Water quality and land use: an integrated study of the Lipanoi River system, Samui Island

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Running head: Water quality & the Lipanoi River

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ABSTRACT

A collaborative research study was integrated into GLOBE teacher training workshop. Integrated activities over the Lipanoi River on Samui Island at six locations from the headwaters to the estuary include hydrology measurements, atmosphere observations and classifications and validation of LANSAT images of surroundings of the river system. Mixed orchards represented the most common form of land use. Significant differences in dissolved oxygen, pH, temperature, conductivity, and transparency were recorded at different locations on the river. Increase in dissolved oxygen, temperature, conductivity and transparency was noted at locations nearer to the river estuary whilst pH was lowest at Lipanoi Bridge.

Key words: land use**,** dissolved oxygen, temperature, conductivity, transparency

Introduction

Samui Island’s significant economic development and the corresponding high rates of urbanisation have brought rapid changes to its natural environment, and greatly increased the amount of stress in the form of waste and pollutants on its ecosystem (Wilkinson, 1989; Kontogeorgopoulos, 1998). These changes, which have significantly affected Samui Island’s water quality, present the local authorities with a complex challenge of balancing rapid urbanisation with the preservation and maintenance of water supply and quality. The island faces severe annual water shortages and generally suffers from the escalating environmental damage and economic isolation common to many island-based tourist destinations (Wilkinson, 1989; Kontogeorgopoulos, 1998). Water quality and water resources will continue to be limiting factors in the island’s development and economic growth in the near future.

Lipanoi River is one of seven main rivers on Samui Island in Suratthani Province. It is a small un-dammed river flowing through some cultivated land and drains into the Gulf of Thailand. Little was known about the water quality of this river and land use of the areas surrounding the river system. As changes in land use can affect stream chemistry (Reynolds et al., 1995) that may impact on aquatic organisms (Harriman et al., 1987), this preliminary investigation of water quality of the Lipanoi River and land use of the areas surrounding the river system was undertaken with a view to gaining greater basic knowledge of water resources on Samui Island.

Land use in areas surrounding aquatic systems greatly transforms the hydrological cycle because it influences storage patterns and water discharge (Richardson & McCarthy, 1994; Ruiz-Luna & Berlanga-Robles, 1999). The effect that land use has on the interconnection and mobility of ecological processes within the areas is of great importance in maintaining biodiversity

(Pearson et al., 1996; Keitt et al., 1997). Thematic maps developed by classifying satellite images and mathematical operation related to the spectral bands that make up a satellite image can be used to generate indicators that are sensitive to the presence and condition of vegetation and other features of interest. In heterogeneous environments, remote sensors provide much data from which current information about land cover may be extracted efficiently and economically (Baily & Nowell, 1996; Green et al., 1996).

Materials and Methods

Samui Island, the main island of a small archipelago of 48 islands in the Gulf of Thailand in Suratthani Province, lies between 99˚38'-100˚7' E longitude and 9˚20'-9˚45' N latitude (Gould et al., 1968). The island is approximately 20.0 km long and 16.7 km wide with an area of 247.0 km^2, making it the third largest island of Thailand after Phuket and Chang Island (Kontogeorgopoulos, 1998).

The climate of Samui Island is dominated by the tropical monsoon. The mean daily temperature varies from 26-29 ºC throughout the year, and the mean humidity from 76-89 % (Gould et al., 1968; Winter et al., 1968). During the dry season, from January to April, monthly rainfall averages 13-68 mm. The southwest monsoon (May-September) brings 135-170 mm of rain per month, and the northeast monsoon season (October-December) has up to 300 mm of rain per month (Gould et al., 1968; Winter et al., 1968). There are seven major streams on Samui Island including the Lipanoi River.

The LANDSAT-7 satellite scene of the Lipanoi River and its immediate surroundings lies between 601845-606825 UTM, and 1049160-1051980 UTM. The image was acquired on 1 August 2001 with the enhanced thematic mapper plus (ETM+). The main characteristics of the scene were described in Table 1. Seven land use classifications were defined and validated in the field as mixed orchards, forest, grassland, urban, river and ocean, coastal zone, and others. The validation was done in the field with the assistance of a GPS (GARMIN model GPSmat 76S). Thematic maps and calculation of the area of each land use category were integrated into a package for digital processing of images, Multispec for Window Version 2.7.

In this study the Lipanoi River was divided into six sampling sites (Table 2). Two sampling sites were located on the upstream tributaries (i.e. Ladwanon Viewpoint and Ladwanon Waterfall). Three other sites took advantage of the existing bridges on the river for sample collection (i.e. Lipanoi Bridge, Small Bridge, and Temple Bridge). The final site was located at the river estuary on the Gulf of Thailand. At each site water samples were collected and measured in the field for dissolved oxygen, pH, temperature, conductivity, and transparency. Temperature and conductivity were measured with a Mettler metre (model MX300); dissolved oxygen with a Wissenschaftlic Technische Weilhëim (WTW) metre (model Oxi 330i); pH with a pH pen; and transparency with a turbidity tube.

All variables were tested for normality using Lilliefors' test and transformed when necessary. The equality of variances was evaluated using Levene's test. The one-way ANOVA was used to test for differences among sampling sites. This was followed by post-hoc tests with Bonferroni adjustment.

Results

Land Use Classification

Seven types of land use were defined: water surface (river and ocean), mixed orchards, forest, grassland, urban, coastal zone, and others (Table 3).

Water Quality

There were significant differences in dissolved oxygen, pH, temperature, conductivity, and water transparency as measured at various sampling locations (One-way ANOVA with Bonferroni adjustment: dissolved oxygen: $F_{5, 42}$ = 143.38, P<0.001; pH: $F_{5, 74}$ = 50.79, P<0.001; temperature: $F_{5, 74}$ = 48.25, P<0.001; conductivity: $F_{5, 42}$ = 1009.50, P<0.001; transparency: $F_{5, 74}$ = 41.21, P<0.001, Table 4, Figure 2a-e). Dissolved oxygen at Ladwanon Viewpoint and Ladwanon Waterfall was similar but it was significantly lower than that at other locations (Figure 2a). Dissolved oxygen at Small Bridge was higher than that at Temple Bridge (Figure 2a). pH at Lipanoi Bridge was lower than that at other locations (Figure 2b). Temperature increased progressively towards the estuary (Figure 2c). Similar temperature was recorded at Ladwanon Viewpoint, Ladwanon Waterfall, and Lipanoi Bridge (Figure 2c). Conductivity was significantly higher at Temple Bridge and the estuary (Figure 2d). Transparency increased towards the estuary (Figure 2e).

Discussion

The natural systems at the headwaters of the Lipanoi River are currently under environmental stress mainly as a result the rapid human population growth and its corresponding demand for food. Agriculture and urbanisation have been the main transformers of the natural land cover in the Lipanoi River system. More than 50% of the land in this area has been transformed into mixed orchards of coconut, durian, and other fruits. Coastal areas have become degraded due to nutrient enrichment from agricultural fertilisers, toxins from insecticides and pesticides in the mixed orchards, extensive invasion of non-native species, and untreated wastewater from expanding tourist hotel and resort facilities (pers. comm.).

Dissolved oxygen of natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure (e.g. Hutchinson, 1957; Chapman & Kimstach, 1996; Wetzel, 1999). The solubility of oxygen decreases as temperature and salinity increase (Millero et al., 2002). Dissolved oxygen may be enhanced during the day due to photosynthesis but it declines at night with respiratory oxygen demand and may fail to recover the next day (Demars & Harper, 1998; Mason, 2002). Our study shows a very low level of dissolved oxygen in the Lipanoi River ranging between 4.1 and 5.3 mg/l. Concentrations of dissolved oxygen below 5.0 mg/l may adversely affect the functioning and survival of biological communities, and below 2.0 mg/l may lead to the death of most fish (Chapman & Kimstach, 1996). There was less dissolved oxygen in the Lipanoi tributaries (i.e., Ladwanon Viewpoint and Ladwanon Waterfall) than at other locations. This could be due to the fact that the tributaries are in a primary tropical rain forest that allows only a very limited amount of light through together with a limited amount of algae on the riverbed. Less vegetative cover and a greater amount of algae on the riverbed were observed closer to the river estuary. In addition, oxygen may dissolve into the water at the waterfall where there are many ripples and turbulences.

Normal streams have a pH of 6.5 to 9.0 and frequently experience changes in pH between 6.5-7.5 with no ill effects on the animals and plants (Horne & Goldman, 1994). When pH falls below 6.0 over the long term, there is a noticeable reduction in the abundance of many species including snails, amphibians, crustacean, zooplankton and fish (Horne & Goldman, 1994). According to our study, the pH of the Lipanoi River was on average between 6.3 and 7.1, which is within an acceptable range of near neutral pH.

The temperature of water surfaces is influenced by latitude, altitude, season, time of day, air circulation, cloud-cover, and the flow and depth of the water body. Temperature in turn affects physical, chemical, and biological processes in water bodies. Increased temperature decreases the solubility of oxygen, but at the same time it increases the metabolic rate of aquatic organisms leading to greater oxygen consumption and more rapid decomposition of organic matter. Our study showed that water temperature increased at the locations near the river estuary. This could be due to two possible reasons. First, there was less vegetative cover near the river estuary. Secondly, the collection of data at the locations was done in the afternoon. However, the latter was very unlikely, as it was observed that the water temperature at the headwaters of the Lipanoi River did not change much throughout the day.

Conductivity, which is an indicator of mineral content, is influenced by the amount of electrical charge on each ion, ion mobility, and water temperature. The conductivity of freshwater ranges from 10 to 1000 μS/cm, but it may exceed 1000 μS/cm in polluted waters, those receiving large quantities of land run-off or connecting with the ocean (Chapman & Kimstach, 1996). Our results showed that conductivity at Temple Bridge and the estuary of more than 1000 μS/cm was higher than at other locations. This indicates that the Lipanoi River retains its fresh water characteristics up to Temple Bridge, but the water becomes brackish at the river estuary.

Transparency of water depends on types and concentration of suspended matter in water column. Suspended matter consists of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton, and other microscopic organisms (Wetzel, 1983, 1999; Chapman & Kimstach, 1996). Transparency can vary seasonally according to biological activity in the water column and surface run-off carrying soil particles. Our results showed that water transparency increased nearer the river estuary. This is likely due to the fact that soil and other suspended particles gradually sink to the riverbed as the flow rate of the river decreases at the locations nearer to the estuary.

Acknowledgments

We thank T. na Nagara for comments on previous versions of the manuscript. Invaluable assistance in the field and laboratory was provided by 50 Global Learning and Observations to Benefit the Environment (GLOBE) participants, N. Kumlangkua, S. Thongsuk, and N. Klanniwat. We thank GLOBE for providing the Satellite image. We thank Centre for Scientific and Technological Equipment for providing some fieldwork instruments. This work was supported in part by the Institute for the Promotion of Teaching Science and Technology and Walailak University Consortium (GLOBE project) and the Complex System Research Unit, the Institute of Research and Development, Walailak University.

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Table 1. Main characteristics of the LANDSAT-7 image used to evaluate trends of pattern coverage in the Lipanoi River. Wavelengths of the TM sensor bands: (1) 0.45-0.52 mm (blue); (2) 0.52-0.60 mm (green); (3) 0.63-0.69 mm (red); (4) 0.76-0.90 mm (near infrared); (5) 1.55-1.75 mm (shortwave infrared); (6) 10.40-12.50 mm (thermal infrared); (7) 2.08-2.35 mm (shortwave infrared); and (8) 0.52-0.90 mm (panchromatic).

Acquisition date	August 2001
LANDSAT7 sensor	ETM+
Available bands	1,2,3,4,5,6,7,8
Original pixel size (m)	30 x 30
Corrected pixel size (m)	30 x 30

Table 2. Six sampling locations (UTM) and elevation (m) of the Lipanoi River.

Location	UTM		Elevation (m)
Ladwanon Viewpoint	605527	1050341	46.5
Ladwanon Waterfall	605326	1050349	44.8
Lipanoi Bridge	603992	1050331	33.0
Small Bridge	603278	1051142	26.6
Temple Bridge	602826	1051346	26.3
River Estuary	602646	1050943	25.1

Table 3. Land use in the Lipanoi River system (in percentage & km^2).

Types	Land use (%)	Land use (km^2)
Mixed Orchards	58.2	8.58
Grassland	11.5	1.69
Forest	11	1.62
River & Ocean	9.8	1.44
Urban	3.8	0.56
Coastal zone	2.5	0.36
Others	3.3	0.48
Total	100	14.73

Table 4. The mean ± SD of physiology of the Lipanoi River, Samui Island, Thailand. DO stands for dissolved oxygen.

Location	DO (mg/L)	pH	Temperature (°C)	Conductivity (μS/cm)	Transparency (cm)
Ladwanon Viewpoint	4.27±0.30	7.13±0.06	24.80±0.17	48.41±4.95	88.10±0.85
Ladwanon Waterfall	4.06±0.16	7.06±0.24	25.95±0.33	43.81±3.03	82.40±5.79
Lipanoi Bridge	5.18±0.09	6.33±0.05	26.58±0.37	42.42±0.39	100.11±2.37
Small Bridge	5.33±0.12	7.00±0.07	27.58±1.03	45.04±0.27	103.03±8.27
Temple Bridge	4.88±0.01	7.00±0.07	28.90±0.72	1915.33±58.31	112.47±5.28
River Estuary	5.22±0.21	7.00±0.15	31.00±0.50	2736.67±338.29	105.00±3.00

Figure 1. Sampling locations of the Lipanoi River: (1) Ladwanon Viewpoint, (2) Ladwanon Waterfall, (3) Lipanoi Bridge, (4) Small Bridge, (5) Temple Bridge and (6) River Estuary.

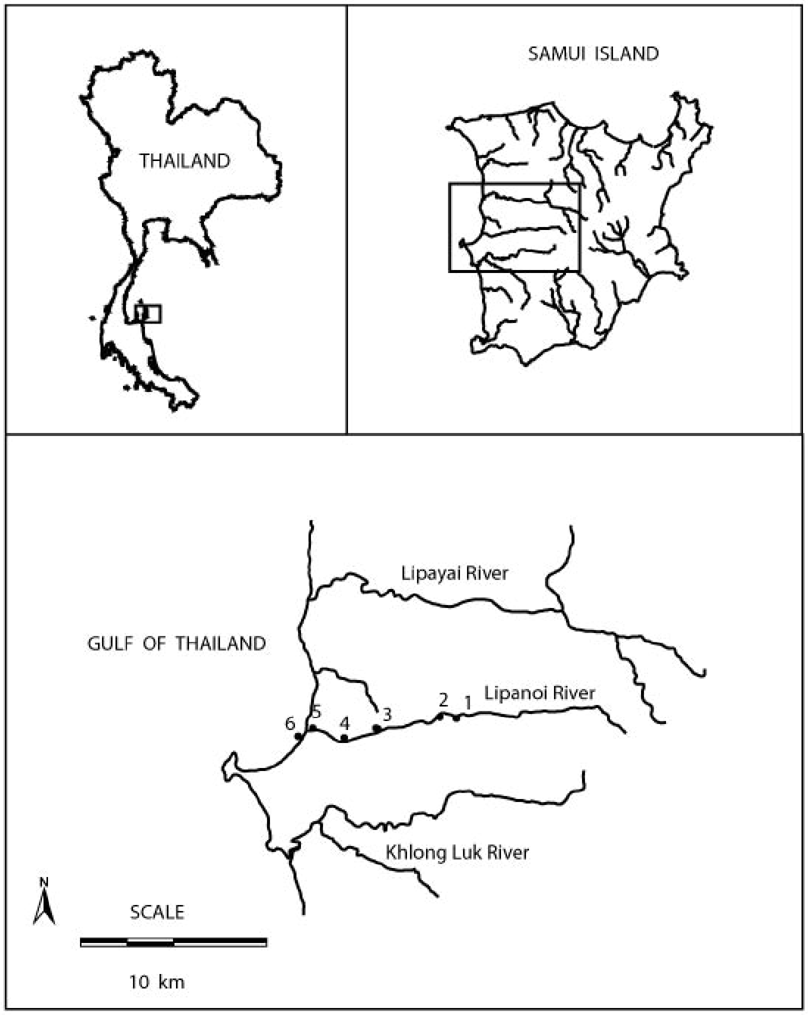
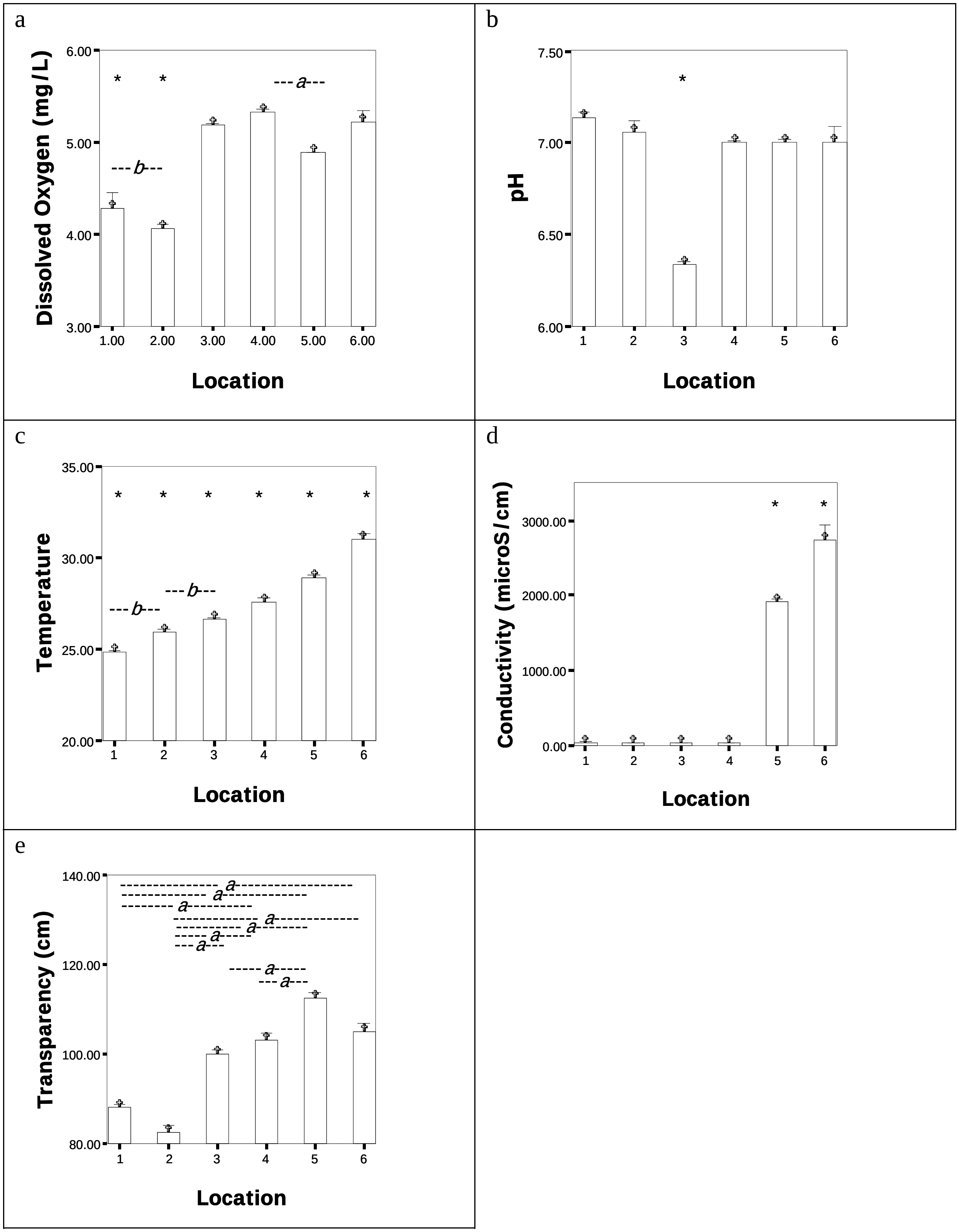


Figure 2. Comparisons of physiology of the Lipanoi River, Samui Island, Thailand. (a) Dissolved oxygen (mg/l), (b) pH, (c) temperature (°C), (d) conductivity (μS/cm) and (e) transparency (cm). * represents other five locations significantly different from this location at $P < 0.001$; *a* represents significantly differed between pairs, and *b* represents non-significantly differed between pairs.


a
Dissolved Oxygen (mg/L)
6.00
5.00
4.00
3.00
1.00
2.00
3.00
4.00
5.00
6.00
Location
b
pH
7.50
7.00
6.50
6.00
Location
c
Temperature
35.00
30.00
25.00
20.00
Location
d
Conductivity (microS/cm)
3000.00
2000.00
1000.00
0.00
Location
e
Transparency (cm)
140.00
120.00
100.00
80.00
Location