CHAPTER 3

RESULTS AND DISCUSSION

1. Water level

Water level in the Pattani Dam Reservoir on 16 May 2000, 13 July 2000, 25 September 2000, and 4 May 2001, which are the periods of sampling, was about 11.3, 11.4, 12.1 and 11.4 m above mean sea level, respectively. The draining was at the rate of 78.8 m^3/s (or 6.8×10^6 m^3/day) on 16 May.

2. Temperature, Light and Oxygen

Temperature ranged from 25 to 31.8 °C, the latter being reached at noon. There was little different between sites due to difference of sampling time in each site. Maximum-minimum values of Secchi depth were in the range of 20-150 cm, whereas the median was 50 and mean was 69 cm. Standard deviation indicated that 50% of samples was in the range of 30-100 cm with no any extreme case (Figure 5). Impoundments can also exhibit a range of thermal patterns at varying times of the year because of fluctuating water levels caused by their operating regimes.

Dissolved oxygen levels ranged from 5.6 to 7.8 mg/L, the former was at 75% saturation (Figure 6.). Within the reservoir, higher levels are attributed to photosynthesis by aquatic macrophytes, as phytoplankton concentrations in the water were generally very low (see below).

Figure 5 Transparency of Pattani Dam Reservoir

(May 2000-May 2001)

The boxplot of dissolved oxygen (Figure 6) shows that the median value was 6.5 mg/L. Maximum and minimum value were 7.8 and 5.6 mg/L, respectively. The box indicates that 50% of samples are included.

Based on the classified water type of Pattani Dam Reservoir, the Surface Water Quality standards for DO of surface water for agricultural and domestic supply water utilization is at minimum of 4 mg/L (Notification of the National Environment Board, 1994). In this study, DO was found higher than the standard value, which is an indication of the reservoir's good constitution.

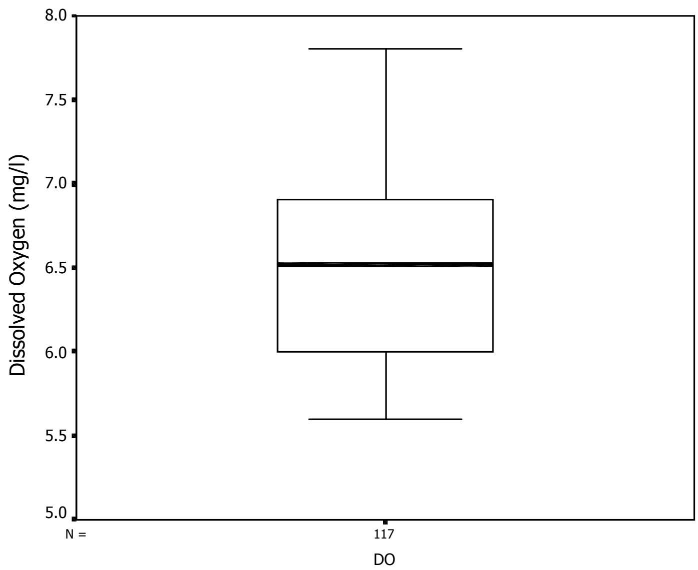

Figure 6 Dissolved Oxygen of Pattani Dam Reservoir
(May 2000-May 2001)

3. Biochemical Oxygen Demand (BOD_5)

The boxplot of BOD_5 (Figure 7) shows that the median value was 2.4 mg/L. minimum-maximum value was in the range of 0.95-3.4 mg/L, the mean was 2.27 mg/L. The values were found higher than the Surface Water Quality standards for BOD_5 of surface water for domestic use, aquatic-animal conservation, fishery and water sport purposes (Type II: 1.5 mg/L). It is slightly higher than the standard for agricultural irrigation (Type III 2 mg/L) (Notification of the National Environment Board, 1994). Therefore, the BOD_5 observed indicates that organic matter contamination do not seem to represent a major problem of the Pattani Dam Reservoir ecosystem.

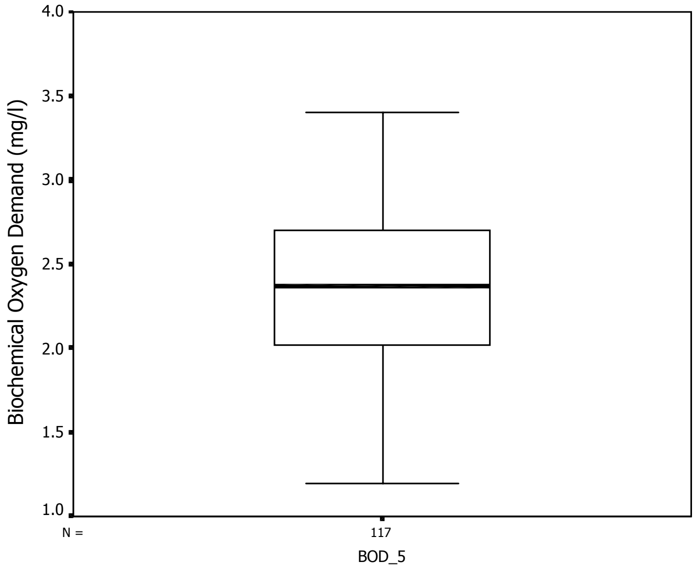

Figure 7 BOD_5 of Pattani Dam Reservoir (May 2000 - May 2001)

4. Nutrients in reservoir water

Total phosphorus concentrations were generally low, with the minimum-maximum of 0.003-0.035 mg/L, the median of 0.016 mg/L, and the mean of 0.017 mg/L (Figure 8). Nitrite levels were very low, the maximum and the mean recorded being 0.006 and 0.002 mg/L, respectively. Ammonia levels were higher than those of nitrite, but were still low compared with those of nitrate. The maximum-minimum values of ammonia concentration were in the range of 0.020-0.078 mg/L, and the mean was 0.042 mg/L. The median of nitrate concentrations was 0.067 mg/L, with the minimum-maximum of 0.003-0.131, and the mean of 0.062 mg/L (Figure 9).

Relatively low concentrations of nitrogen and phosphorus in the reservoir water probably resulted from their losses by natural processes and by man-made activities. The major losses of nitrogen may occur by the effluent outflow from the reservoir, depending on draining rate of the day (about 6×10^6 m^3/day in 17 May 2000), and by those organisms utilizing nitrate as rapidly as it is produce.

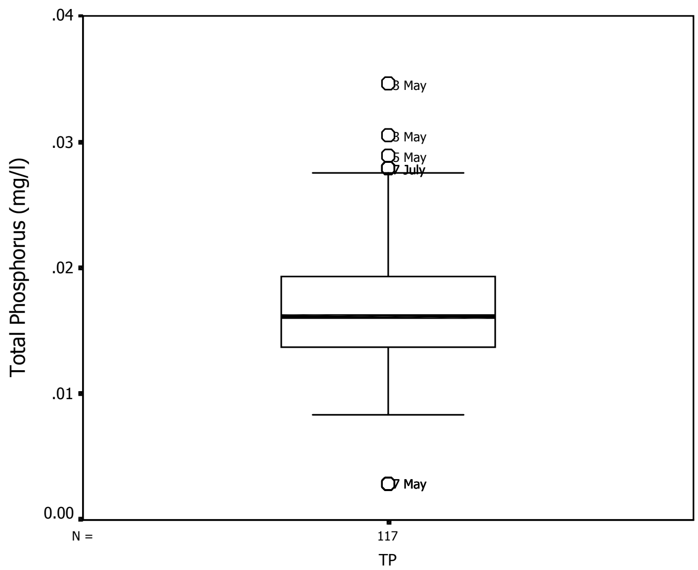

Figure 8 Total phosphorus content of Pattani Dam Reservoir (May 2000-May 2001)

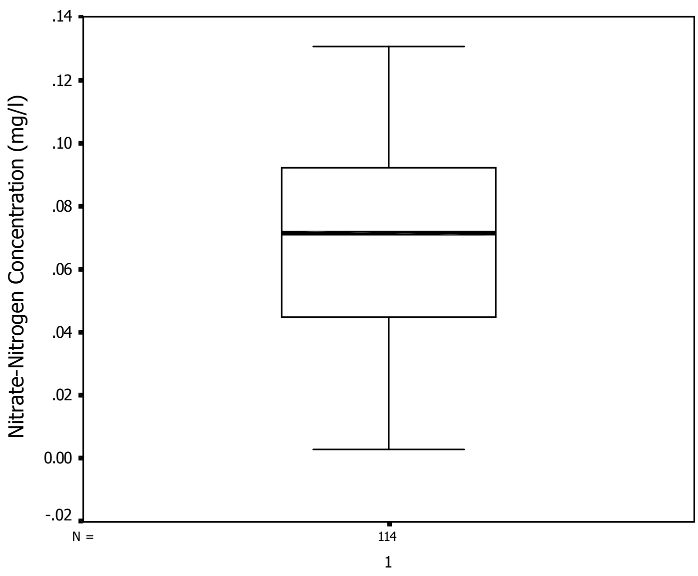

Figure 9 Nitrate-nitrogen content of Pattani Dam Reservoir (May 2000-May 2001)

For phosphorus in the reservoir water, its losses may occur by active uptake of phosphorus by phytoplankton and macrophytes. It had been found that when phosphorus was added to the water, rapid uptake by the littoral vegetation as well as phytoplankton occurred (Wetzel, 1975).

In Toussaint Lake, a small acidic lake with a well-developed littoral zone of rooted aquatic plants, phosphorus was lost to this compartment 50 times or more rapidly than its loss through the outlet (Coffin *et al*., 1949 cited by Wetzel, 1975). Therefore, it is possible that in the Pattani Dam Reservoir, a major loss of phosphorus may occur by very abundant macrophytes trapping water-born nutrients.

Although the amount is small, nutrients are supplied into water continuously from discharging basin via tributaries and by direct precipitation. Some of them flow out from the lake via effluent rivers, and others precipitate to the bottom through chemical (coagulation and flocculation) and physical (sorption to suspended matter) reactions and also precipitate in the form of plankton and detritus after they are taken up by biological activities. As times go on, the depth of a lake decrease by the precipitation and deposition of suspended matter into bottom sediments. The decrease in the depth, i.e. volume of lake water, increase the average concentration of nutrients in lake water and enhances phytoplankton production even if the loading of nutrients is unchanged. The increase amount of phytoplankton precipitation from the epilimnion into hypolimnion and decreased oxygen in the hypolimnion would result in the rapid decrease in dissolved oxygen concentration in the hypolimnion by oxygen consumption of phytoplankton and bacteria. If dissolved oxygen near the bottom is depleted, the release of nutrients, particularly phosphorus, from the bottom sediments is enhanced. Under this condition, nutrient budget of lake water changes significantly, i.e. the contribution of internal loading to the total nutrient loading increases (Okada, 1989).

5. Chlorophyll-*a*

The amount of chlorophyll-*a* in reservoir water was low, but still slightly high compared with those of Pattani River water (1.7 µg/L). The maximum-minimum values were in the range of 0.15 – 62.16 µg/L; the median value was 5.8 µg/L; the mean value was 12.8 µg/L. There was a minor peak at site 7 in May, but as there was no visual evidence of a bloom at the time of collection, this is attributed to contamination by microscopic epiphytic algae stirred up at the time of collection. Site 7 was a region of very high macrophyte biomass.

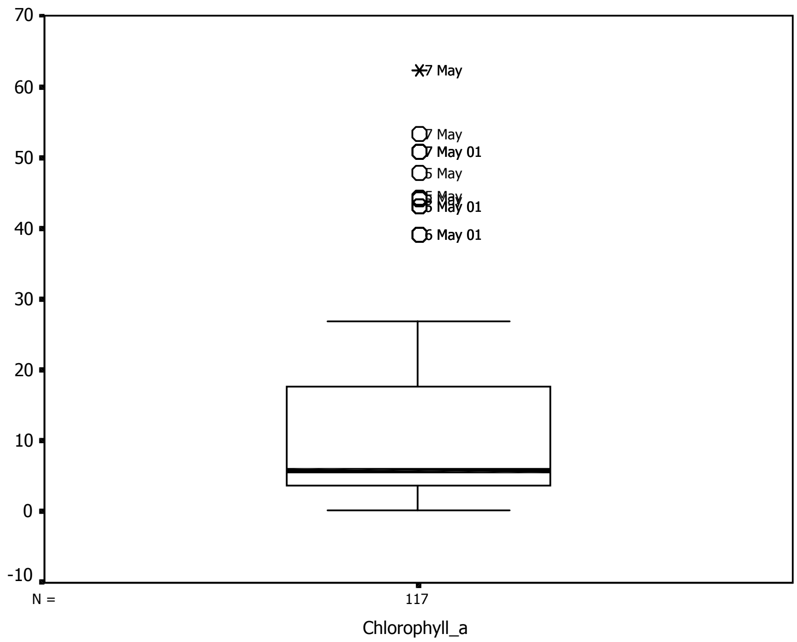

Figure 10 Chlorophyll-*a* content of Pattani Dam Reservoir (May 2000 - May 2001)

Figure 10 shows chlorophyll-*a* content in Pattani Dam Reservoir, the median value is 5.8 μg/L. There were extreme cases in May (>39μg/L), which was in the dry season. Maximum-minimum values range between 0.15-62.2 μg/L. In comparison with OECD's lake clssification criteria (Table 1), the content of chlorophyll a was very low to be classified as eutrophic lake type (average value 14.3 mg/m^3).

The low content of chlorophyll-*a* in the Pattani Dam Reservoir may be due to the reservoir turbidity. The Pattani Dam Reservoir is a turbid reservoir, where the restriction of light penetration into the water column resulted from high concentrations of inorganic suspended solids. This restricted light penetration can potentially limit the growth of both benthic and suspended algae in natural water just as it can restrict phytoplankton biomass (Hoyer and Jones, 1983 cited by Smith; Tilman and Nekola, 1999). Thus, although reservoir water was frequently perceived as nutrient saturated, factors such as light limitation and short hydrolic residence times should restrict or prevent any potential algal response to nutrient enrichment (Smith; Tilman and Nekola, 1999). In order words, although phytoplantonic productivity of reverine sections of reservoirs can be high per unit water volume, the limited photic zone reduces areal productivity, as is similarly the case in large river (Wetzel and Likens, 2000). Often the riverine portion of a reservoir funtions analogously to large, turbid rivers in which turbulence, sediment instability, high turbidity, reduced light availability, and other characteristics limit photosynthesis despite high nutrient availability (Wetzel and Likens, 2000).

Furthermore, a number of fish living in the Pattani Dam Reservoir, some of these fish may be herbivore grazing, often is noted as an additional biological constraint on periphyton growth and productivity (Smith; Tilman and Nekola, 1999).

As noticed, neither loading of BOD nor content of chlorophyll-*a* was in such amount causing eutrophic condition in this reservoir. Therefore, other parameters were then observed.

6. Conductivity and pH

Conductivity reading (Figure 11) shows that 50% of samples were included in between 56-66 µS/cm. The maximum and minimum readings were in the range around 44-92 µS/cm. High conductivity was observed in dry season. This occurred from small quantity of water in the reservoir, leading to high conductivity. Then the

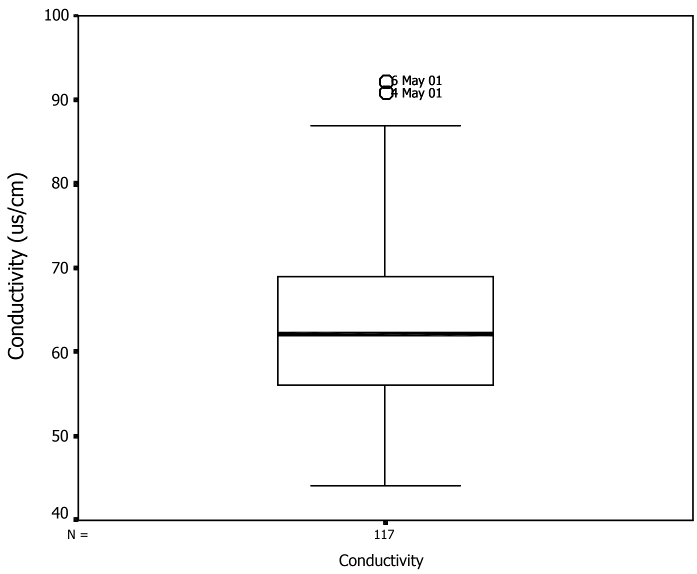

Figure 11 Conductivity reading of Pattani Dam Reservoir (May 2000 - May 2001)

conductivity slightly decreased in the wet season, resulting from dilution effect.

The amount of current conducted is proportional to the concentration of ions in solutions (Wetzel and Likens, 2000).

For pH in Pattani Dam Reservoir, the mean value was 6.9. Maximum reading (8.8) was found in site 10 May 2000, whereas the minimum (6.1) in site 8 July 2000 (Figure 12). Seasonally modified pH may be due to rain events according to Avila-Perez *et al*. (1999) reporting that rain events during the rainy season add a substantial water volume, which modifies physicochemical parameters like pH and dilutes chemical species in the Alzate Reservoir.

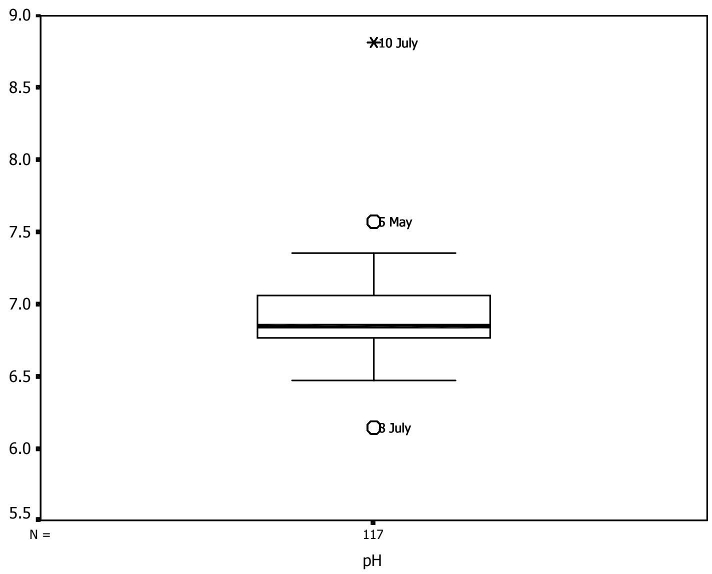

Figure 12 pH reading of Pattani Dam Reservoir (May 2000 - May 2001)

The lethal effects of most acids appear when pH<5.5 and of most alkalis near pH 9.5, although the tolerances of many organism are considerably more restricted within these pH extremes (Wetzel and Likens, 2000). Therefore, the observed pH indicate low occurring opportunity of adverse effects of both acidity and alkalinity in the reservoir water.

In this study, nitrite-nitrogen was the most probable limiting factor for algal growth because the correlation between chlorophyll-*a* (an index of primary productivity) and nitrite-nitrogen concentrations (R = 0.658) was higher than that for total phosphorus, nitrate-nitrogen, and ammonia-nitrogen. This result is in agreement with those of Okada (1989) that indicate a considerable number of eutrophic lakes limited by nitrogen although most lakes are limited by phosphorus. Thus, in Pattani Dam Reservoir, the limitation of algal growth by nitrite-nitrogen might not be overlooked.

7. Trophic State Assessment in Pattani Dam Reservoir

Trophic state in Pattani Dam Reservoir was assessed with two methods: Trophic State Index and squared Euclidean distance.

Trophic State Index (TSI) and criteria of Calson (1977), including TSI for secchi depth, for chlorophyll-*a*, and for total phosphorus, were all adopted simultaneously. As a result, the TSI value for secchi depth (68; P=0.998) would place it in eutrophic class of lakes, whereas TSI value for chlorophyll-*a* (49.83; P=1.000) and for the total concentration of phosphorus (44.08; P=0.998) would both place it in mesotrophic class.

It appears that the adoption of Calson's criteria yields contradictory cases: the reservoir was classified into eutrophic lake from secchi depth, whereas it was classified into mesotrophic lake from both chlorophyll-*a* and total phosphorus concentrations. This is the disadvantage of taking a single parameter for an index for compared with the boundary values (Okada, 1989).

The concept of squared Euclidean distance (dissimilarity), therefore, was applied to assess the reservoir to determine whether it is an oligotrophic, a mesotrophic, or a eutrophic water body. The distance calculated from the standardized variables is the measure of how far between the observed values of this study and the criteria values of OECD. Distance measures are smallest for cases that are most similar.

The distances of the cases are 3.361, 9.232, and 9.762, respectively for the mesotrophic, oligotrophic, and eutrophic case. Taking into account these criteria, it seems reasonable to consider the Pattani Dam Reservoir a mesotrophic water body.

The advantage of applying the squared Euclidean distances is that all parameters are weighted equally before combined to be a single value indicating the possible trophic state of a water body.

Comparison with Previous Study

Some information is available for Pattani Dam Reservoir in 1994 (NIDA, 1999), and is compared with results from the present study in Table 3. However, they can only be roughly compared, since the different studies used different methods. From these limited data there is evidence for increase in conductivity reading and decrease in nitrate and pH. This is attributed to the different in rates of nitrogen fixation. The rates of nitrification in open lake water are typically low in the early morning, reach a maximum in midday at maximum insolution and photosynthesis (Wetzel, 1975). In the 1994 survey, the water samples were collected at noon which is a time when rate of nitrogen fixation is maximum, while in this study water samples were collected in the morning, a time when the rate of nitrogen fixation are low.

Table 3 Comparison of water chemistry analysis for Pattani Dam Reservoir in the previous study (NIDA, 1999) and the present study

Analysis	Previous Study (Mean)	Present study (Mean)
Nitrate-N (mg/L)	0.5	0.06
PH	7.5	6.9
Temperature (º C)	34	29
Conductivity (μS/cm)	45	64
Salinity (ppt)	0	-

The pH value of the present study is slightly lower than that of the previous survey, while conductivity reading is slightly higher. At pH levels between 6 and 7, uptake of phosphorus by the diatom *Asteronella* is greatest (Mackerth, 1953 cited by Wetzel, 1975), suggesting that there is more phosphorus uptake efficiency in the present study because the pH levels were at the optimum range.

The total concentrations of phosphorus (17 µg/L) of Pattani Dam Reservoir would place it in the oligotrophic class of lakes (Vollenweider, 1968), whereas mean chlorophyll-*a* concentration (14.3 µg/L) would place it in mesotrophic class. However, when regarding the cover and extent of macrophytes around the sampling sites and around the large areas of littoral zones not accessible by boat, many parts of the reservoir, especially the littoral zones, can be considered eutrophic.

Cluster analysis of Physico-chemical Parameters

With the help of cluster analysis, sampling sites could be clustered and classified into small groups based on the calculation of all variables. Another possibility is that all variables be clustered and grouped together. The correlation between the parameters is finally observed.

Based on the above reasons, cluster analysis was introduced and applied in this study, aiming to test the capacity of cluster analysis for further purpose in ecosystem classification.

From cluster analysis with all chemical parameters, the dendrogram (Figure 13) shows the grouping of DO, BOD_5, total phosphorus, and pH which indicate a trophic state. A clear relationship between phosphorus and chlorophyll-*a* has been demonstrated in many cases, but is not recommended in the Pattani Dam Reservoir. Transparency is not a good indicator of algal density in this reservoir water in which high inorganic suspended solid can be observed visually. Okada (1989) stated that the increase in turbidity by suspended materials other than phytoplankton such as silt, organic debris, and so on can decrease secchi disk transparency.

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Figure 13 Correlation between all chemical parameters used in Pattani Dam Reservoir (May 2000 – May 2001)

Method: Peason's Correlation

The dendrogram (Figure 14) was classified into three main divisions. The first division consisted of all sites in July 2000 except site 10. Including site 10 July, the second division consisted of all sites in September 2000, whereas the third division consisted of all sites in both May 2000 and May 2001.

It is obvious that the grouping is dependent on changing of seasons from rainy season with low precipitation, rainy season with high precipitation, to dry season. The first division included the sites in rainy season. The second division also included the sites in rainy season but with more precipitation. The third division, unlike the first two divisions, included the sites in dry season.

Based on cluster analysis, the similarity in chemical composition of water samples in different months was clearly classified. It can be observed that the seasonal pattern between dry and wet season showed no influences from different

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C A S E           1                                                  -0.258
site-date      Num  +---------+---------+---------+---------+---------+

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  5 July       14   ⇩⬃        ▭⇩⇩⇩⬂
  8 July       17   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃    ▭⇩⇩⇩⇩⇩⇩⇩⬂
  9 July       18   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃       ⇔
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  4 May 01     33   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃    ▭⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃   ⇔
  7 May 01     36   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩×⇩⇩⇩⇩⇩⬃            ⇔
  9 May 01     38   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃                ⇔
```

2 May 2 ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩

Figure 14 Similarity of sampling sites using Average Linkage (Between Groups) of Chemical Data, Pattani Dam Reservoir (May 2000 - May 2001)

Method: Cosine

Seasons, not from different sites. The sampling sites in any parts were not separated, showing no significant differences between sites.

From these results, cluster analysis is a useful tool for this classification method. It shows the pattern of seasonal effect, indicating that the changing season patterns, rather than the sites, had a significant effect on water quality of the Pattani Dam Reservoir.

Macrophyte

1. Distribution and Frequency

Macrophytes were observed and collected bimonthly at all sites they occurred, except in May 2001, in order to compare the composition of communities.

As in many other eutrophic lakes, macophytes in the Pattani Dam Reservoir bloom all year round with the abundance of a few species. Fourteen species of macrophytes were found in the reservoir during May 2000 - May 2001, as shown in the data matrix (Table 4).

Hutchinson (1975) reviewed many regional studies concerning the abundance of submerged macrophytes in lakes. These studies suggest a large number of factors that could bring about wide variations in macrophytes covering the water surface and biomass in lakes.

It is presumed that oligotrophic lake tend to have lower macrophyte biomass than more productive ones, implying that increases in lake productivity should result in higher macrophyte abundance.

The important environmental factors influencing these macrophytes and biomass in nature comprise light availability, substrate characteristic, lake trophic status (Hutchinson, 1975), and lake morphology (Spence, 1982) as the most important environmental factors able to affect macrophyte covers and biomass in nature, which will also be observed in this study.

2. Cluster Analysis of Macrophyte Communities

With the help of cluster analysis, sampling sites could be clustered and classified into small groups based on the distribution of macrophyte communities. Another possibility is that all macrophytes could also be clustered and grouped together because of the similarity within their communities.

The correlation between the sampling sites and macrophyte are finally observed. Accordingly, cluster analysis was introduced and applied in this study, aiming to test the capacity of cluster analysis in the reservoir for additional purposes.

The dendrogram shows that 14 species of macrophytes were found in the reservoir, predominantly in the eastern littoral areas of the reservoir (Figure 15).

After applying cluster analysis by Peason's correlation index, the species could be classified by forming four main groups and two negative groups, signifying its difference from the other groups.

The distribution patterns ranked from the normal distribution on the top of the dendrogram to the specific location in the bottom.

Hydrilla verticillata and *Ceratophyllum demersum* were common species, which were distributed, but not in abundance. Two species in the genus *Cyperus* were found together with many other species along the shoreline of the Pattani Dam Reservoir.

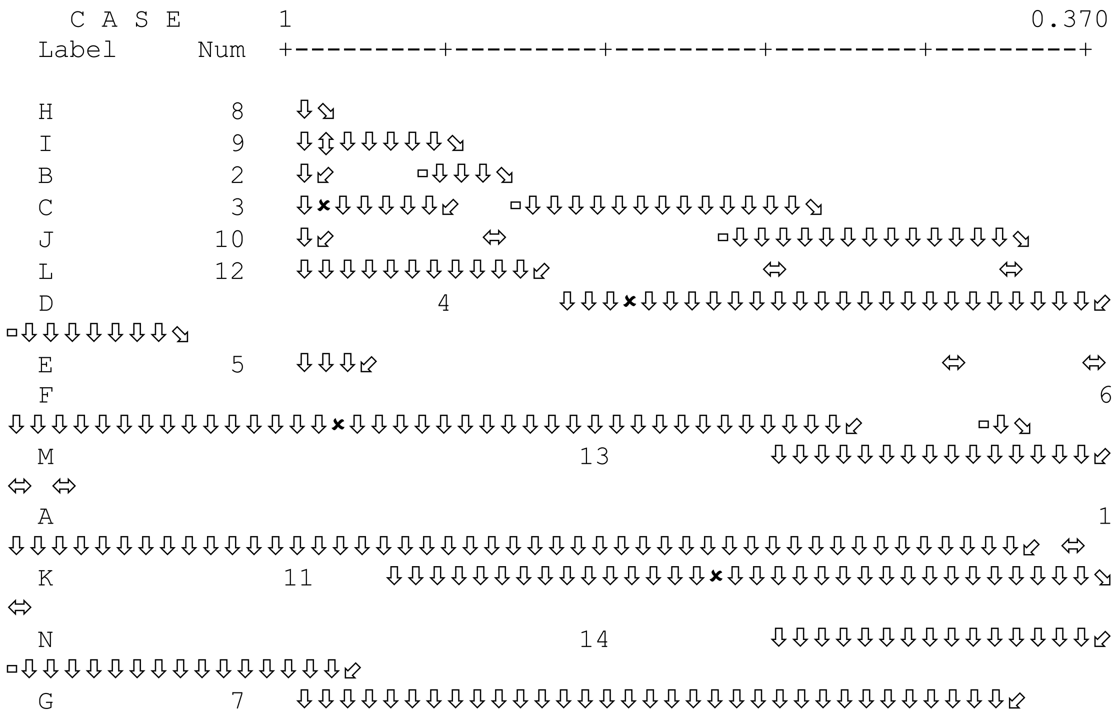

Figure 15 Distribution pattern of 14 macrophyte species in the Pattani Dam Reservoir.

Index: Pearson's Correlation.

Key A: *Ceratophyllum demersum* B: *Colocasia esculenta*

C: *Cyperus cephalotes* D: *Cyperus papyrus*

E: *Cyperus platystylis* F: *Eichhornia crassipes*

G: *Hydrilla verticillata* H: *Ipomoea aquatica*

I: *Ludwigia ascendens* K: *Paspalum vaginatum*

L: *Pistia stratiotes* M: *Polygonum tomentosum*

N: *Salvinia cucullata*

There are two small division in the first group; the first subdivision includes *Ipomoea aquctica*, *Ludwigia ascendens*, and *Colocasia esculenta* which were distributed only in the littoral zone areas and always grouped together as a community. The second subdivision consists of *Cyperus cephalotes* and *Nymphaea lotus*, both of which were found in the littoral zone near the bank of the reservoir.

They also formed communities. *Pistia stratiotes* was separated from the rest because it was found not only in the littoral zone areas, but also in areas around the inlet (Site 2).

The fourth group was distributed in littoral zone areas, which were *Cyperus papyrus* and *Cyperus platystylis*, but not predominantly.

Eichhornia crassipes is an indicator of the eutrophic situation, and was found mainly in the some shoreline areas of many small islands within the reservoir.

Ceratophyllum demersum was separated from other species because it was found in site 5 only.

Paspalum vaginatum, *Salvinia cucullata*, and *Hydrilla verticillata* were different from the rest and showed negative correlation with regard to others. *Paspalum vaginatum* is a dominant aquatic as well as terrestrial species around the shallow areas. *Salvinia cucullata* was found mainly in the dry season and become abundant and dominated around site 3 and 7 (Western part of the reservoir). *Hydrilla verticillata* covered the water surface, while its roots were attached to the bottom sediments. It increased in number annually, indicating a high saprobic condition.

According to the cluster analysis using Peason's correlation, the dendrogram clearly shows the grouping of macrophyte communities based on the similarity of the sampling sites (Figure 16).

The dendrogram is classified sites into four divisions. The first division (A) includes all samples in site 7 and 10, both of which are situated in the eastern part of the Pattani Dam Reservoir, the second division (B) is the group in the western part of the reservoir, the last division (C) represent the samples from the shoreline sites.

The dendrogram undoubtedly shows the different ecosystem in each group. The ranking of dendrogram signifies the abundance of macrophytes, ranging from rich communities on the top of dendrogram, the ones near shoreline area, and the poorest one located in the bottom of the dendrogram.

The littoral zone near the shoreline of the Pattani Dam Reservoir is the most eutrophic part, which could also be observed by the aerial photo. The aerial photograph taken in 1975 and the recent estimation showed that macrophytes grew in a half area (0.5 km^2) of Pattani Dam Reservoir. This macrophyte blooming could result from many factors. The distinction between the environmental factors however plays an outstanding role in the distribution of macrophytes.

```
C A S E          0                                                 82.17
  Site-Date  Num +---------+---------+---------+---------+---------+

  10 July    10  ⇩⇘
  10 May 0   22  ⇩▫           A1
  7 May       4  ⇩⇳⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘
  7 Sep      15  ⇩▫         ⇔
  10 Sep     16  ⇩⇙          ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘
  3 July      7  ⇩✖⇩⇩⇩⇘    A2 ⇔         ⇔
  7 July      9  ⇩⇙  ▫⇩⇩⇩⇩⇩⇩⇩⇙         ⇔
  7 May 01   21  ⇩⇩⇩⇩⇩⇙                ⇔
  5 May       3  ⇩⇘        B1
▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘
  5 May 01   20  ⇩⇳⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘       ⇔
⇔
  5 July      8  ⇩▫          ⇔        ⇔
⇔
  5 Sep      14  ⇩⇙          ⇔        ⇔
⇔
  2 May       1  ⇩✖⇩⇘        ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙
⇔
  3 May       2  ⇩⇙ ▫⇩⇩⇩⇘       ⇔
⇔
  2 July      6  ⇩⇩⇩⇙   ⇔   B2  ⇔
⇔
  2 Sep      12  ⇩⇘     ▫⇩⇩⇩⇩⇩⇩⇩⇙
⇔
  3 Sep      13  ⇩⇳⇩⇩⇩⇘ ⇔
⇔
  3 May 01   19  ⇩⇙   ▫⇩⇙
⇔
  2 May 01   18  ⇩⇩⇩⇩⇩⇙
⇔
  S May       5  ⇩⇩⇩✖⇩⇘     C1
⇔
  S Sep      17  ⇩⇩⇩⇙ ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘
⇔
  S July     11  ⇩⇩⇩⇩⇩⇙     C2
▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙
  S May 01   23  ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙
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Remark: S = shoreline sites

Figure 16 Similarity of the sampling sites, based on the composition of macrophyte communities.

Similarity Index: Squared Euclidean Distance

Groups: A = Eastern part of the reservoir C = Inlet part of the reservoir (Dry season)

B = Western part of the reservoir D = Inlet part of the reservoir (Wet season)

Rankings: A-B rich macrophyte-communities in different composition

C poor macrophyte-communities

D poorest macrophyte-communities

3. Co-incidence of the Macrophyte Community

According to Figure 16 and Table 4, each of the first and the second groups (A and B) was grouped together due to the same species found: *Hydrilla verticillata* for group A1 and *Hydrilla* verticillata, *Salvinia culcullata*, *Paspalum vaginatum* for group A2. The first subdivision of group B (B1) was grouped together because only *Ceratophyllum demersum* was always found, whereas the second subdivision (B2) was grouped because other species were also found, but sometimes no species could be observed. The third group is identified as the same group based on the similarity of macrophyte found. These were all samples observed from littoral areas adjacent to the shoreline (or edge) of the reservoir. The abundance of both the number of species and the frequency found constitute an index to point out the grouping of these samples. The highest number of species was the sample in May 2001, which 14 species was found. The dominant species of Pattani Dam Reservoir were *Hydrilla verticillata* and *Ceratophyllum demersum*. This is an indication of the eutrophication situation of the littoral zones close to the shoreline of the reservoir, where more species have been found.

It is obvious that the grouping of sampling sites in the Pattani Dam Reservoir are formed into three different groups: the eastern part of reservoir, the western part of reservoir, and the part along the shoreline, indicating significant differences found among the sampling sites.

It also appears that the different seasons have no much influence on macrophyte composition at most sites. At some sites such as site 2 and site 3, however, the seasons have little influence on the macrophyte composition, observable from no

Table 4 Co-incidence of macrophyte community between taxon and sampling site in Pattani Dam Reservoir (May 2000 – May 2001)

Sampling Site/Time	Species													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
10 July	-	-	-	-	-	-	5	-	-	-	-	-	-	-
10 May 01	-	-	-	-	-	-	5	-	-	-	-	-	-	-
7 May	-	-	-	-	-	-	5	-	-	-	-	-	-	-
7 Sep	-	-	-	-	-	-	4	-	-	-	-	-	-	-
10 Sep	-	-	-	-	-	-	4	-	-	-	-	-	-	-
3 July	-	-	-	-	-	-	5	-	-	-	3	-	-	4
7 July	-	-	-	-	-	-	5	-	-	-	3	-	-	4
7 May 01	-	-	-	-	-	-	5	-	-	-	-	-	-	4
5 May	5	-	-	-	-	-	-	-	-	-	-	-	-	-
5 May 01	5	-	-	-	-	-	-	-	-	-	-	-	-	-
5 July	4	-	-	-	-	-	-	-	-	-	-	-	-	-
5 Sep	4	-	-	-	-	-	-	-	-	-	-	-	-	-
2 May	-	-	-	-	-	2	-	-	-	-	-	-	2	-
3 May	-	-	-	-	-	3	-	-	-	-	-	-	2	-
2 July	-	-	-	-	-	4	-	-	-	-	-	-	1	-
2 Sep	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 Sep	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 May 01	1	-	-	-	-	-	-	-	-	-	-	-	-	-
2 May 01	-	-	-	-	-	2	-	-	-	-	-	2	-	-
S May	5	2	2	-	-	2	4	3	2	1	2	2	2	1
S Sep	4	2	2	-	-	1	4	2	1	1	2	1	1	1
S July	4	2	2	-	1	3	5	3	2	2	2	2	2	2
S May 01	4	2	5	3	3	2	5	3	2	3	3	3	2	5

Remark: S = Shoreline sites

Key A: *Ceratophyllum demersum* B: *Colocasia esculenta*
C: *Cyperus cephalotes* D: *Cyperus papyrus*
E: *Cyperus platystylis* F: *Eichhornia crassipes*
G: *Hydrilla verticillata* H: *Ipomoea aquatica*
I: *Ludwigia ascendens* K: *Paspalum vaginatum*
L: *Pistia stratiotes* M: *Polygonum tomentosum*
N: *Salvinia cucullata*

Ranking Score Record: 0-5 indicating of not found to many individuals found

species found in September 2000, during high precipitation. This may be because the high water loading during rains caused the high depth of water, which restricted rooting zone of macrophytes in the reservoir. Therefore, the macrophytes of many sites in the littoral zone were found almost absent during rainy season.

Extent and Cover of macrophytes

The prominence of macrophytes, especially *Hydrilla verticillata* and *Ceratophyllum demersum*, is a striking feature of Pattani Dam Reservoir. These plants occupy a large area of the reservoir where water seems to be non-flowing (lake-like condition), or flowing with decrease water velocity due to increased cross-sectional area. Because of decreasing of water velocity, suspended materials settle, and algal productivity increases due to increase water clarity (USEPA, 1999a). In these zones of reduced flow velocity, a majority of the phosphorus load can deposit to sediments. Algae growing on sediments are able to utilize phosphorus of these sediments effectively (Golterman, *et al*., 1969 cited by Wetzel, 1975). Thus, the transition zone area and the shore area near the bank of the Pattani Dam Reservoir possess a more diverse flora and much more macrophyte cover because macrophytes obtain most of their nutrient requirements from sediments (Barko and Smart, 1981 cited by Harper 1992).

There are few data for macrophyte biomass in the reservoir in earlier years. Mr. Chinawat Prommanop (Personal Communication) and other local residents do not recall prominent stands of *Hydrilla verticillata* and *Ceratophyllum demersum* in 1961-1980, and had noted a marked increase in their amount in recent years; the plant has reached nuisance proportions, impeding boat progress in dry season. This is in keeping with the aerial photo of Pattani Dam Reservoir (Royal Thai Survey Department, 1995) from which the appearance of macrophytes covering large areas in both the eastern and the western parts of the reservoir can be observed. The amount of macrophytes colonizing in the western part of the reservoir observed in this study is relatively low compared with those appearing at the same places indicated in the aerial photo. This may be due to a present measure of harvesting macrophytes, proposed by the Pattani Water Supply and Maintenance Project Office; however, the macrophyte covering is typically affected by spatial factors.

In general, spatial variability of cover and extent within the littoral areas can be a result of the spatial factors, such as substrate type, topography, disease, insect infestation, and local sources of nutrients and turbidity (USEPA, 1999a), one of which observable in the Pattani Dam Reservoir system was wave action.

In Pattani Dam Reservoir, the eastern part shows a much higher density of macrophytes colonizing the littoral areas along the shore than the western part because of the absence of wave action. On the contrary, site 2, 3, 4, 6, 8, and 9, showed little or no macrophyte composition because all the sites were located around the center part of the reservoir which can be greatly affected by wave action. This is in agreement with the fact that existence of dense macrophyte cover in the lakes depends on the absences of wave action (Space, 1988).

Indicated by these results, the principal factor that affects the cover and extent of macrophyte in Pattani Dam Reservoir is the site effect. The composition of macrophyte communities was considered similar within the same parts. Each of the parts includes the same sites of different months, indicating that site effect, rather than seasonal effect, had a significant influence on macrophyte composition in Pattani Dam Reservoir.

Ecological Risk Associated with Eutrophication

Based on physico-chemical parameters and macrophyte observed in this study, the ecological risk associated with eutrophication in the Pattani Dam Reservoir can be characterized qualitatively.

The reservoir water was considered mesotrophic according to the trophic state index and the squared Euclidean distance, indicating medium characteristics of nutrients, algal biomass, and water clarity. The reservoir, however, could be considered eutrophic based on the macrophyte cover and extent of low species composition with few dominant species. These were the observable present effects of eutrophication in the Pattani Dam Reservoir.

In the near future, it is possible that the eutrophication effects would be more serious than nuisance increase in macrophyte growth as occurring in most eutrophic reservoirs (Smith; Tilman, and Nekola, 1999). In brief, the degradation of the reservoir water resources by macrophyte blooming could result in losses of their component species, as well as losses of the amenities or services that the reservoir provides. The problems of eutrophication are likely to exacerbate pose significant ecological risk in the Pattani Dam Reservoir in the coming years because eutrophication has already caused major changes in the structure and function of macrophyte communities in the reservoir. According to Wetzel and Likens (2000), the productivity of aquatic macrophytes of the wetland constitutes a major source of organic matter input for a majority of the lakes of the world. Much of the organic matter produced by these larger aquatic plants remains in the wetlands and littoral zone of lakes and undergoes decomposition. Floating-leaved and many submerged macrophytes decompose relatively rapidly, the tough structural components of emergent macrophytes have markedly reduced rates of decomposition. When the decomposing tissue falls to the sediments in detrital masses, the environment of the aggregates rapidly becomes anaerobic. Under these reducing conditions, rates of decomposition are decreased greatly. According to Okada (1989), the high productivity in eutrophic lakes stimulates the accumulation of bottom sediments and the rate of decrease in depth increase. Based on this knowledge, the shallow depressions of the Pattani Dam Reservoir system already gained excessive organic matter deposits through submerged and floating-leaved macrophytes indicate fundamental to the terminal stages of the biotic transformation from lake-like condition to a landscape with the rapid rate of transformation.

Lead

1. Lead in Sediment

The boxplot of lead in sediments (Figure 17) shows that the median value was 345 mg/kg. The maximum and minimum values were 523 and 105 mg/kg, respectively. The box indicates 50% of samples ranged between 250 and 395 mg/kg. The average concentration of lead for all sampling sites for all campaigns was 322 mg/kg.

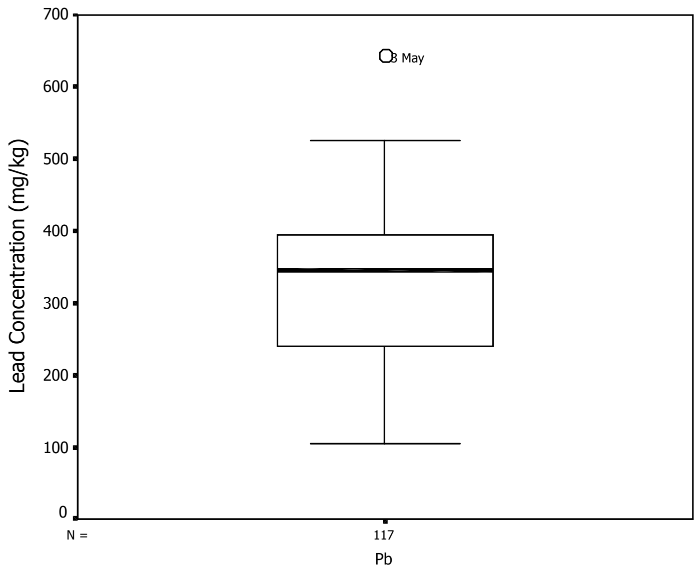

Figure 17 Concentration of Lead in Sediment from Pattani Dam Reservoir (May 2000 – May 2001)

According to LSD, the concentration of lead was significantly highest in May 2000, whereas the concentrations of lead in other sampling campaigns were not statistically different between each other (P=0.167, 0.258, and 0.800). The statistical differences in the concentration of lead among the different sampling sites were also observed, suggesting lead not uniformly distributed. The lead concentrations of the sediments were found to decrease in the sequence of sites: 1 > 5 > 7 > 9 > 6 > 4 > 8 > 10 > 3> 2 (Table 5). Site 1 is located close to the Pattani River inlet, whereas Site 5, and Site 7 are areas where macrophytes blooming could be visually observed all year round. In other words, the concentration of lead in sediments of the Pattani Dam Reservoir ranged from very high contamination in its inlet areas to considerable contamination closer to the outlet. This probably resulted from sedimentation process.

Table 5 Comparison of lead concentrations of Pattani Dam Reservoir (May 2000 - May 2001) with threshold effect level and probable effect concentration sediment quality guidelines (SQGs).

Site Location	Mean Lead (mg/kg)
1	439
2	171
3	222
4	333
5	403
6	338
7	380
8	320
9	360
10	225
Sediment Quality Guideline	
TEL	35
PEC	128

The lead concentrations in Table 5 were compared to two classes of sediment quality guidelines: a threshold effect level and a probable effect concentration (Table 1). Threshold effect level (TEL) values are intended to estimate the concentration of a chemical below which adverse biological effects only rarely occur (Smith *et al*., 1996). Probable effect concentration (PEC) values are intended to estimate the concentration of a chemical above which adverse effects frequency occur (Ingersoll and Mcdonald, 1998).

All of the Pattani Dam Reservoir sites had lead contaminated in sediments exceeding PEC value; most of the sites show multiple exceedances of the TEL value. Therefore, at these sites, the superficial sediments were sufficiently contaminated to present a greater probability risk to the aquatic organisms, especially benthos (Smith *et al*., 1996). Hence, lead was the predominant parameters of concern in the Patani Dam Reservoir.

The lead concentrations in Table 5 were also compared to other two sediment quality criteria: Sediment quality criteria and Pre-industrial reference value (Table 6).

Table 6 Sediment quality criteria (SQC) and Contamination factor (C) of sediments from Pattani Dam Reservoir and Pattani River (May 2000- May 2001).

Site	Criteria	
	SQC	C_f
Pattani Dam Reservoir		
1	Heavily polluted	Very High
2	Heavily polluted	Moderate
3	Heavily polluted	Considerable
4	Heavily polluted	Considerable
5	Heavily polluted	Considerable
6	Heavily polluted	Considerable
7	Heavily polluted	Considerable
8	Heavily polluted	Considerable
9	Heavily polluted	Considerable
10	Heavily polluted	Considerable

PIV	70
SQC	
Non-polluted	<40
Moderately polluted	40-60
Heavily polluted	>60

Notes: C_f <1 low contamination;1≤ C_f <3 moderate contamination; 3≤ C_f <6 considerable contamination; C_f >6 very high contamination.

Sediment quality guidelines (SQG) by USEPA are intended to categorize sediments into three classes including non-polluted, moderately polluted, and heavily polluted (Giesy and Hoke, 1990). Pre-industrial reference value (PRV) is intended to estimate the contamination factor indicating qualitative level of lead contaminating in sediments (Håkanson, 1980).

At all of the Pattani Dam Reservoir sites, the average concentrations of lead contaminated in sediments were 'heavily polluted' by SQG. With the comparison of the pre-industrial reference value, the sediments of all sites were considerably contaminated by lead, except site 1 and site 2, the contamination status of which were very high and moderate, respectively.

In order to characterize ecological risk associated with lead, the hazard quotients (HQs) calculated by dividing the observed exposure concentration (OEC) by its associated effect benchmark was applied to this study. The OEC used was the average total lead concentrations from Table 5. The effect benchmark used was the threshold effect level (TEL) value (35 mg/kg)(Smith *et al.*, 1996). The harzard quotients are summarized by site in Figure 18.

It is evident from Figure 18 that all of the Pattani Dam Reservoir sites had the hazard quotients exceed the benchmark value of 1, indicating risk from sediment contaminated by lead considered not negligible (Hill *et al*., 2000). In other words, it implies a high probablity of adverse effects impacting the benthological community (Ingersoll and MacDonald, 1998) in the Pattani Dam Reservoir. Most sites of the reservoir had the hazard quotient values greater than 6, some greater than 10, and only site 1 had the quotients value as high as 12.

The high concentrations may be influenced from a large discharge of Pattani River water polluted by leaching of lead from the intensive tin mining in Amphoe Bannangsata, Yala Province over a long period (Arrykul and Kooptarnon, 1993). Although most of these mining areas have been abandoned, the high lead concentration in the river was found because lead can be emanated from abandoned mines (Rösner, 1998).

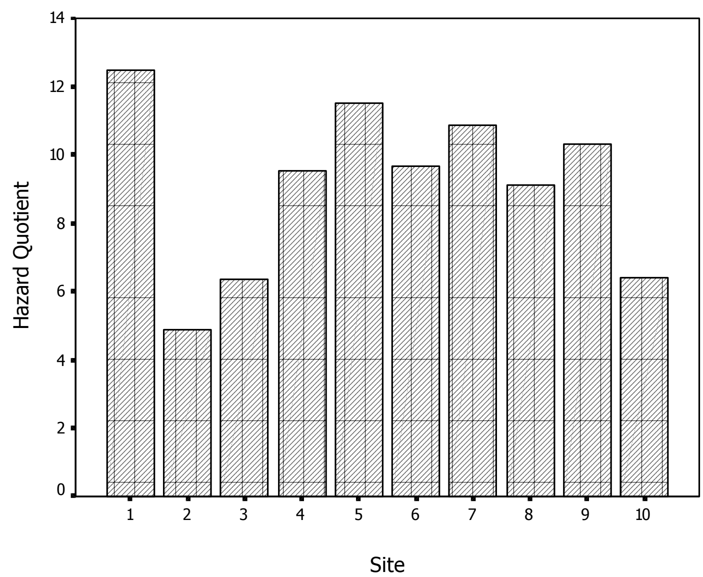

Figure 18 Hazard quotients for Pattani Dam Reservoir (May 2000 - May 2001). Site numbers on the X-axis are defined in Figure 1 (Pattani Dam Reservoir Map).

Based on the example on the effect of historical mining activities on surface water provided by Rösner (1998), lead-bearing fine sediments might be washing out of the abandoned mines by heavy rains and entering the river. Then, lead was transported downstream along Pattani River to the reservoir and began depositing to the bottom sediments.

By these processes, the continuous discharge of lead-bearing fine sediments into Pattani River will continue to increase the magnitude of lead concentration in Pattani Dam Reservoir to intolerable limits, and this may have severe impact on aquatic macrophytes and other organisms in the reservoir.

2. Lead in Macrophytes

Macrophytes in Pattani Dam Reservoir accumulated lead in appreciable amounts. The lead concentrations in a whole tissue of the macrophyte *Ceratophyllum demersum* collected from site 5 and of *Hydrilla verticillata* collected from site 7 and 10 were 59.8, 57.1, and 22.2 mg/kg dw, respectively.

Although standards of lead in aquatic macrophytes were now unavailable, the contamination of lead in the macrophytes has been compared with the reports of Ali *et al*. (1999) and Håkanson (1980). Ali *et al*. (1999) revealed that the high amount of lead found in a whole tissue of most macrophytes in the contaminated lake in India are in the range of 24-56 mg/kg dw. Further, the concentrations of lead in the reservoir are higher than the background levels referred by Håkanson (1980) (2.7 mg/kg) by a factor of 8-22. Thus, the levels of lead found in macrophytes collected from Pattani Dam Reservoir could also be considered high and might be significant for bioindicator of lead in sediments from the reservoir.

A significant positive correlation (r = 0.748) exists between lead in macrophytes and lead in sediments, suggesting that lead contaminated in sediments was taken up by the macrophytes through their root. *Ceratophyllum demersum* has a high ability of lead absorption, according to the study of Parfenov (1988) and was found to be highly capable of removing pollutants from the effluent (Subramahi *et al*., 1999).

Ecological Risk Associated with Lead Contamination

Based on lead Persistence, Environmental Fate, and Bioaccumulation Data for Lead reviewed by USEAP (1999b) and the Hazard Quotients described in this assessment, the probability of ecological risk from lead contaminated in sediment exposures in Pattani Dam Reservoir ecosystem is considerably high. A large numbers of people may be at risk through consumption of contaminated aquatic food, especially bivalve and fish living in the reservoir, and direct contact with contaminated water. In other words, increases in concentration of lead contaminated with increasing of the trophic levels of the Pattani Dam Reservoir ecosystem as a result of biomagnification might pose a significant risk to reservoir living resources as well as public health. Furthermore, lead may inhibit the bacterial degradation of dissolved organic matter (Roth; Zeh and Maier, 1992), an important role of self-purification process in most natural water.