Storage of sediment and nutrients in littoral zones of a shallow tropical reservoir: a case of Timah Tasoh Reservoir, Perlis, Malaysia

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Abstract Studies on nutrient transport in rivers is still in its infancy in Malaysia. This study investigates the effects of different land-use activities on the transport of nutrients and sediments into the Timah Tasoh Reservoir, northern Malaysia, during the low flood periods (January–June 2001). Nutrient retention and sedimentation were observed in the littoral zone of the reservoir resulting in suspended sediment concentrations (TSS) and nutrients being almost one third lower in the main body of the reservoir compared to the incoming sources. Nitrate concentrations were also reduced by 20%. Mean sedimentation rates in the reservoir were 300 mg day^{-1}, ranging from 120 mg day^{-1} in the middle of the reservoir to a maximum of 800 mg day^{-1} near the littoral zones.

Key words land use; nitrate; suspended sediment; Timah Tasoh Reservoir; Malaysia

INTRODUCTION

River pollution, contamination and thus water quality issues have received increased attention among scientists worldwide. Human activities such as urbanization, agricultural and industrial development change water pathways and the supply of materials to river systems (Peters *et al.*, 1997). Anthropogenic activities especially those related to agriculture often result in increased nitrate (NO_3) in the aquatic environment and nitrate is now considered to be a widespread pollutant in aquatic ecosystems. It is typical of nonpoint source pollution by agricultural and residential activities (Van Herpe & Troch, 2000). Over the past 10 years, many studies focusing on the effect of different agricultural land uses in catchment areas on stream-water nutrient concentrations have been reported (Nearing *et al.*, 1993; Edwards *et al.*, 1996; Jordan *et al.*, 1997).

The threat of degradation to river systems through land-use changes and other waste disposal activities is high in Malaysia. Moreover increased sediment and nutrient inputs to reservoirs may result in eutrophication of these water bodies. Given the number of dams in Malaysia that impounded agricultural catchments there are water quality concerns for these reservoirs.

Situated downstream of rivers draining several land-use types, Timah Tasoh is a typical Malaysian reservoir that is under threat of pollution from river inputs. This study was initiated to look at the effects of the diverse land-use activities in the upper catchment areas on nutrient and sediment transport into the reservoir and, to examine the function of wetlands fringing the reservoir in storing sediment and removing nutrients.

STUDY AREA

Timah Tasoh Reservoir (6°36′N; 100°14′E) (Fig. 1) is located approximately 13 km north of the town of Kangar near the Thailand border. At 29.1 m above sea level, the reservoir has a mean surface area of 13.33 km^2 and a capacity of about 40 million m^3. The reservoir receives inputs from two rivers, the Sg. Tasoh and the Sg. Pelarit, which have a combined catchment area of 191 km^2. These two rivers supply about 97 million m^3 of water into the reservoir annually. The area surrounding the reservoir and its upstream catchment includes mainly agricultural land such as rubber estates, sugar and timber plantations. The drowned area of the reservoir consisted of swamps and rubber estates before the dam was filled. The reservoir is shallow with the maximum depth of 10 m and submerged aquatic plants can be seen along the shoreline and shallow area. At present the main purpose of the reservoir is to supply water for domestic and industrial use but it is also used for irrigation and flood control.

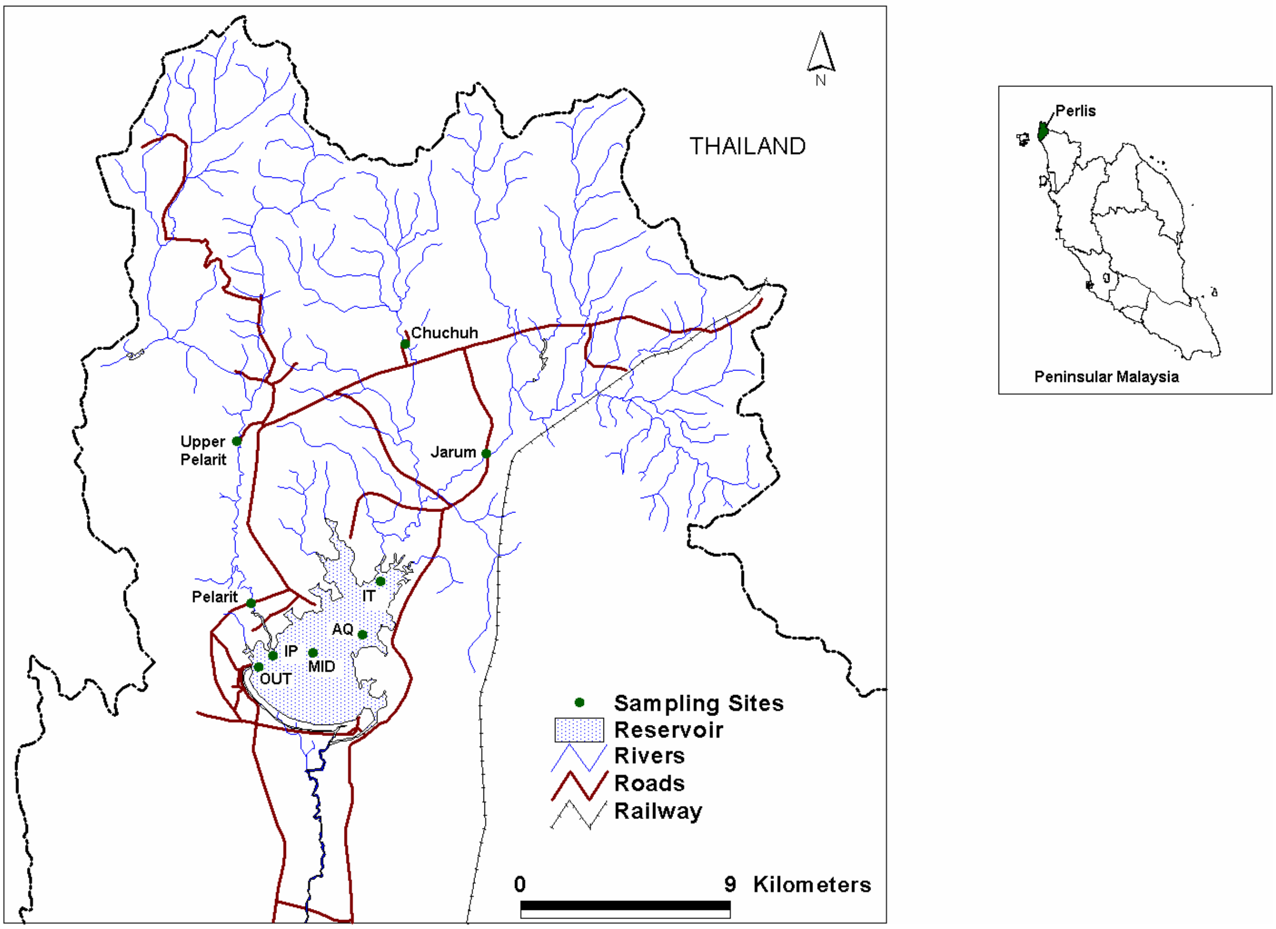

Fig. 1 Study sites showing sampling stations.

METHODS

Water samples were collected fortnightly at various sites in the reservoir and rivers and additional samples were taken during heavy precipitation. Dissolved oxygen was measured *in situ* using a YSI Model 58; total dissolved solids (TDS), conductivity and temperature measured using a Hach conductivity/TDS meter; and pH by a Cyberscan 20. Samples were collected with a 2-l Kemmerer water sampler and were kept cold (4°C) for the determination of nitrate-nitrogen and soluble reactive phosphorus (SRP). Prior to the determination of nitrate-nitrogen and soluble reactive orthophosphate, water samples were filtered through 0.45 μm membrane filters (Whatman). The nutrients were determined following APHA's (1989) recommendations: soluble reactive phosphorus (SRP, ascorbic acid) and nitrate plus nitrite (cadmium column; diazoic complex). Three replicates were performed for each parameter measured. Sedimentation in the reservoir was measured using an 80-mm-diameter PVC column suspended in the water using floats and anchored to the bottom of the reservoir with weights. The sediment trapped in the column was collected at monthly intervals and filtration was used to estimate the weight of the sediment.

RESULTS AND DISCUSSION

Hydrology

The annual rainfall distribution for the study area shows two distinct wet seasons; May and September–November (Fig. 2). Rainfall in May is approximately 200 mm month^{-1} while from September to November it is 280 mm month^{-1}. The average weekly precipitation during the study period was 28.04 mm, 18.7 mm and 24.0 mm at Tasoh, Pelarit and Jarum respectively. Between 11 February and 10 March 2001 no rainfall occurred in the catchment area (Fig. 3) resulting in a period of low flow to the reservoir (Fig. 3(b) and (c)). Only the rivers at Upper Pelarit and Jarum show continuous discharge within the study period while at Chuchuh there was no discharge on several sampling dates. The mouths of both the Tasoh and Pelarit rivers were stagnant during most of the study period except when there was a significant rainfall. This is because of the backwater effect which causes the water to stagnate most of the time when the reservoir is full.

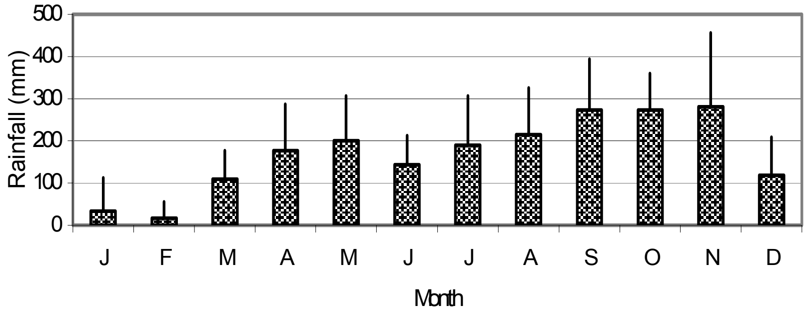

Fig. 2 Rainfall at Kaki Bukit north of the Timah Tasoh Reservoir 1975–1990.

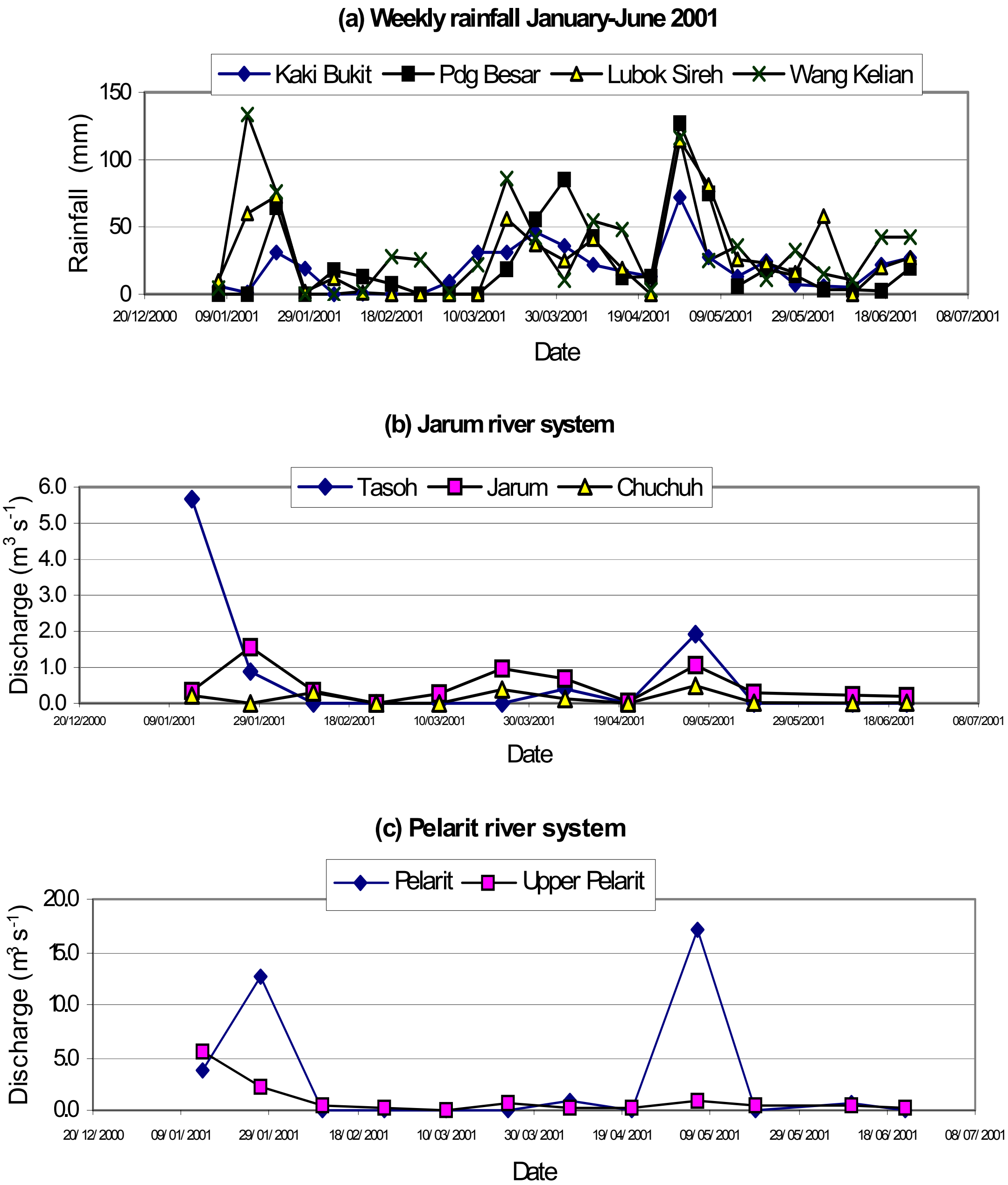

Fig. 3 Weekly rainfall in the catchment areas (a), discharge of the Jarum river system (b), discharge of the Pelarit river system (c).

A significant rain event that affected river discharge was recorded in the end of April and early May when a total of 72 mm rain was recorded at Kaki Bukit, 127 mm at Padang Besar and 114 mm at Lubok Sireh near Sg. Tasoh. The most significant effects were observed on the river discharge especially at Tasoh and Pelarit (Fig 3(b) and (c)).

Physical and chemical characteristics

The chemical and physical parameters measured are presented in Table 1. Dissolved oxygen (DO), specific conductance and pH were almost the same at all sites. The water was generally alkaline with pH ranging from 7.3 to 7.8. Alkalinity and pH are almost comparable between rivers and reservoir samples. Timah Tasoh catchments mostly consist of extensive limestone outcrops (Kamal Roslan & Che Aziz, 2001) particularly in the Pelarit catchment which would influence the pH value of the water. Dissolved oxygen was higher at Jarum and Pelarit because at these sites there is always flowing water in the river. A lower DO was observed in the Chuchuh River, which did not flow due to lack of rainfall. Water temperature varied slightly from about 25°C in the rivers to 30°C in the reservoir.

Turbidity was significantly high ($p < 0.05$) in the rivers, reflecting a high input of suspended sediment. The values tend to increase toward the river mouth and sharply decreased to about 10% in the reservoir. Suspended sediment concentrations were higher in the river (range: 22.6–26.2 mg l^{-1}) and river mouth (range: 35.5–39.9 mg l^{-1}), but lower in the reservoir (range: 12.5–22.3 mg l^{-1}) reflecting sediment retention and filtration of sediment by aquatic plant in the meandering section of the river and in the littoral zones.

Table 1 The average of physical and chemical parameters in Tasoh River, Pelarit River and Timah Tasoh Reservoir from January to June 2001.

	Tasoh River system:		Pelarit River	River mouth:		Reservoir	
	Jarum River	Chuchuh River	Upper Pelarit	Tasoh	Pelarit	Tasoh inlet	Pelarit inlet
Discharge ($m^3 s^{-1}$)	0.59 ± 0.56	0.15 ± 0.2	0.8 ± 1.5	0.68 ± 1.91	3.43 ± 6.78		
Dissolved oxygen (mg l^{-1})	6.2 ± 0.8	6.0 ± 0.5	5.4 ± 0.1	5.0 ± 0.3	6.5 ± 0.5	5.8 ± 0.5	5.6 ± 0.5
Water temperature (°C)	28.1 ± 1.1	25.8 ± 0.4	26.3 ± 0.1	27.3 ± 1.0	26.4 ± 0.6	30.2 ± 3.7	28.5 ± 0.1
pH	7.4 ± 0.1	7.3 ± 0.1	7.8 ± 0.1	7.3 ± 0.1	7.6 ± 0.1	7.6 ± 0.1	7.4 ± 0.1
Conductivity (mS cm^{-1})	0.3	0.2	0.3	0.2	0.3	0.2	0.2
Turbidity (FTU)	122.0 ± 12.0	275 ± 18.0	78.3 ± 13.2	211.0 ± 29.4	117.0 ± 8.0	28.0 ± 2.4	19.0 ± 1.6
PO_4-P (mg l^{-1})	0.06± 0.05	0.05± 0.07	0.03 ± 0.02	0.04± 0.04	0.02± 0.01	0.02 ± 0.02	0.02 ± 0.01
NO_3-N (mg l^{-1})	0.83 ± 0.45	0.46 ± 0.37	0.36 ± 0.13	0.50 ± 0.19	0.33 ± 0.16	0.12± 0.21	0.07 ± 0.03
TSS (mg l^{-1})	26.2 ± 12.0	25.9 ± 46.5	22.6 ± 42.7	39.9 ± 67.2	35.5 ± 74.3	22.3 ± 10.4	12.5 ± 8.60

FTU: Formazin Turbidity Unit.

Nutrients

Nitrate concentrations at different locations throughout the study area are given in Fig. 4. Most of the river input was almost three times higher than that recorded in the reservoir (see also Table 1). This could be attributed to a degree of filtration of the nutrient by the plants at the fringes of the reservoir as well as sedimentation. Nutrient concentration tends to decrease from the river toward the reservoir. Nitrate concentrations were also almost similar in the reservoir during the study. Nitrate concentrations in the rivers range between 0.36 and 0.83 mg l^{-1} and are significantly

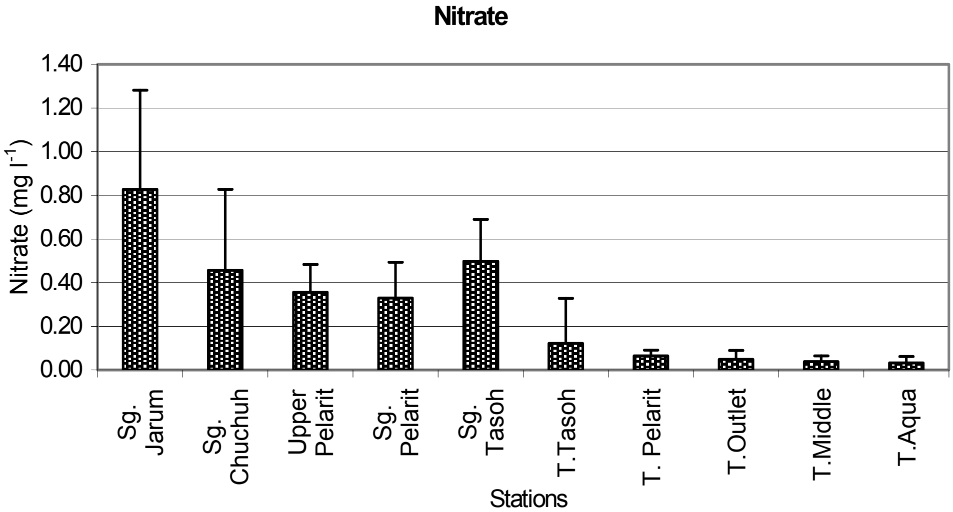

Fig. 4 Nitrate concentrations in the study period showing lower concentration in the reservoir samples.

higher ($p < 0.05$) than those in the reservoir which range from 0.07 to 0.12 mg l^{-1}. The fluctuation of nitrate concentration seems to follow the discharge pattern.

Phosphate concentrations were low, ranging from 0.02 to 0.06 mg l^{-1} in the rivers, and were roughly about 0.02 mg l^{-1} in the reservoir. High phosphate concentrations in the rivers coincided with occasional precipitation in January, March and May 2001, while in the reservoir the concentration was almost constant throughout the entire study period.

Reservoir sedimentation

High sedimentation rates were observed in the reservoir with a mean deposition rate of *c.* 300 mg day^{-1}, ranging from 120 mg day^{-1} in the middle of the reservoir to a

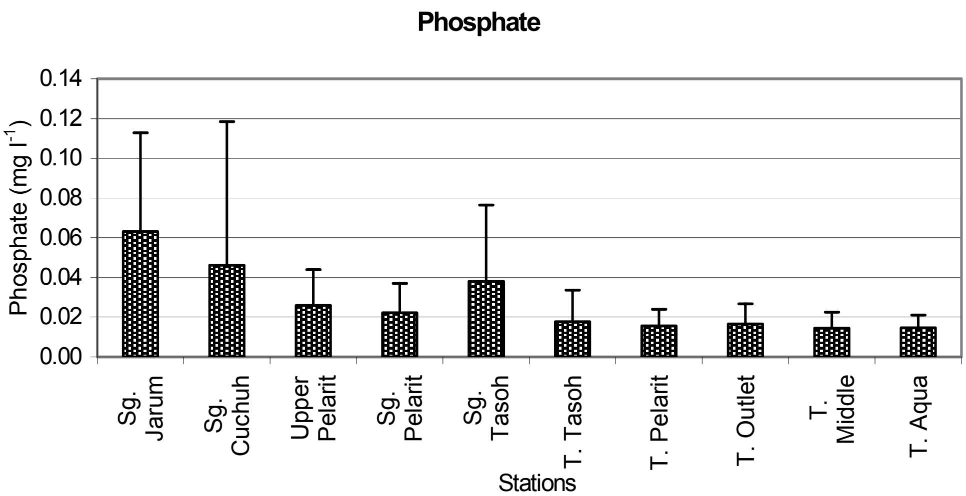

Fig. 5 Phosphate concentration during the study period showing lower concentration in the reservoir samples.

maximum of 800 mg day^{-1} near the littoral zones. There were three stations in the littoral zones (IP, IB and IT in Fig. 6) all of which showed a higher sedimentation rate compared with stations in the middle of the reservoir (e.g. MID, OUT and AQ shown in Fig. 1). This suggests that sediment and nutrients are deposited in the littoral zones thus maintaining good water quality in the reservoir (Wan Ruslan *et al.*, 2001).

Synthesis

The study shows that the Timah Tasoh Reservoir has the potential to receive large amounts of nutrients from rivers. However, due to lack of precipitation, some of the rivers have low discharges resulting in low nutrient input to the reservoir. Therefore, distinctly different concentrations of nutrients exist between the rivers and the reservoir. There is a nutrient gradient with the nutrient concentration highest in the rivers, followed by the river mouths and then lowest in the reservoir. The nutrients are transported towards the reservoir but once the flow in the river mouth is reduced as it encounters the larger water mass, the flow is not high enough to transport the nutrients into the reservoir. Consequently, there were reductions of about 20% and 30% in nitrate and phosphate concentrations respectively in the river mouth and further reductions of 30% and 40% in phosphate and nitrate concentrations in the reservoir.

Suspended sediment concentrations increased by almost 50% from the river to the river mouth and then reduced by 50–60% in the reservoir (Table 1). The reduction is possibly due to high sedimentation rates in the littoral zones (Fig. 6).This study has revealed that the area between the river mouth and reservoir is the main nutrient and sediment trap for the reservoir during low flow periods. However, this phenomenon may be different during wet periods when many rainfall events could trigger high flows capable of moving large amounts of nutrients and sediment into the reservoir.

Both nutrient and sediment concentrations are high in the rivers but low in the reservoir. There could be some retention en route and in the littoral zones before entering the main water body of the reservoir. Wetland plants as well as riparian vegetation along the rivers could be acting to trap nutrients and sediments before the water enters the reservoir. Proper management of the upper catchment areas should be able to reduce and keep the sediment loads at a minimum.

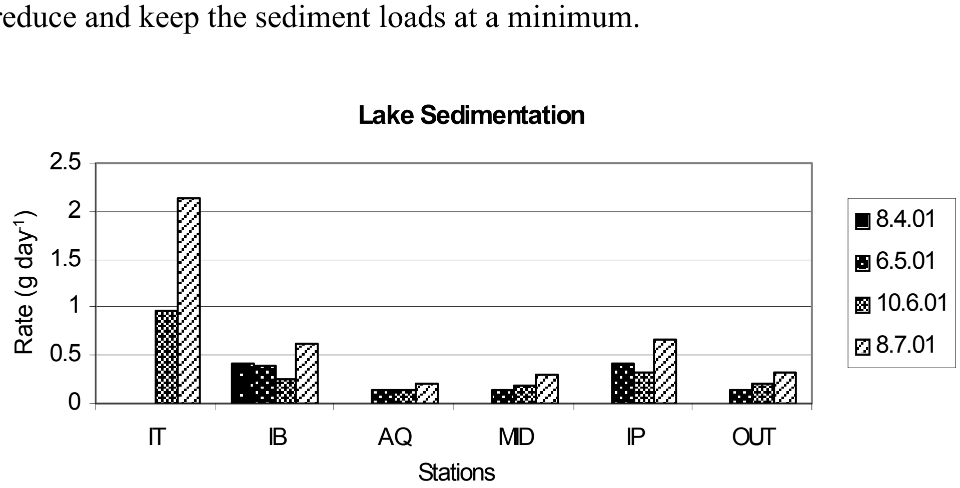

Fig. 6 Sedimentation rate (g day^{-1}) in the reservoir at various locations between April and July 2001.

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REFERENCES

APHA (1989) *Standard Methods for Examination of Water and Wastewater*, 17th edn. American Public Health Association, Washington, DC.

Edwards, D. R., Daniel, T. C., Scott, H. D., Murdoch, J. F., Habiger, M. J. & Burks, H. M. (1996) Stream quality impacts of best management practices in a northwestern Arkansas basin. *Wat. Resour. Bull.* **32**(3), 449–510.

Jordan, T. E., Correll, D. L. & Weller, D. E. (1997) Non point source discharges of nutrients from Piedmont Watershed of Chesapeake Bay. *J. Am. Wat. Resour. Ass.* **33**(3), 631–645.

Kamal Roslan Mohamed & Che Aziz Ali (2001) Geologi Kawasan Perlis Utara. In: *Kepelbagaian Biologi dan Pengurusan Taman Negeri Perlis: Persekitaran Fizikal dan Biologi Wang Kelian* (ed. by Faridah Hanum, I. & Kasim Osman dan A. Latiff), 79–96. Jabatan Perhutanan Perlis, Kangar, Perlis.

Nearing, M. A., Risse, R. M. & Rogers, L. F. (1993) Estimating daily nutrient fluxes to a large Piedmont Reservoir from limited tributary data. *J. Environ. Qual.* **22**, 666–671.

Peters, N. E., Buell, G. R. & Frick, E. A. (1997) Spatial and temporal variability in nutrient concentrations in surface waters of the Chattahoochee River basin near Atlanta, Georgia, USA. In: *Freshwater Contamination* (ed. by B. Webb) (Proc. Rabat Symp. April–May 1997),153–165. IAHS Publ. no. 243.

Van Herpe, Y. & Troch, P. A. (2000) Spatial and temporal variations in surface water nitrate concentrations in a mixed land-use catchment under humid temperate climatic conditions. *Hydrol. Processes* **14**, 2439–2455.

Wan Ruslan Ismail, Khairul Rizal A. B., Norhidayat, K., Zullyadini A. Rahaman & Ahyaudin B. Ali (2001) A preliminary study on the role of the littoral zone in maintaining water quality of tropical reservoir during periods of low flow: the case of Timah Tasoh Reservoir, Perlis, Malaysia. *Proc 9th Int. Conf. Conservation and Management of Lakes* (11–16 November 2001, Shiga, Japan). BIWAKO.