CHAPTER 2

METHOD OF STUDY

1. Site Description

The investigation of this study was developed at ten stations of the Pattani Dam Reservoir located in the province of Yala, southern Thailand (Figure 3).

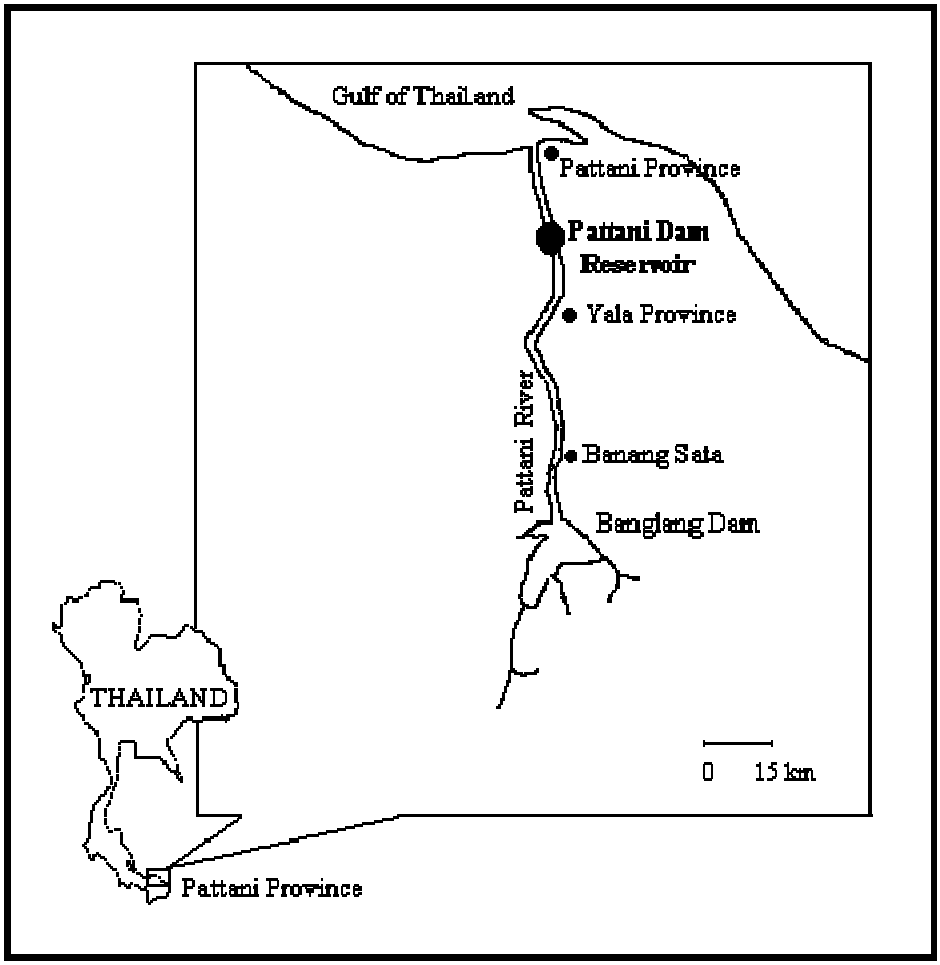

Figure 3 Map of Sampling Sites in the Pattani Dam Reservoir

Water and sediment samples were collected from 10 sites situated at the Pattani Dam Reservoir (Figure 4) according to the procedures specified in the Field Operation Manual for Lakes (Baker *et al*., 1997), the Environmental Sampling and Analysis: A Practical Guide (Keith, 1991), and in the technical guidance for designing a sampling program for lakes and reservoirs bioassessment (USEPA 1999a).

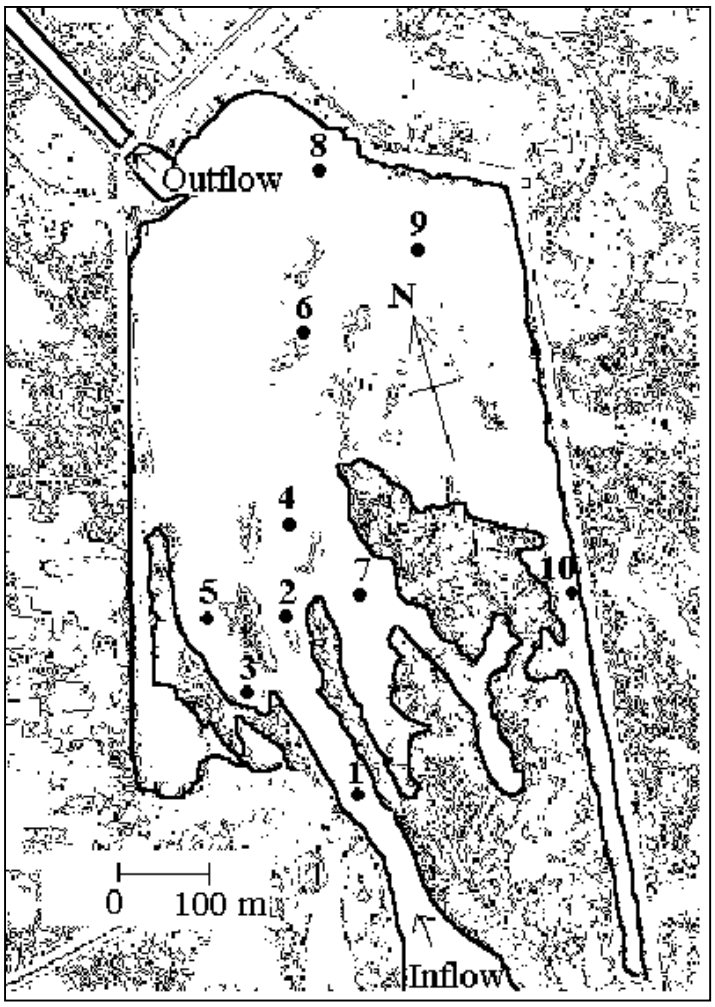

Figure 4 Sampling Sites in the Pattani Dam Reservoir.

Site 1: It is situated at the inlet of the Pattani Dam Reservoir through where the rapid flowing can be observed visually. This site is considered the site of most deep, the average depth is about 5.3 m. The substratum is dominated by small bivalves in the bottom and is mainly composed of sand and rock sediments. Absent of aquatic macrophytes is also the common characteristic of this site. This site is used to represent the river-like part of the reservoir where low productivity of aquatic macrophytes is theoretically expected.

Site 2: This site is relatively shallow (1.6 m) and situated backward the small island at the inlet part of the reservoir. Because the island helps blocking the inflow current, the water flows through this site with a slow rate. This site is covered by submerged macrophytes in dry months, but the absent of macrophytes is observed when the water levels rise during the wet months. The substratum is consisted of about 90% mud and 10% sand. Site 2 is used to represent the inlet part of the reservoir where the influence of the current to the sampling area is less than that in site 1.

Site 3: It is situated in the area of lake-like condition. The water is very shallow (0.8 m) and, very slow flowing, and relative turbid. The substratum consists by brown silt. It is possible that high deposition rate of sediments in this area is the principal limiting factor for the macrophyte production.

Site 4: It is about 5 m from the island situated in the middle part of the reservoir. The water is rapid flowing, having an average depth of 2.6 m.

Site 5: It is about 30 m from the bank. The water is clear and slow flowing and has an approximate depth of 1.4 m Communities of submerged aquatic plants are observed in most of the water surface area. The dominant species is *Ceratophyllum demersum*. The substratum is dominated by roots in the bottom and composed of black mud.

Site 6: It is about 4 m from the island situated in the middle part of the reservoir as well. The water is fast flowing, having an average depth of 1.6 m. There is no appearance of any macrophyte species.

Site 7: It is about 50 m from the bank. The water is clear but low light penetration due to the obstruction of the plant biomass. The water very slow flowing and has an approximate depth of 1.7 m. Communities of submerged aquatic plants are also observed in most of the water surface area. The dominant species is *Hydrilla verticillata*. The substratum is dominated by roots in the bottom and composed of black mud. This site represents the lake-like part of the reservoir.

Site 8 is situated near the outlet in the northern part of the reservoir and about 60 m from the bank. This site is close to the Office of Pattani Dam Reservoir Project's resort, where human activities such as washing and bathing can affect the reservoir water quality. The water is turbid, mid-flowing with waves, having an average depth of 3.1 m.

Site 9 is situated in the eastern part of the reservoir and about 40 m from the bank. The water is relative turbid, mid-flowing, and having an average depth of 3.4 m. The substratum consists by blown silt.

Sites 10 is situated about 2 m from the eastern bank of the reservoir. The water is very clear, very slow flowing with no waves, having an approximately depth of 0.8 m. The substratum is dominated by roots in the bottom and composed of plant debris and black clay.

The Pattani Dam Reservoir (6° 39' N, 101° 17' E) is situated in the flood plain of the Pattani River. The reservoir is located at an altitude of 12.75 m above mean sea level, covering a catchment area of 2.2 km^2, 15 km North of Muang Yala District, maximum depth of 7 m, a reservoir storage capacity of approximately 6.9×10^6 m^3. At present, the reservoir is used for multiple purposes such as agricultural irrigation, with rice as the most important product of this area, domestic

supply, controlling the flood regime of the Pattani River below the reservoir, bathing, fishing, and drinking water for cattle.

In Table 2 some characteristics of the Pattani Dam Reservoir are summarized. The climate of southern Thailand at where the reservoir located is characterized by distinct seasonality between wet and dry period. Therefore, flow and storage levels of the reservoir underlie this seasonality too, except when the reservoir is being fed by effluent water from the Banglang Dam Reservoir, a larger dam with the storage capacity of 1.4 X 10^9 m^3 (Pattani Water Supply and Maintenance Project, 1998).

Further details on the general morphometric and hydrological features of the Pattani Dam Reservoir have been reported elsewhere (Pattani Water Supply and Maintenance Project, 1998)

Table 2 Characteristics of the Pattani Dam Reservoir (Pattani Water Supply and Maintenance Project, 1998)

Parameter	Value
Origin of Inflow	Pattani River
Surface Area	1 km^2
Mean Water Residence Time	5 days
Maximum Water level	5.3 m

The Pattani River is located in the two provinces, Yala and Pattani. Its drainage basin occupies an area of 127,632 km^2. The river receives urban wastewater discharges from 2 municipalities, as well as industrial water discharges, both treated and untreated. The industrial water discharges to the Pattani River come from a wide range of industrial activity in: food processing; leather, natural and synthetic textiles; production and printing of paper; rubber and polymer production; processing of non-metallic minerals; wood and metal furniture fabrication; equipment and machinery ensemble, among others (NIDA, 1999). The Pattani River provides water for

agricultural irrigation, recreation, fish, wildlife, and communities and industrial water supplies.

Many of industrial and domestic discharges between the river source and the Pattani Dam Reservoir make the Pattani River and the Pattani Dam Reservoir probable much contaminated water bodies in the province of Yala, the catchment area of which (5,500 km^2) comprises a large population of about 548,650 inhabitants.

2.2 Field Sampling & Measurement and Laboratory Analysis

The sampling period extended from May 2000 to May 2001. The sampling frequency was bimonthly except the last sampling (May 2000, July 2000, September 2000, and May 2001).

The field crew consisted of staff provided by the Pattani Water Supply and Maintenance Project Office and volunteer students of the Faculty of Environmental Management, Prince of Songkla University.

The stratified (judgmental) random sampling approach (Keith, 1991) was applied for the selection of sampling stations of this study; the station selection was based on both aerial photo and site visiting. As a result, the reservoir area was stratified into three zones: riverine, transitional, and lacustrine. Then, eight stations randomly located among these zones were selected for monitoring (Figure 3).

In the monitoring, water was sampled between 8.00 – 12.00 am. at 0.5 m depth from the surface of the reservoir, totalizing 10 sampling stations.

Prior to launching the boat for the sampling, all sample containers were labeled and forms were filled out for station ID, parameter ID, and date. The completed forms and labels were double-checked to verify that all pertinent information is included. All glassware and sampler bottles were cleaned using the procedure recommended by APHA (1995).

A real-time, global positioning system (GPS) unit was used to determine station positions by receiving digital codes from three or more satellite systems computing

time and distance, and then calculating and earth based position. The position accuracy of the GPS measurements was between 0.5-5 m. GPS measurements were converted from degree/minute format to decimal format for preparation of the site maps. In addition, station verification was based on not only GPS, but also map coordinates and evidence signs.

The samples of water for chlorophyll-*a* analysis were collected at 0.5 m depth using a rinsed, 1-liter sample bottle that inverted and held at depth (arm's length) by hand, turned up to fill, and brought to the surface (USEPA, 1994a).

The samples of water for chemical analysis were collected at the same depth as chlorophyll-*a* using Van Dorn Sampler and then kept in the sampler bottles that had been cleaned in a phosphate-free detergent and rinsed three times in reservoir water in the field. The samples were preserved in the field, or not, depending upon which parameters are to be analyzed.

All samples were stored in ice containers during their transport to the laboratory. The processing of the samples was done usually within their holding time.

The parameters analyzed were pH, temperature, Secchi depth, dissolved oxygen (azide modification), BOD_5, nitrate-nitrogen (cadmium reduction method), nitrite-nitrogen (colorimetric method), ammonia-nitrogen (Phenate method), total phosphorus (ascorbic acid method), and chlorophyll-*a*. The methodology followed the APHA (1995) recommendations except for chlorophyll-*a*.

Chlorophyll-*a* was filtered in situ through glass-fibre filters and extracted with ethanol in the dark. The optical density of the extract was determined with a spectrophotometer (Lenz and Frische, 1980).

Temperature, dissolved oxygen (DO), pH, conductivity, and Secchi depth were measured at each site in the same depth as the previous water sample. Both DO and temperature were measured by using the dissolved oxygen/temperature electrode

(EPA Method 360.1). The electrode was calibrated against standard chemical titration methods before and after field use.

pH was determined by using the calibrated pH meter, whereas Secchi depth (a measure of transparency) was obtained with the 20 cm metal Secchi disk that divided into black and white quadrants on a nonstretchable line, calibrated in centimeters. The disk was lowered into the water until it disappeared from view, then was raised slowly to the point where it reappeared. Secchi depth is the average of the two depths. Observations were made from the sunny side of the boat, without sunglasses, and as close as possible to the water (USEPA, 1999a).

Sediment samples were collected using an Ekman grab (15.2 × 15.2 cm); approximately 1 kg of the middle of each sample was put in a polyethylene bag by using plastic spoon and stored at 4 °C during its transport to the laboratory. Sediments were dried in an oven at 50 °C for 48 h, then were ground in an agate mortar, sieved through a 200-mesh sieve and homogenized. The homogenized sediments were digested following the USEPA (1994) recommendation. Solution concentration of lead was determined using flame atomic absorption spectrophotometer. A two step procedure for cleaning glassware used for lead Analysis included the washing in a neutral detergent and a 24 h bath in a 10% nitric acid solution. Between the two steps and the end of the procedure, the glassware were rinsed with distilled and de-ionized water (Avila-Perez, 1999).

The macrophyte survey in the Pattani Dam Reservoir was done with an aerial photograph and visual reservoir surveys. During the surveys, the macrophyte was visually observed and manually sampled whenever they appeared at all stations where water and sediments were collected simultaneously. The taken macrophytes were identified and sorted by species using the manuals issued by Department of Biology, Faculty of Science, Prince of Songkla University (Artharamas, 1984, 1988).

The percent cover of submerged and floating macrophytes of each station was estimated visually; the most dominant species was identified. The relative

abundances of macrophyte taxa were estimated by scoring species for presence or absence within quadrants, which can be applied instead of estimating biomass and/or stem-count (Weber *et al*. 1995). Each quadrant was sampled from each station, and each species receives one point for every mesh of quadrant in which it occurs.

Any potential nutrient source to the reservoir was observed and listed. Visual impression of the trophic status was given as oligotrophic (little or no biomass in the reservoir water), mesotrophic (intermediate amounts of biomass in the water), eutrophic (large amounts of biomass in the reservoir water), or hypertrophic (choked reservoir, with more biomass than water).

Data for rainfall and flow have been made available from the closest meteorological station and the Pattani Water Supply and Maintenance Project Office.

After the first sampling, additional measurements of lead in aquatic macrophytes were performed and two sampling stations in the reservoir was additionally located (Station 9 and 10 in Figure 3).

2.3 Statistical method

2.3.1 Data Analysis and Statistical Methods

2.3.1.1 Data Sets: A variety of data sets including quantitative data sets in term of water temperature, depth, transparency, conductivity, pH, DO, saturated oxygen, BOD_5, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total phosphorus, chlorophyll-*a* analysis results, for each site, for each season, was analyzed using SPSS program.

A quantitative macrophyte data set in the form of ranking score in each species per site was analyzed using cluster analysis (Gauch, 1989).

The mean and standard deviation concentrations and coefficient of variation value for lead in each sediment sample from the reservoir were computed with the aid of the SPSS program. The Least Significant Difference (LSD) method was used to compare the concentration of lead in the sediment of each site.

2.3.1.2 Data Analysis and Statistical Methods

a) Cluster Analysis

The cluster analysis models was used to place similar samples into clusters, which are subsequently arranged in a hierarchical treelike structure called a dendrogram (Gauch, 1989), in order to classify similarity and difference among analyzed parameters and macrophyte found within each site and between sites.

b) Correlation Coefficient

Correlation coefficient was taken for the measurement of similarity to determine relationship between physico-chemical parameters, and biological parameters. Pearson's product moment correlation coefficient was taken as similarity measures.

The difference statistical methods were performed with a 95% confidence (α=0.05).

2.4 Water Quality Indices

2.4.1 Trophic State Indices (TSI) for Lakes (Carlson, 1977)

A Trophic State Index is calculated from each Secchi depth (SD), chlorophyll-*a* (Chl), and total phosphorus concentrations (TP) (Carlson, 1977).

$$TSI\ (Chl) = 30.6 + 9.84\ \ln(Chl)$$

$$TSI\ (TP) = 4.15 + 14.42\ \ln(TP)$$

$$TSI\ (SD) = 60 - 14.41\ \ln(SD)$$

$$TSI \leq 40 \Rightarrow \text{Oligotrophic}$$

$$41 \leq TSI < 50 \Rightarrow \text{Mesotrophic}$$

$$51 \leq TSI < 70 \Rightarrow \text{Eutrophic}$$

$$TSI \geq 70 \Rightarrow \text{Hypereutrophic}$$

2.4.2 Trophic State Classification Criteria of the OECD (Vollenweider, 1982)

2.5 Sediment Index

2.5.1 Sediment Quality Guidelines by USEPA (Giesy and Hoke, 1990) was used as a sediment quality criterion in this study. Sediment was categorized into three classes: non-polluted, moderately polluted and heavily polluted.

2.5.2 Hazard Quotient (HQ) method is commonly used in screening ecological risk assessment to estimate risk to wildlife at contaminated sites.

$$HQ = \frac{\text{Estimated or Observed Exposure}}{\text{Effect Benchmark}}$$

If HQ < 1, it indicates risk considered negligible and there is no need to consider them further in a detailed-level ecological risk assessment (DLSA), whereas if HQ > 1, it indicates risk considered not negligible (Hill *et al*., 2000).