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Full Paper

Water quality variation and algal succession in commercial hybrid catfish production ponds

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Abstract: This study on water quality variation and algal succession in commercial hybrid catfish production ponds was conducted in 2007 in Bang Pa-In district, Ayutthaya province, Thailand. The study covered two fish crops, May-August and September-December. The physico-chemical water quality in the catfish ponds changed dramatically over the study period due to the practices of water changing, lime application and the culture duration before harvesting. Samples of algae collected during the first crop period contained 83 species belonging to the following divisions: Chlorophyta (34 species), Cyanophyta (28 species), Euglenophyta (12 species), Bacillariophyta (6 species), Chrysophyta (1 species), Pyrrhophyta (1 species) and Cryptophyta (1 species). Samples collected during the second crop contained 60 species of the following divisions: Chlorophyta (28 species), Cyanophyta (16 species), Euglenophyta (10 species) and Bacillariophyta (6 species). Cyanophyta was the most abundant in both crops, followed by Chlorophyta, Euglenophyta, Bacillariophyta, Chrysophyta, Cryptophyta and Pyrrhophyta. The blue-green algae *Microcystis* increasingly dominated the algal population during the course of the culture period. *Pseudanabaena* spp. were succeeded by *Oscillatoria* spp. and then *Microcystis* spp. in the first crop. *Microcystis* spp. dominated during the first two months of the second crop, and then was succeeded by *Planktolyngbya* spp. and *Nitzschia* spp. in the third and fourth months. In summary, water quality may account for algal proliferation resulting in algal blooms and influence algal succession in commercial catfish production ponds.

Keywords: water quality, algal succession, commercial production pond, hybrid catfish

INTRODUCTION

Hybrid catfish, the offspring of *Clarias macrocephalus* crossed with *Clarias gariepinus*, is among the most popular freshwater fish cultured commercially in South-east Asia, especially in Thailand [1]. In 2006, the production of this hybrid catfish in Thailand was estimated at 149,000 tons and valued at about 4,998.9 million Baht [2]. Since they are air breathers, hybrid catfish can be pond-cultured at extremely high density, up to 100 fish/m^2, with production reaching up to 100 tons/ha [1]. However, the off-flavour in the flesh of cultured catfish can be a problem, leading to market value reduction and/or making the fish unmarketable for a certain period of time, from a few days to weeks [3]. The off-flavour problem in cultured catfish is caused by compounds produced by certain kinds of blue-green algae, which are absorbed by the catfish and impart a bad flavour to the flesh if the harvest is delayed [4]. These blue-green algae can be found growing in catfish production ponds where an excessive amount of waste nutrients are generated. High density of the fish stocks and intensive feed input can result in extreme quantities of waste nutrients entering the production pond, which may account for the algal proliferation and resulting algal blooms [5]. Catfish cultured entirely and intensively in production ponds are commonly fed with pellet feed, trash fish and ground chicken skeletons and offal. Although the water in the production pond is normally changed completely during each production cycle of about 120-150 days, such feeding nevertheless causes a general deterioration of water quality and a decrease in dissolved oxygen in the pond water [6]. Low water quality also influences fish growth. In addition, the wastewater effluent from hybrid catfish production ponds can contain concentrated algal compounds and nutrients with a high nitrogen content, making it unsuitable for other profitable uses such as the culturing of other aquatic animals [7–9].

The seasonal succession of nutrients and phytoplankton populations in temperate and tropical systems has been extensively documented [10,11]. In tropical shallow water systems the roles of wet/dry seasons and wind typically have a greater impact on phytoplankton biomass production than inter-seasonal variations [12]. However, many other different types of algae prevailing in other climates also exhibit these wide swings in population densities. Some possible causes of these fluctuations include changes in temperature, pH, carbon dioxide, light intensity, nutrient concentration and the release of toxins by other organisms including competing algae [3]. Inthamjit et al. [9] reported a significant change in water quality during intensive culturing of hybrid catfish, where the value ranges of the parameters contributing to water quality were: dissolved oxygen (DO), 4.8-30.8 mg/L; biochemical oxygen demand (BOD), 24-90 mg/L; chemical oxygen demand (COD), 62-330 mg/L; chlorophyll a, 218-1,908 μg/L; total suspended solids (TSS), 378-1,490 mg/L; ammonia-nitrogen (NH_3-N), 0.003-0.270 mg/L; nitrate-nitrogen (NO_3^--N), 0.00-0.06 mg/L; nitrite-nitrogen (NO_2^--N), 0.01-0.03 mg/L; total phosphorus (TP), 1.50-5.81 mg/L; orthophosphate phosphorus (PO_4^{3-}-P), 0.00-2.11 mg/L; alkalinity, 91-388 mg/L; hardness (as $CaCO_3$), 300-580 mg/L; electrical conductivity, 800-1,900 μS/cm; and pH, 6.7-7.8. Stephens and Farris [13] compared the water quality from two channel catfish farms near Paragould, Arkansas (USA) during the summer of 2001 and found the following values: DO, 8.3 and 9.6 mg/L; chlorophyll a, 62 and 143 mg/L; TSS, 102 and 81 mg/L; NH_3-N, 0.16 and 0.16 mg/L; NO_3^--N, <0.005 and <0.005 mg/L; NO2¯N, <0.81 and <0.001 mg/L; phosphorus (as soluble reactive

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phosphorus (SRP)), 1.188 and 2.38 mg/L; alkalinity, 118 and 167 mg/L; hardness, 93 and 192 mg/L; conductivity, 303 and 354 µS/cm; pH, 9.0 and 8.9; water temperature, 23 and 29 ºC; and fecal coliform bacteria, 603 and 433 CFU/100 mL.

In Thailand, Ayutthaya province has many commercial hybrid catfish farms. Geographically, the province is mainly a lowland plain situated in the Chao Phraya River basin of central Thailand, where the soil is highly fertile and water is readily available year-round. Because of these natural advantages, the province is an important farming area for many other types of fish in addition to hybrid catfish. Based on Thailand's fisheries statistics in 2005 [2], Ayutthaya, with a total land area of 2,412.8 ha, has a total of 3,623 farms engaged in pisciculture with a total yield of 2,176 tons. In Bang Pa-In district of the province (Figure 1) where this study was conducted, various forms of fish culture are practiced, including extensive, semi-intensive, intensive and integrated fish culture. For commercial hybrid catfish farming in this area, most of the culture are intensive systems.

This study investigated the variations of water quality in terms of physical, chemical and biological aspects, as well as the succession of algae in commercial hybrid catfish production ponds.

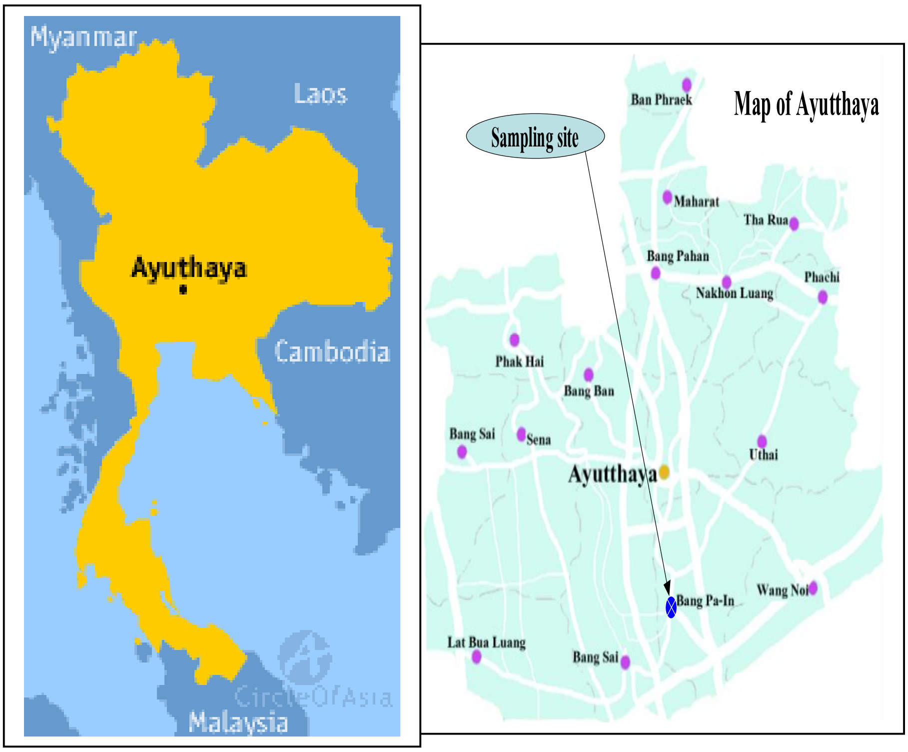

Figure 1. Map of Thailand and location of the study area in Phra Nakhon, Sri Ayutthaya province

MATERIALS AND METHODS

Study Area

The study area selected, Bang Pa-In district of Ayutthaya province (Figure 1), has a total land area of 488.8 ha, where 873 farmers were involved in fish culture [14]. Early in 2007, a field survey was conducted in the district. Three hybrid catfish farms, which were located near to one another and

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which practiced similar fish culture systems, were selected as the sampling sites for this study. The study duration covered two fish crops in 2007, with the first crop from May to August and the second from September to December. Three replicates of water samples were collected monthly from the hybrid catfish production ponds at the three selected fish farms. In keeping with standard industrial practice for the culture of hybrid catfish, farmers released fingerlings into the production ponds (each 0.08 ha in size) at a density of 50 fingerlings/m2. The fingerlings were fed twice a day between 8-9 a.m. and 5-6 p.m. with pellet feed during the first and second months. Then during the third and fourth months they were fed chicken offal mixed with cassava chips in a ratio of 95:5. Water changing and lime application were carried out occasionally to manage water quality in the production ponds. The fish were cultured for 120-130 days before being harvested. The average fish yields were 59.38 tons/ha and 57.50 tons/ha for the first and second crops respectively, with the food conversion rate reaching 3.8-4.2.

Physico-Chemical Water Quality Analysis

Three replicates of water samples were collected monthly from the production ponds during both fish crops: May-August and September-December, 2007. All water samples were collected at a depth of 0.3-0.4 m and then preserved in an icebox until further processing. Water temperature, pH and DO were measured in situ using a portable hand-held meter (Multi 350i; WTW, Germany). Water transparency and water depth were measured using a Secchi disk and a measuring tape respectively. The analyses of chemical parameters were then carried out using suitable methods [15-16]: BOD by azide modification method; NH_3-N by Nesslerisation method; NO_3^--N by phenoldisulphonic acid method; total Kjeldahl nitrogen (TKN) by macro-Kjeldahl method; total phosphate by persulphate digestion/stannous chloride method; and orthophosphate phosphorus (PO_4^{3-}-P) by stannous chloride method.

Algal Analysis

For the algae count, the water sample (500 mL) from each production pond was transferred to a 500-mL cylinder and fixed with 5 mL of Lugol's solution (20 g glacial acetic acid, 20 g potassium iodide and 20 g iodine dissolved in 200 mL distilled water). The preserved sample was left to stand in the dark for 10 days to allow concentration by decantation. A 20-25 mL sample from the lower layer of the 500-mL cylinder, containing the sedimented algae, was obtained and transferred to a 50-mL cylinder. A second decantation was conducted after another 7 days in the dark; a 10-mL sample from the lower layer of the 50-mL cylinder, containing the sedimented algae, was put into a glass vial and stored in a dark cupboard [17]. This concentrated sample of algae was used for their identification [18-22] and counting under a compound light microscope [17].

Statistical Analysis

Collected data were statistically analysed using SPSS software program, version 14. Differences in means of water quality and algal population were established using analysis of variance (ANOVA), and relationships between algae and water quality parameters were tested using Pearson product-moment correlation. The level of significance was set at 0.05.

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RESULTS AND DISCUSSION

Water Quality

Water quality based on physico-chemical and biological parameters from production ponds at all three sampling sites and for both fish crops is presented in Table 1. The temperature optimum for aquaculture in Thailand is between 25-33ºC, depending on the species of fish being cultured; at temperatures above or below the optimum, fish growth is reduced [23]. There was a significant difference in temperature between the two study crops and a marked decline during the 4^{th} month (December) for the second crop. The optimal water transparency for aquaculture is 30 cm [24]. Water transparency in the study ponds ranged between 2.3-25.5 cm for the first fish crop and 1.1-10.3 cm for the second crop—a significant difference between the two crops. There was no significant difference in water depth between the two crops.

The optimal pH range for water used in aquaculture is between 6.5-8.5; however this will vary slightly depending on the cultured species [25]. Ingthamjit et al.[9] reported a pH range of 6.8-7.9 in hybrid catfish production ponds. The pH in the study ponds ranged between 6.6-7.1 for the first fish crop and 6.7-7.4 for the second crop. Generally, it is recommended that alkalinity be maintained within 50-300 mg/L to provide a sufficient buffering (stabilising) effect against pH swings that occur in ponds due to the respiration of the aquatic flora [25, 26]. Alkalinity in the study ponds ranged between 115.7-145.7 mg/L and 114.4-160.0 mg/L in the first and second fish crops respectively, thus displaying a significant difference.

DO is probably the most critical water quality variable in freshwater aquaculture ponds. To achieve optimal growth, a good rule of thumb is to maintain the DO level at saturation or at least 5 mg/L [25, 26]. The ranges of DO values in the study ponds were between 0.8-4.8 mg/L during the first fish crop and 1.5-4.3 mg/L during the second crop, with a significant difference in the 4^{th}-month values of the two study crops. Also, in the 4^{th} month, BOD reached 78.3 and 85.8 mg/L for the first and second fish crops respectively. These values were significantly different from the 1^{st}- and 2^{nd}-month values for both fish crops.

According to a study by Boyd [26] on unfertilised woodland ponds in Alabama, the average total NH_3-N (NH_4^+ plus NH_3 expressed in terms of N) was 0.052 mg/L and and that for NO_3^--N was 0.075 mg/L. In intensive fish culture ponds, much higher concentrations of inorganic N are common. Channel catfish culture ponds can contain up to 0.5 mg/L of total NH_3-N and 0.25 mg/L of NO_3^--N [26]. NH_3-N concentrations in the study ponds showed no significant difference between the first and second fish crops (0.06-1.77 mg/L). NO_3^--N concentrations varied between 0.01-0.24 mg/L and 0.02-0.03 mg/L for the first and second fish crops respectively, a significant difference being found between the 1^{st} and 4^{th} months of the first crop. Nitrogen is also present as soluble organic compounds and as constituents of living and dead particulate organic matter. Concentrations of organic nitrogen are usually well below 1 mg/L in unpolluted natural water [26]. In fish production ponds, phytoplankton blooms are normally heavy and the concentration of organic nitrogen may exceed 2-3 mg/L. In the study ponds, the TKN concentration reached a maximum level (5.6 mg/L) in the 4^{th} month of the second fish crop.

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Table 1. Monthly means and standard deviations (mean ± SD) of physico-chemical characteristics of water samples from commercial hybrid catfish production ponds, Ayutthaya province, Thailand, 2007

Parameter	Month							
	Crop 1 (mean ± SD)				Crop 2 (mean ± SD)			
	May	June	July	August	September	October	November	December
Water temperature (ºC)	$29.4^{a} \pm 0.1$	$31.8^{a} \pm 0.1$	$31.0^{a} \pm 0.1$	$30.8^{a} \pm 0.1$	$29.0^{b} \pm 0.1$	$28.8^{b} \pm 0.1$	$28.4^{b} \pm 0.1$	$27.5^{b} \pm 0.3$
Water transparency (cm)	$25.5^{a} \pm 0.1$	$10.4^{a} \pm 0.9$	$5.7^{a} \pm 0.8$	$2.3^{a} \pm 0.2$	$10.3^{b} \pm 0.3$	$5.5^{b} \pm 0.9$	$1.7^{b} \pm 0.2$	$1.1^{b} \pm 0.1$
Water depth (m)	1.25 ± 0.1	1.25 ± 0.1	1.25 ± 0.1	1.25 ± 0.1	1.25 ± 0.1	1.25 ± 0.1	1.25 ± 0.1	1.00 ± 0.2
pH	6.7 ± 0.1	$7.1^{a} \pm 0.2$	6.6 ± 0.1	$7.0^{b} \pm 0.1$	6.7 ± 0.1	$6.7^{b} \pm 0.1$	6.7 ± 0.1	$7.4^{a} \pm 0.2$
Alkalinity as $CaCO_3$ (mg/L)	$145.7^{a} \pm 5.1$	$140.0^{a} \pm 3.0$	$123.7^{b} \pm 3.5$	$115.7^{b} \pm 2.1$	$121.1^{b} \pm 3.9$	$114.4^{b} \pm 1.9$	$151.0^{a} \pm 3.6$	$160.0^{a} \pm 1.7$
DO (mg/L)	4.8 ± 0.6	3.2± 0.9	2.6 ± 0.4	$0.8^{b} \pm 0.2$	4.3 ± 0.4	3.5 ± 0.3	2.4 ± 0.5	$1.5^{a} \pm 0.3$
BOD (mg/L)	$24.2^{b} \pm 1.4$	$38.2^{b} \pm 2.8$	65.1 ± 6.8	78.3 ± 6.0	$49.7^{a} \pm 3.2$	$61.1^{a} \pm 4.6$	75.0 ± 2.5	85.8 ± 5.2
NH_3-N (mg/L)	0.2 ± 0.1	0.06 ± 0.02	0.7 ± 0.1	1.7 ± 0.1	0.06 ± 0.04	0.1 ± 0.05	0.6 ± 0.2	1.8 ± 0.3
NO_3^{-}-N (mg/L)	$0.01^{b} \pm 0.01$	0.02 ± 0.01	0.03 ± 0.02	$0.2^{a} \pm 0.04$	$0.03^{a} \pm 0.01$	0.02 ± 0.01	0.03 ± 0.01	$0.03^{b} \pm 0.01$
TKN (mg/L)	1.2 ± 0.1	1.0 ± 0.1	2.4 ± 0.4	$2.9^{b} \pm 0.3$	1.3 ± 0.05	1.27 ± 0.2	2.0 ± 0.2	$5.6^{a} \pm 0.7$
Total P (µg/L)	4.1 ± 3.4	11.8 ± 2.9	11.9 ± 2.4	22.1 ± 4.3	6.0± 1.0	17.0 ± 3.8	12.7 ± 2.5	14.9 ± 3.5
PO_4^{3-}-P (µg/L)	$0.1^{b} \pm 0.1$	$0.8^{b} \pm 0.5$	9.5 ± 1.8	$16.6^{a} \pm 0.9$	$4.5^{a} \pm 1.2$	$8.6^{a} \pm 1.2$	8.6 ± 1.3	$10.6^{b} \pm 0.5$

Note: Values in the same row followed by different superscripts indicate significant difference ($p<0.05$).

The phosphorus concentration in water is usually quite low; dissolved orthophosphate concentration lies within 5-20 µg/L and seldom exceeds 100 µg/L even in highly eutrophic waters, while the concentration of total phosphorus seldom exceeds 1,000 µg/L [26]. Total phosphorus concentrations in the study ponds varied between 4.1-22.1 µg/L with no significant difference between the two crops, while PO_4^{3-}-P concentrations were significantly different between the two crops in the 1st, 2nd and 4th months.

The waste effluent from intensive fish culture as a source of pollution of natural bodies of water has been a major concern [27]. In the present study, water quality deteriorated as the farming season progressed, an occurrence shared by several other findings [9, 13, 28-30]. However, there was a difference in the amount of nutrients added to the water in the fish production ponds owing to difference in the feed applied. In this study, hybrid catfish were fed chicken offal mixed with cassava chips as fresh feed, which actually caused the water quality to deteriorate more rapidly. This was similar to the findings of Yi et al. [6], who showed that using trash fish and chicken offal as feed for fish culture could lead to a rapid deterioration of water quality.

Algal Succession

Algae found in the water samples of the first fish crop were categorised into 83 species of 7 divisions, namely Chlorophyta (34 species), Cyanophyta (28 species), Euglenophyta (12 species), Bacillariophyta (6 species), Chrysophyta (1 species), Pyrrhophyta (1 species) and Cryptophyta (1 species), whereas those of the second fish crop were categorised into 60 species of 4 divisions, namely Chlorophyta (28 species), Cyanophyta (16 species), Euglenophyta (10 species) and Bacillariophyta (6 species) (Table 2).

Abundance percentages of the algal divisions are shown in Table 3. There was no significant difference between the two fish crops in the number of algae of each division. Chlorophyta was most abundant in both fish crops, followed by Cyanophyta, Euglenophyta, Bacillariophyta, Chrysophyta, Cryptophyta and Pyrrhophyta. This confirmed the results obtained by Ingthamjit et al. [9] and Boyd [26] as well as several other reports [28-33]. Phytoplankton occurring in fish production ponds includes members of the following taxonomic divisions: green algae (Chlorophyta), blue-green algae (Cyanophyta), euglenophytes (Euglenophyta), yellow-green and golden-brown algae, diatoms (Chrysophyta) and dinoflagellates (Pyrrhophyta) [26, 28-33]. The dominant algae in the first fish crop were *Microcystis* spp., followed by *Pseudanabaena* spp., *Monoraphidium* spp., *Oscillatoria* spp., *Scenedesmus* spp., *Euglena* spp., *Merismopedia* spp., *Cyclotella* spp., *Coelastrum* spp., *Tetrastrum* sp. and *Spirulina* sp.(Table 4). The second fish crop was dominated by *Microcystis* spp., followed by *Planktolyngbya* sp., *Spirulina* sp., *Cyclotella* spp., *Pseudanabaena* spp., *Merismopedia* spp., *Nitzschia* spp., *Monoraphidium* spp., *Scenedesmus* spp., *Tetrastrum* sp. and *Phacus* spp. (Table 5). Algae of the division Cyanophyta (*Microcystis*) grew densely and were the dominant division in both fish crops. As reported by Welker et al. [34], *Microcystis* is commonly present in eutrophic temperate lakes during summer. These findings are supported by the results of the present study: *Microcystis* species demonstrated better growth in summer and under eutrophic conditions with high concentrations of nutrients in the fish production pond water. Lin [32] and Chowdhury and Mamun[33] also reported that Cyanophyta dominated nutrient-rich channel catfish ponds.

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Table 2. Diversity and classification of algae occurring in commercial hybrid catfish production ponds, Ayutthaya province, Thailand, 2007

DIVISION CHLOROPHYTA
Actinastrum hantzschii, Ankistrodesmus sp., *Closteriopsis* sp., *Closterium* sp. 1, *Coelastrum astroideum, Coelastrum pseudomicroporum, Coelastrum* sp.1, *Cosmarium* sp.1, *Crucigenia crucifera, Crucigeniella rectangularis, Dictyosphaerium granulatum, Dictyosphaerium* sp., *Elakatothrix* sp., *Kirchneriella* sp, *Monoraphidium arcuatum, Monoraphidium caribeum, Monoraphidium contortum, Monoraphidium griffithii, Monoraphidium minutum, Oocystis* sp., *Pediastrum duplex, Pediastrum simplex, Scenedesmus bernardii, Scenedesmus disciformis, Scenedesmus microspina, Scenedesmus opoliensis, Scenedesmus pannonicus, Scenedesmus perforates, Scenedesmus velitaris, Scenedesmus* sp. 1, *Scenedesmus* sp. 2, *Staurastrum cingulum, Tetraedron caudatum, Tetrastrum heteracanthum*
DIVISION CYANOPHYTA
Anabaena catenula, Aphanothece sp., *Arthrospira* sp., *Chloroflexus* sp., *Chroococcus minutes, Chroococcus* sp, *Cylindrospermopsis curvispora, Cylindrospermopsis helicoidea, Cylindrospermopsis raciborskii, Gomphosphaeria* sp., *Komvophoron* sp., *Lyngbya* sp., *Merismopedia convulata, Merismopedia glauca, Merismopedia punctata, Microcystis aeruginosa, Microcystis wesenbergii, Microcystis* sp., *Oscillatoria agardhii, Oscillatoria limosa, Oscillatoria redekei, Planktolyngbya limnetica, Pseudanabaena catenata, Pseudanabaena* sp.1, *Pseudanabaena* sp.2, *Raphidiopsis* sp., *Romeria* sp., *Spirulina* sp.
DIVISION EUGLENOPHYTA
Euglena acus, Phacus orbicularis, Phacus triqueter, Phacus sp.1, *Phacus* sp.2, *Phacus* sp.3, *Strombomonas* sp., *Trachelomonas acanthostoma, Trachelomonas caudata, Trachelomonas cylindrical, Trachelomonas volvocina, Trachelomonas* sp.
DIVISION BACILLARIOPHYTA
Aulacoseira granulata, Cyclotella sp., *Fragilaria* sp., *Melosira* sp., *Nitzschia* sp.1, *Nitzschia* sp.2
DIVISION CHRYSOPHYTA
Isthmochloron sp.
DIVISION PYRRHOPHYTA
Peridinium sp.
DIVISION CRYPTOPHYTA
Cryptomonas sp.

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Table 3. Means and standard deviations of the percentages of abundance of each algal division in hybrid catfish ponds by month

Division	Abundance (%)							
	Crop 1 (mean ± SD)				Crop 2 (mean ± SD)			
	May	June	July	August	September	October	November	December
Chlorophyta	16.26 ± 8.43	34.67 ± 2.61	19.42 ± 12.52	29.79 ± 10.30	12.29 ± 10.88	9.24 ± 7.15	10.56 ± 4.11	21.23 ± 7.18
Cyanophyta	68.40 ± 14.84	41.26 ± 8.59	73.23 ± 5.91	53.57 ± 1.9	74.77 ± 15.68	76.03 ± 12.46	69.02 ± 16.76	49.40 ± 12.98
Bacillariophyta	3.77 ± 0.52	9.51 ± 10.69	2.69 ± 1.29	15.59 ± 11.85	7.33 ± 4.96	9.51 ± 5.16	19.88 ± 14.21	28.36 ± 7.73
Euglenophyta	8.61 ± 4.83	12.10 ± 11.52	4.66 ± 0.65	0.75 ± 0.07	5.60 ± 0.38	5.19 ± 1.6	0.54 ± 0.21	1.02 ± 0.5
Chrysophyta	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.31 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pyrrhophyta	1.07 ± 0.38	2.47 ± 1.80	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cryptophyta	1.89 ± 1.63	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

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Table 4. Means and standard deviations of the percentages of abundance of each algal genus in hybrid catfish ponds by month (Crop 1)

Genus (Division)	Abundance (%)			
	May	June	July	August
Microcystis spp. (Cyanophyta)	0.00 ± 0.00	1.45 ± 0.37	74.66 ± 7.60	28.89 ± 3.27
Pseudanabaena spp. (Cyanophyta)	47.96 ± 21.62	4.14 ± 0.91	3.38 ± 1.01	4.39 ± 3.80
Monoraphidium spp. (Chlorophyta)	12.62 ± 8.20	27.43 ± 8.60	3.17 ± 0.34	11.50 ± 9.15
Oscillatoria spp. (Cyanophyta)	4.92 ± 0.76	37.37 ± 3.89	3.59 ± 1.37	1.30 ± 0.71
Scenedesmus spp. (Chlorophyta)	11.41 ± 0.24	6.86 ± 3.99	4.83 ± 1.63	9.10 ± 4.64
Euglena spp. (Euglenophyta)	12.58 ± 6.01	10.75 ± 9.08	1.53 ± 0.42	0.62 ± 0.04
Merismopedia spp. (Cyanophyta)	3.73 ± 6.46	0.68 ± 1.18	3.57 ± 6.18	13.18 ± 4.99
Cyclotella spp. (Bacillariophyta)	0.00 ± 0.00	3.47 ± 2.81	2.15 ± 2.33	14.35 ± 10.03
Coelastrum spp. (Chlorophyta)	6.79 ± 5.96	2.07 ± 0.46	1.48 ± 1.18	2.33 ± 1.99
Tetrastrum sp. (Chlorophyta)	0.00 ± 0.00	4.76 ± 5.02	1.29 ± 0.64	5.14 ± 4.06
Spirulina sp. (Cyanophyta)	0.00 ± 0.00	1.00 ± 0.57	0.67 ± 0.46	9.18 ± 9.54

Table 5. Means and standard deviations of the percentages of abundance of each algal genus in hybrid catfish ponds by month (Crop 2)

Genus (Division)	Abundance (%)			
	September	October	November	December
Microcystis spp. (Cyanophyta)	32.93 ± 4.57	30.03 ± 5.45	23.31 ± 11.12	16.22 ± 9.73
Planktolyngbya sp. (Cyanophyta)	14.21 ± 4.32	9.56 ± 6.30	28.90 ± 23.35	6.51 ± 4.89
Spirulina sp. (Cyanophyta)	17.68 ± 8.68	29.84 ± 11.36	3.37 ± 0.63	0.95 ± 0.63
Cyclotella spp. (Bacillariophyta)	3.80 ± 2.04	7.04 ± 7.20	19.21 ± 18.01	16.65 ± 3.49
Pseudanabaena spp. (Cyanophyta)	14.33 ± 7.13	10.83 ± 1.20	12.77 ± 20.85	6.51 ± 4.89
Merismopedia spp. (Cyanophyta)	3.91 ± 4.15	5.17 ± 0.68	5.50 ± 4.33	15.93 ± 6.86
Nitzschia spp. (Bacillariophyta)	1.20 ± 0.38	0.00 ± 0.00	0.52 ± 0.13	19.48 ± 2.33
Monoraphidium spp. (Chlorophyta)	3.91 ± 4.15	1.42 ± 1.11	1.87 ± 1.49	8.94 ± 6.15
Scenedesmus spp. (Chlorophyta)	3.09 ± 0.77	2.57 ± 3.28	2.14 ± 0.76	6.09 ± 5.99
Tetrastrum sp. (Chlorophyta)	2.34 ± 3.01	0.22 ± 0.38	1.85 ± 0.80	1.25 ± 1.92
Phacus spp. (Euglenophyta)	4.37 ± 4.42	1.91 ± 0.72	0.20 ± 0.20	0.18 ± 0.13

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Figure 2 shows the dominant species among the algal populations during the different months of the study. *Pseudanabaena* spp. were the dominant species during the 1st month of the first fish crop, followed by *Oscillatoria* spp. and *Microcystis* spp. in the 2nd and 3rd months respectively. For the 2nd fish crop, *Microcystis* spp. dominated during the first two months, followed by *Planktolyngbya* sp. in the 3rd month and *Nitzschia* spp. in the 4th month. The succession of algae seemed to be associated with nutrient accumulation and water changing. This could be determined from the results of the correlation analysis of algal populations and water quality parameters. The prevalence of *Pseudanabaena* spp. was found to be significantly associated with water transparency, which was at the highest level in the first month when these species were the dominant algae. *Microcystis* spp. showed a high correlation with nitrate-nitrogen levels, which increased in the 3th and 4th months of the first fish crop and in the 1st and 2nd months of the second fish crop. The decrease in nitrate-nitrogen level also coincided with a decline in the population of *Microcystis* and an increase of *Planktolyngbya* and *Nitzschia* in the succeeding months. *Planktolyngbya* sp. showed no significant correlation with any of the studied water quality parameters, but tended to grow better in water with less transparency and lower temperature. *Nitzschia* spp. were found to significantly correspond to TKN level. An increase in TKN during the last month of the second fish crop might contribute to the succession of *Nitzschia* spp., as also indicated in studies by Ingthmjit et al.[9], Brunson et al. [35], and Zimba et al [36]. However, the succession of algae in the catfish production ponds differs from that occurring in natural lakes, owing to the dense stock of fish in the ponds and the daily feeding which provides abundant nutrients. As reported by Stephens and Farris [13], algal density in commercial channel catfish production ponds is limited more by nutrient availability than by light. Many other different types of algae also exhibit these wide swings in population density. Possible causes of these fluctuations include changes in temperature, pH, carbon dioxide concentration, light intensity and nutrient concentration, and the release of toxins by other organisms including competing algae [3].

CONCLUSIONS

The physico-chemical water quality in commercial hybrid catfish production ponds located in Ayutthaya changed dramatically over the culture period. Certain water quality parameters influenced algal dominance and succession. While *Microcystis* of the division Cyanophyta dominated throughout, *Pseudanabaena* was succeeded by *Oscillatoria*, followed by *Microcystis* in the first fish crop period, whereas *Microcystis* was succeeded by *Planktolyngbya* and *Nitzschia* in the second fish crop period.

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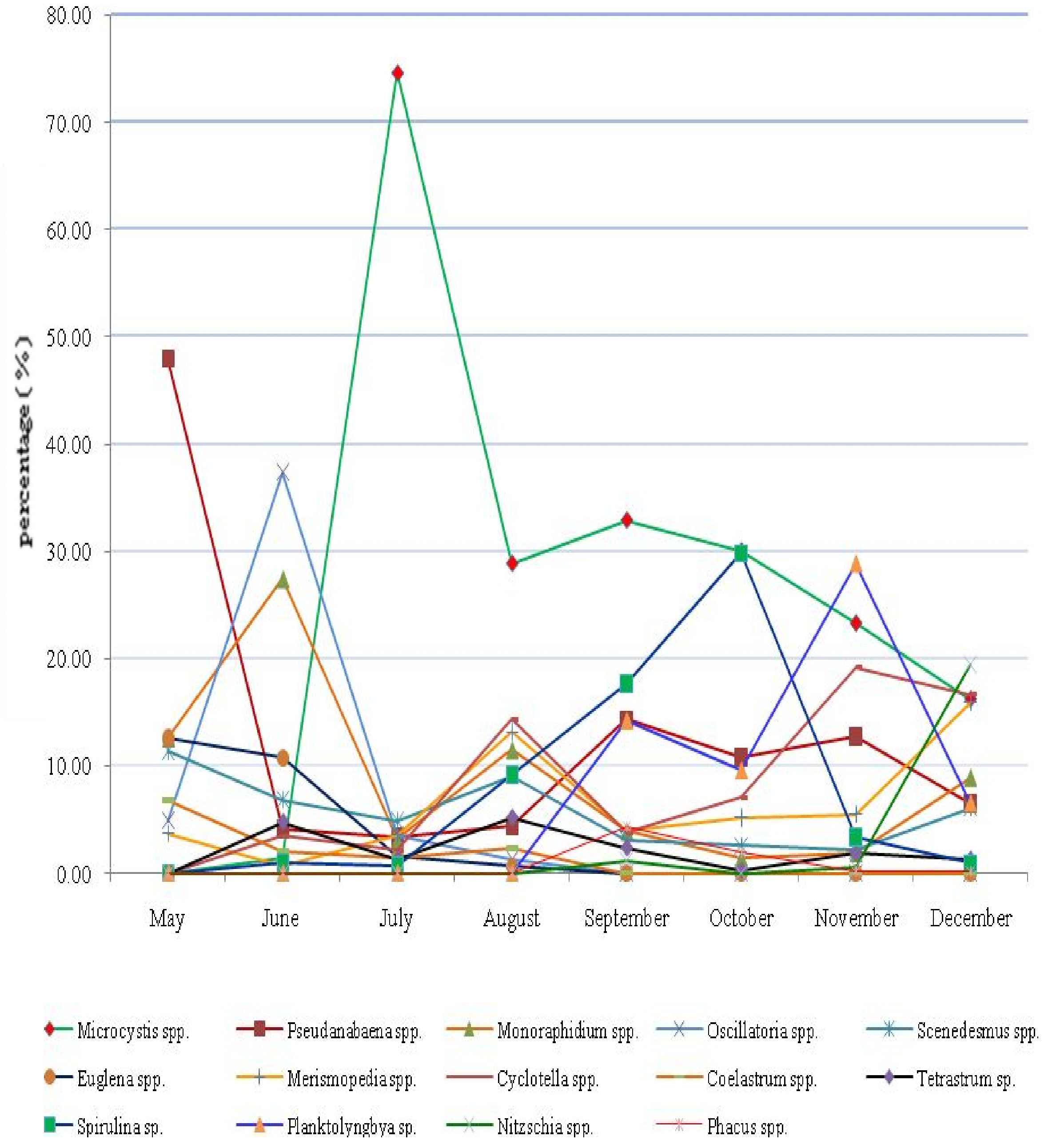

Figure 2. Percentages of abundance of algae in hybrid catfish ponds by month

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