CORRELATIONS BETWEEN PHYTOPLANKTON DISTRIBUTIONS AND LAND USE/LAND COVER IN PHUKET RESERVIORS

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Abstract: This study examined the correlations between land use/land cover types and phytoplankton composition and density in six reservoirs of Phuket province, southern Thailand, during June 2011- January 2012. Using geographic information system, land use/land cover types around the reservoirs were classified into three main groups: three reservoirs with a high proportion of urban land use; two reservoirs with a combination of urban land use and forest cover; and a reservoir with a high proportion of forest cover. Spatial and temporal variations of phytoplankton composition and density were evident in the reservoirs. The two reservoirs with a combination of urban land use and forest cover were dominated by Cyanophyceae and Chrysophyceae. Other reservoirs were dominated by Chlorophyceae. The reservoir with the forest cover had the lowest total abundance of phytoplankton ($17.43x10^6$ cells/L) whereas the reservoirs with the urban land use had high total abundance of phytoplankton ($58.71x10^6$ cells/L). Total phytoplankton density was higher in wet season in all the reservoirs studied. *Oscillatoria* sp. and *Dinobryon* sp. dominated in the reservoir with combination of urban land use and forest cover, especially in wet season. *Staurastrum* sp. was highly observed in other reservoirs. These results suggest spatial and temporal distribution of the phytoplankton were significantly related to land use/land cover characteristic.

INTRODUCTION

Significant correlations between land use/land cover (LULC) and water qualities have been found in water resources around the world (Ren et al., 2003; Basima et al., 2006; Tu, 2011; Ferrareze, 2012). To understand how LULC affects water quality is important to understand non-point source loading. Residential, urban and built-up areas are dominant factors in generating large amounts of non-point source pollution from water discharge into water surface (Basnyat et al., 2000). Generally, LULC changes are related to an increase in economic development and, consequently, have adverse impacts on water quality. Higher percentages of developed land use areas are related to higher concentrations of water pollutants. In contrast, undeveloped lands (e.g. forest) are usually related to good water quality (Tu, 2011).

Phytoplankton composition and distribution are widely used as biological indicators of water quality in reservoirs (Case, 2008; Khuantrairong and Traichaiyaporn, 2008). Phytoplankton is the basis of food chains directly providing food for zooplankton, fishes and some aquatic animals. They are defined as free-floating organisms that play an important role in global climate change by removing carbon dioxide from the atmosphere through photosynthesis. Assessments of phytoplankton composition and distribution in relation to LULC and water uses have been established elsewhere (Basima et al., 2006; Beaver et al., 2012; Paul et al., 2012).

Phuket province, southern Thailand, is one of the many tourist destinations where economic development is expanding rapidly and significantly from tourism activities and, correspondingly, high rates of population growth and urbanization. These lead to an increasing demand for water uses and may raise water shortage issues in dry seasons. Man-made reservoirs in the province are important water resources to supply water to residential community and tourist business sectors. Despite this, to our best knowledge, neither monitoring water quality in these reservoirs nor detecting non-point sources due to LULC adjacent to them have been previously reported. The main purpose of this study was an investigation of the correlation between phytoplankton distribution and LULC in six major reservoirs of Phuket province.

METHODS

Study area

Phuket island is the famous tourist destination, situated on the western coast of southern Thailand in the Andaman Sea. The island has a tropical monsoon climate, with a dry season from November to April and a wet season from May to October. Average temperatures are consistent year-round 23°C to 33°C. Its topology is covered by mountains with 70 percent of the total area, stretching from north to south, and the remaining being plains located in the central and eastern sides of the island. The island does not have any major rivers. Two concrete dams and over a hundred man-made reservoirs are served as major sources for water supply supporting a number of activities in the region. These reservoirs were abandon mining pits that had ceased when falling in tin prices in early 1980s. Consequently, they have become important reservoirs for collecting and storing rain and runoff water. In the present study, six major reservoirs, namely Bangmaruan, Nok, Anupas, Banthai, PSU, and Chaofah, were selected to monitoring water quality in relation to different land use types around them (Fig. 1). The largest reservoir was the Anupas reservoir with its size approximately 0.13 square kilometers and the smallest reservoir was PSU reservoir (0.02 square kilometers).

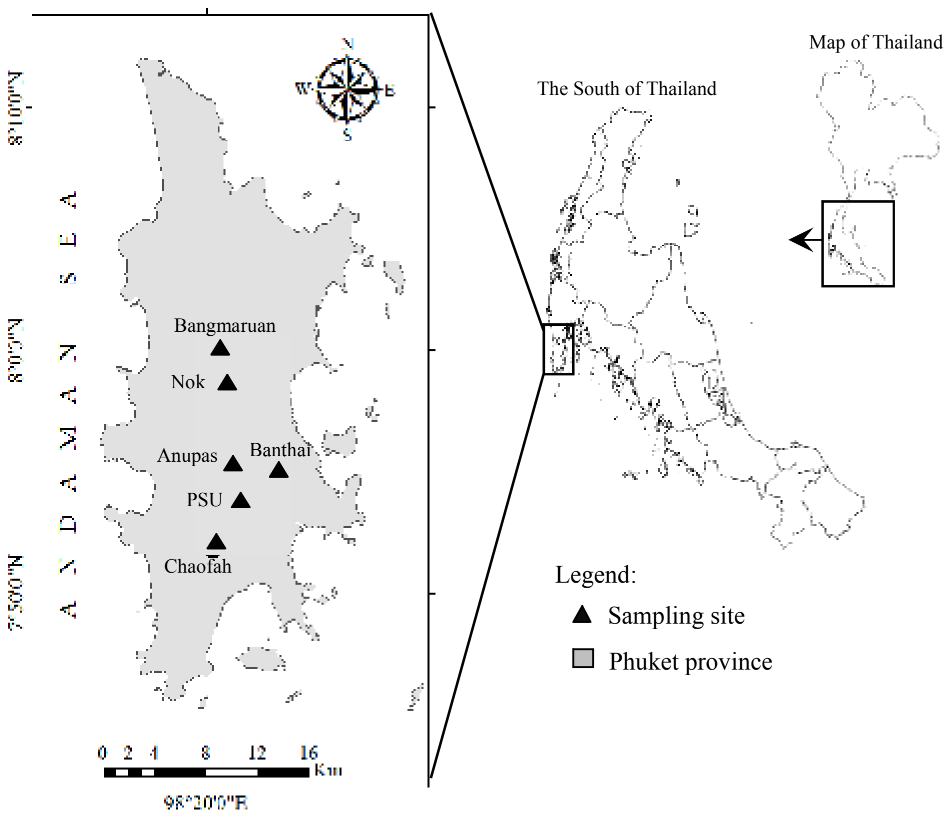

Figure 1: Sampling sites at six major reservoirs in Phuket province.

Phytoplankton sampling and identification

Phytoplankton samples were collected four times during June 2011 to January 2012; two samples for wet seasons (November 2011 and January 2012) and the other two for dry season (June and September 2011). At each reservoir, phytoplankton samples were collected by dragging and filtering water through 20 μm mesh size plankton net far from the bank about 50 meters. The samples were fixed with 5% formalin solution before transportation. In the laboratory, abundance of phytoplankton genera was determined by enumeration of cells in a Sedgwick-Rafter counting chamber using an inverted light microscope. The genera were identified using keys by Wongrat (1999).

Land use/Land cover classification

Data used in the study were land use map of 2010 obtained from the Land Development Department, Ministry of Agriculture and Cooperatives of Thailand. Each reservoir boundary was delineated and LULC types were classified in buffer zones within 500 meters adjacent to each reservoir using ArcGIS 10.0 software. The LULC were classified into five types, including urban, agriculture, forest, water and others. Then, we regrouped the land use types into three categories:

(I) *Highly-urbanized area* refers to as a result of a grouping of urban and agricultural area. The urban lands included industries, commercials, residential areas, a golf course and infrastructures (i.e. roads). The agriculture area was covered mainly by para rubber plantation.

(II) *Combination area* refers to as the reservoir to which LULC adjacent was a combination of urban, agriculture, forest, water and other cover.

(III) *Less-urbanized area* refers to as the reservoir that was covered mainly by dense evergreen forest combined with para rubber agriculture.

RESULTS

Temporal and spatial distributions of phytoplankton abundance and composition

Temporal differences in proportions of phytoplankton composition at a particular reservoir during dry and wet seasons are shown in Figure 2. Abundance of phytoplankton in wet season was higher than that in dry season in all reservoirs, except for in Anupas reservoir having the highest abundance in January 2012.

Spatial distributions of a total of 35 phytoplankton genera are shown in Table 2. The highest diversity was Chlorophyceae (18 genera), accounting for 54% of the total genera list. Other groups were represented by fewer genera. They included Cyanophyceae (7 genera), Dinophyceae (3), Euglenophyceae (3), Bacillatiophyceae (3) and Chrysophyceae (1). Chlorophyceae were found over 70 % of all composition in the Anupas and Bangmaruan reservoirs and over 40% in other reservoirs. Banthai reservoir had a high proportion of Cyanophyceae (42%) whereas a high proportion of Chrysophyceae (47%) was found in PSU reservoir.

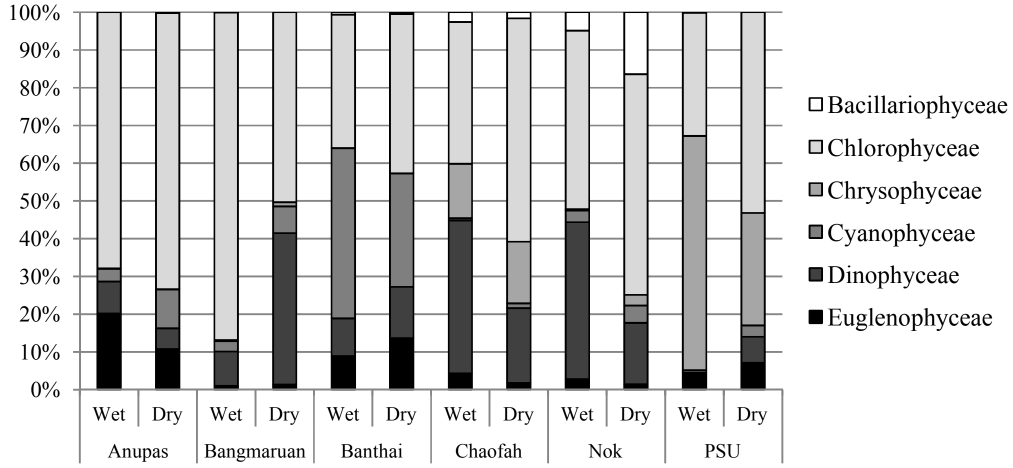

Figure 2: Temporal and spatial relative compositions of the phytoplankton groups in the six Phuket reservoirs between dry and wet seasons during 2011-2012.

Table 2: List of phytoplankton genera and averaged cell density found along the six sampling sites during the study period of 2011-2012. The density (cells/mL) is presented in - = not found; + = 1-100; ++ = 101-500; +++ = 501-1,000; ++++ = 1,001-5,000; +++++ = 5,001-10,000.

Class	Genus	Density (Cells/mL)					
		Anupas	Bangmaruan	Banthai	Chaofah	Nok	PSU
Cyanophyceae	*Chroococus*	++	++	+	+	+	-
	Merismopedia	+	-	++	+	-	-
	Lyngbya	-	-	-	-	+	+
	Oscillatoria	+++	+	+++++	+	+	+
	Spirulina	+	+	++++	+	-	+
	Anabaena	++	+	+	-	+	+
	Cylindrospermopsis	-	-	+	-	-	-
Chlorophyceae	*Eudorina*	++	++	++++	++	++	+++
	Pediastrum	+	+	++	++	+	+
	Coelastrum	++	++	++++	+	+	++
	Ankistrodesmus	-	+	-	-	+	+
	Kirchneriella	+	+	++	-	-	-
	Monoraphidium	+	+	+	+	-	++
	Oocystis	+	+	-	+	+	++
	Tetraedron	++++	++	++	+	+	-
	Actinastrum	+	+	++++	-	+	+
	Micractinium	++	+	+	+	+	+
	Scenedesmus	++	+	++++	++	+	+
	Spirogyra	+	-	+	-	-	-
	Closterium	-	-	+	+	+	+
	Cosmarium	++	++	-	+	++	-
	Desmidium	++	-	+	-	+	++
	Micrasterias	+	+	++	++	+	+
	Onychonema	-	-	-	-	+	-
	Staurastrum	+++++	+++++	++++	++++	++++	+++
Euglenophyceae	*Euglena*	+++	+	++	+	+	++
	Phacus	++	+	++++	+		+
	Trachelomonas	++++	+	++++	+	+	++
Bacillariophyceae	*Synedra*	+	-	+	-	+	+
	Navicula	-	+	+	-	+	-
	Nitzchia	-	-	++	+	++	+
Chrysophyceae	*Dinobryon*	+	+	+	+++	+	++++
Dinophyceae	*Ceratium*	+	+	+	+	+	+
	Peridinium	++++	++++	++++	++++	++++	++
	Protoperidinium	-	-	-	-	+	-

Land use/Land cover classification

Three categories of land use adjacent to the reservoirs were represented in Table 1. In category I, three reservoirs included Bangmaruan, Chaofah and Anupas with a total area of urban and agriculture being 1.15 (95%), 1.24 (97%) and 1.74 square kilometers (93%), respectively. Category II consists of Banthai and PSU reservoirs with a combination of different land use types. Banthai had a total area of urban and agriculture about 0.63 square kilometers (45%) and water bodies about 0.79 square kilometers (55%). PSU had a total area of urban and agriculture about 0.42 square kilometers (37%) and a total area of forest and water land use was 0.73

square kilometers (63%). The major land use of Nok reservoir was forest areas combined with para rubber plantation; there were a few urban areas. Therefore, this reservoir was grouped in category III.

Table 1: Percentage of land use/land cover area within 500 meters surrounding of each reservoir studied.

Category	Reservoir	Percentage (%) of Land use/cover area				
		Urban	Agriculture	Forest	Water	Other
I	Bangmaruan	48.54	46.47	0.00	0.00	4.99
	Chaofah	64.27	32.83	2.90	0.00	0.00
	Anupas	92.58	0.27	1.00	6.15	0.00
II	Banthai	43.53	1.14	0.00	55.32	0.00
	PSU	34.21	2.46	49.51	13.82	0.00
III	Nok	10.99	62.05	10.86	16.10	0.00

Correlation between LULC and phytoplankton community

Different LULC types had direct effects on the population dynamics of phytoplankton. When effects of LULC on phytoplankton community in each reservoir were analyzed, the reservoir in category III had the lowest total abundance of phytoplankton with approximately 17.17×10^6 cells/L whereas the reservoirs in category I had high total abundance of phytoplankton with approximately 59.87×10^6 cells/L. Both category I and III were similar dominated by Chlorophyceae with dominance of genera *Staurastrum* and *Peridinium*. In category II, Banthai reservoir was dominated by Cyanophyceae with dominance of genus *Oscillatoria* in both wet and dry seasons. Another reservoir in the category, PSU was dominated by Chrysophyceae with dominance of genera *Dinobryon* which was high density in wet season.

DISCUSSION

The results of the correlation analysis in this study indicate a linkage between LULC and the phytoplankton community characteristics in the reservoir. Specifically, the reservoirs with a combination of highly-urbanized and agricultural areas had positive relationships with the phytoplankton abundance and composition while the reservoir with less-urbanized areas had negative relationships. Our findings were similar to many previous reports (Liu et al., 2000; Tong and Chen, 2002; Basima et al., 2006; Hwang et al., 2006; Ferrareze, 2012).

Phytoplankton community varies mainly in accordance with the dry and wet periods in tropical waters (Crossetti et al., 2008).Our study found temporal variations in phytoplankton community structure. A high density was observed in wet season. This is similar to the observations of Mustapha (2009) on a tropical reservoir in Nigeria, but differs from Khuantrairong and Traichaiyaporn (2008) studied on Doi Tao lake, Nothern Thailand, reporting a higher number of species and density of phytoplankton in winter and summer, but lower in the rainy season.

Generally, the one of main factors influencing phytoplankton abundance and distribution are availability of nutrients in tropical reservoirs (Crossetti et al., 2008; Moschini-Carlos and Pompêo, 2008; Chellappa et al., 2009). Our findings disclose that there is a sign of declining in water quality in the reservoirs surrounding by the urbanization and agricultural expansion, but not for the reservoirs with a high proportion of forest combined with the para rubber plantation. After rainfall events, nutrient loads were increased in high flow conditions through LULC area and discharged to the water bodies affecting to a decline in water quality (Arreghini et al., 2005; Siemann et al., 2007; Ferrareze, 2012). A golf course adjacent to Anupas reservoir was a factor may have impact on water quality in our study. Due to maintaining these green turfs in dry season chemical fertilization, pesticide treatments have been used, and thus harm water quality (Winter and Dillon, 2005).

Our study found remarkable abundance of Cyanophyceae in genus *Oscillatoria*, which was abundant in Banthai reservoir during rainy season. This genus was known as an indicator of high concentration of total phosphorus (Havens, 2008). The reservoir was surrounded by a restaurant, a cabaret and many residents these were important phosphorus sources. Total phosphorus could be result in excessive algae growth, eutrophication and the depletion of oxygen in water bodies (Tjandraatmadja et al., 2010; Khan and Ansari, 2005; Chalar, 2009).

An influence of urban land use on the changing water quality was marked in the present study. However, type and nature of urbanization activities and other factors need to be more fully explored. Moreover, our study points out the need to develop land use planning policies that are sensitive to the preservation of water quality.

CONCLUSIONS

The distributions of phytoplankton community in the six major Phuket's reservoirs are influenced by different LULC types adjacent to the reservoirs. The composition of phytoplankton has a similar pattern in each reservoir. In some reservoir has some phytoplankton genus that could potentially develop into algal blooms with changes in water quality. It is very important to maintain or improve the current status of the water quality by controlling and prohibiting any LULC development likely to affect the water bodies and induce environmental impacts. It is also important to investigate the status of reservoirs located in the other areas in order to assess and evaluate the planning of settlers and for better management of water resources.

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