960,000	1,608,500	3,634,400	2,400,967	510317.2

CURRICULUM VITAE

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- Toxic cyanobacteria and microcystin in fish and prawn farm

Publication (2005-2013)

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