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Spatial and Temporal Variations of Water Quality and Trophic Status in Bukit Merah Reservoir, Perak

(Variasi Reruang dan Temporal Kualiti Air dan Status Trofik di Takungan Bukit Merah, Perak)

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ABSTRACT

A study of spatial and temporal variations on water quality and trophic status was conducted twice a month from December 2012 to January 2014 in four sampling stations at Bukit Merah Reservoir (BMR). The concentration of dissolved oxygen (DO), water temperature, conductivity, total dissolved solids (TDS), total phosphorous (TP), PO_4^-, NO_2^-, NO_3^-, NH_4^+ and net primary productivity had significant differences temporally ($p<0.05$*) except for pH, total suspended solids (TSS) and chlorophyll-*a*. Based on correlation analysis, the amount of rainfall and rain days has negatively correlated with secchi depth and chlorophyll-*a *(*$p<0.01$*). The water level has significantly decreased the value of the temperature, pH, conductivity, TP and NO_2^- but it has positive correlation with NO_3^- and NH_4^+. Discharged from Sungai Kurau increased the value of conductivity, TSS, TP and NO_2^- as a result from runoff and erosion, thus decreasing the secchi depth values, NO_3^- and NH_4^+. The water quality of BMR is classified in Class II and TSI indicates that the BMR has an intermediate level of productivity (mesotrophic) and meets the objective of this reservoir which was to provide water for paddy irrigation.*

Keywords: Bukit Merah reservoir; reservoir; trophic status; water quality

ABSTRAK

Suatu kajian variasi reruang dan temporal ke atas kualiti air dan status trofik telah dijalankan dua kali sebulan dari Disember 2012 sehingga Januari 2014 di empat stesen persampelan Takungan Bukit Merah (BMR). Kepekatan oksigen terlarut (DO), suhu air, konduktiviti, jumlah pepejal terlarut (TDS), jumlah fosforus (TP), PO_4^-, NO_2^-, NO_3^-, NH_4^+ dan nilai bersih produktiviti primer berbeza secara signifikan mengikut temporal ($p<0.05$*) kecuali pH, jumlah pepejal terampai (TSS) dan klorofil-*a*. Berdasarkan analisis korelasi, jumlah hujan dan hari hujan berkorelasi secara negatif dengan kedalaman secchi dan klorofil-*a *(*$p<0.01$*). Aras air secara signifikan menurunkan nilai suhu, pH, konduktiviti, TP dan NO_2^- tetapi ia berkorelasi secara positif dengan NO_3^- dan NH_4^+. Pelepasan dari Sungai Kurau meningkatkan nilai konduktiviti, TSS, TP dan NO_2^- akibat daripada air larian dan hakisan, lalu merendahkan nilai kedalaman secchi, NO_3^- dan NH_4^+. Kualiti air dikelaskan sebagai Kelas II dan TSI menunjukkan bahawa BMR mempunyai aras produktiviti pertengahan (mesotrofik) dan memenuhi objektif takungan iaitu membekalkan air untuk pengairan padi.*

Kata kunci: Kualiti air; status trofik; takungan; takungan Bukit Merah

INTRODUCTION

The roles of reservoirs to human life are vital because of the increasing demand of fresh water and the recurring and unpredictable droughts and floods that impact most of the states in Peninsular Malaysia (Bond et al. 2008). The variations of water quantity and water quality depend on types of aquatic ecosystems (e.g. regulated rivers, unregulated rivers, urban streams, ephemeral streams, estuaries, marine, lakes and wetlands) and natural factors such as climate, topography and catchment geology. The quality of water resources is declining from both natural (changes in precipitation; erosion) and anthropogenic (industrial and agricultural activities) factors (Sheela et al. 2012). In addition, all reservoirs are subjected to periodic fluctuations in water levels, due to rain, hydrological regimes that are influenced by irrigation of agricultural lands and temperature changes (Duncan & Kubečka 1995). Moreover, clearance of catchment land use and water extraction modifies the natural flow and associated water quality characteristics. Recently, catchment areas of the Bukit Merah Reservoir (BMR) experience lots of change in land uses due to population growth and economic expanding. For example, excessive water withdrawals, water diversions from the catchment area, lake reclamation for agriculture (oil palm and rubber plantations) of the BMR catchment areas and sand mining near Sungai Kurau mouth can significantly reduce the volume of water in the reservoir and destroying habitats for flora and fauna (Ismail & Najib 2011).

In 2009, 1063 water quality monitoring stations were located at 577 water bodies in Malaysia, out of which 54% of the water bodies were found to be clean, 36%

were classified under the 'slightly polluted' condition and the remaining 10% were considered polluted (Akinbile et al. 2013; DOE 2009). Thus, this study will determine the temporal (average reading by month) spatial (sampling stations) variations of water quality in Bukit Merah Reservoir (BMR) and to evaluate the trophic status of this reservoir.

MATERIALS AND METHODS

Bukit Merah Reservoir (BMR), a modified homogeneous embankment which was built in 1902 and operated in 1906, is one of the oldest man-made reservoirs in Peninsular Malaysia and located in the district of Kerian, Perak (Ismail & Najib 2011). The water sources came from the confluence of two main catchment areas namely, Merah and Sungai Kurau Basin, including several tributaries: Sungai Ara, Sungai Jelutong and Sungai Selarong that link up with the basin. The main purposes of BMR were to provide irrigation water for double cropping to 24000 ha of paddy land under the Krian Irrigation Scheme, domestic and industrial water supply and source of income for the local fishermen. BMR also famous as northern lakefront resort and water park (Bukit Merah Laketown Resort) that support ecotourism. The reservoir is also recognized as a sanctuary for a commercially valuable fish, the Asian Arowana, *Scleropages formosus* (Mohd Shafiq et al. 2014). The main land uses of BMR include of virgin and primary forest (46.29%), agriculture (palm oil plantation) and a breeding farming industry (national Boer breeding centre) for economical purposes (42.80%) (Hasan et al. 2012; Siti Hidayah 2012).

The BMR is located at 05°01'35.42" N, 100°39'42.92" E and it is formed by the construction of a dam in the middle of Sungai Kurau. Four sampling stations (S1, S2, S3 and S4) were established within the reservoir area (Figure 1). All the descriptions and locations are described in Table 1.

MEASUREMENT OF PHYSICO-CHEMICAL PARAMETERS AND PRIMARY PRODUCTIVITY

In situ physico-chemical readings were taken in two replicates twice monthly (week two and four) at each sampling station. Dissolved oxygen (DO), temperature (°C), conductivity (µS/cm) and total dissolved solids (TDS) were measured using the YSI meter (Model 556MPS), pH of the water was measured using a Hach Sension 1 m and water clarity was measured by using a secchi disc and measuring tape. For primary productivity measurement, light and dark bottle technique was used according to Cole (1983) and calculated according to the following equation:

Net productivity (mg C/ L/ h)

$$Pn = (LB - IB) \times 0.375 / (PQ \times t),$$

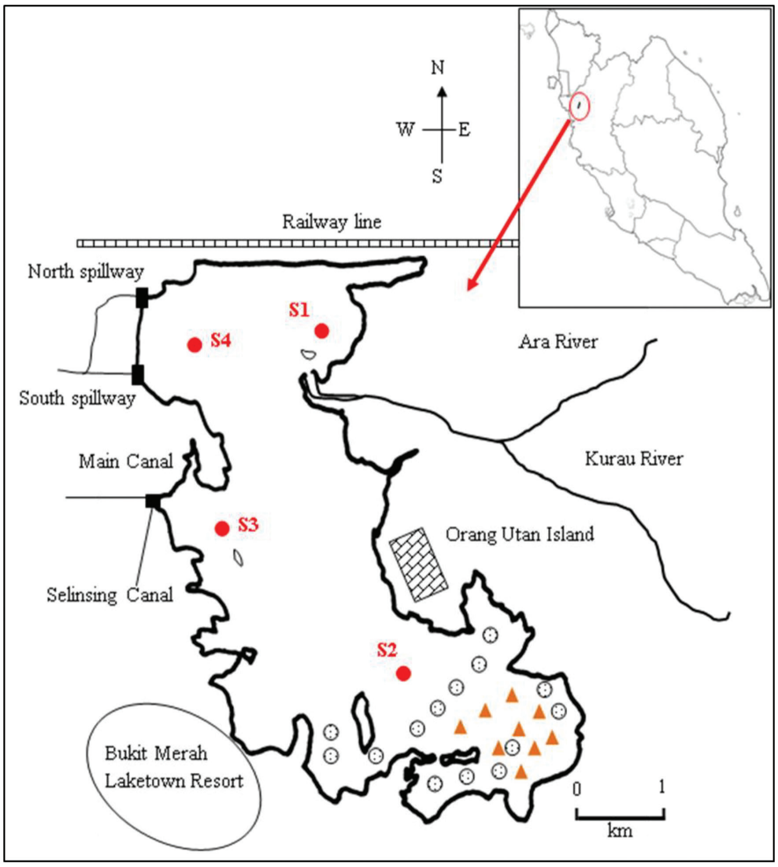


FIGURE 1. Sampling station locations (S1 – S4) of Bukit Merah Reservoir, Perak, Malaysia ◌ = submerged vegetation (*Cabomba* sp.); ▲ = dead tree

TABLE 1. General characteristics of sampling stations with coordinates in Bukit Merah Reservoir

Name of station	Approximate sampling location	Description of station
S1	5°1'56.40"N 100°40'4.3"E	This station is located at the Inlet of Sungai Kurau Basin and near railway line (Plate 3.1). Riparian vegetation consists of *Hanguana malayana* and grass
S2	4°59'48.00"N 100°41'14.5"E	This station is located near the Orang Utan Island. There were many dead trees and submerged vegetation such as *Cabomba* sp. (Plate 3.2). Riparian vegetation consists of *Hanguana malayana*
S3	5°1'4.20"N 100°39'20.30"E	This station is near Intake of the reservoir and Bukit Merah Laketown Resort (Plate 3.3). Riparian vegetation consists of *Hanguana malayana*
S4	5°1'52.1"N 100°39'12.30"E	This station is located near spillway of the reservoir (Plate 3.4). Riparian vegetation consists of *Hanguana malayana*

where LB is the concentration of oxygen in light bottle (mg/L); IB is the initial concentration of light bottle; PQ is the photosynthetic quotient (assumed to be 1.2); t is the hours of incubation; and 0.375 is the molecular weight ratio of carbon to oxygen gas. Monthly hydrological data such as rainfall, rain days, water discharge and mean water level were provided by the Department of Irrigation and Drainage (DID) from December 2012 to January 2014.

NUTRIENT SAMPLE COLLECTION AND ANALYSIS

Water samples were collected at approximately one meter depth from the boat in two 1 L HDPE bottles. All samples were stored at 4°C on ice packs after collection. Nutrient samples were delivered to the laboratory and stored in a refrigerator within the 48 h. Laboratory analysis for total suspended solids (TSS), total phosphorous (TP), orthophosphate (PO_4^-), nitrite (NO_2^-), nitrate (NO_3^-), ammonia nitrogen (NH_4^+) and chlorophyll-*a* was completed by following the method of Adams (1991).

STATISTICAL ANALYSIS

The DO, temperature, conductivity, total dissolved solids (TDS), pH, secchi depth values, primary productivity, TSS, TP, PO_4^-, NO_2^-, NO_3^-, NH_4^+ and chlorophyll-*a* were $\log_{10}$ (× +1) transformed to stabilize the variance for statistical comparison analysis and subjected to Shapiro-Wilk test to determine the normality of their distributions based on two factors, temporal and spatial. Comparisons of temporal and spatial variations of each data were made using one-way ANOVA (parametric test) and Kruskal-Wallis (non-parametric test) using SPSS 11.5 (Coakes et al. 2006). Correlation analysis was carried out to determine the relationship between hydrological units (rainfall, rain days, discharge and water level) and all parameters.

CARLSON'S TROPHIC STATE INDEX (TSI)

The level of eutrophication can be determined by the trophic state index (TSI). Transparency (measured by secchi depth), total phosphorous (TP) and chlorophyll-*a* concentrations are used in estimating trophic status and one of the most commonly used is Carlson's Trophic State Index (TSI) (Carlson 1977) with the formula:

$$\text{TSI (SD)} = 60 - 14.41 \ln(\text{SD})$$

$$\text{TSI (Chl-}a) = 9.81 \ln(\text{Chl-}a) + 30.6$$

$$\text{TSI (TP)} = 14.42 \ln(\text{TP}) + 4.15$$

$$\text{TSI} = \frac{[\text{TSI}(\text{TP}) + \text{TSI}(\text{Chl}-a) + \text{TSI}(\text{SD})]}{3}$$

Oligotrophic = TSI < 40
Mesotrophic = 40 < TSI < 50
Eutrophic = TSI > 50

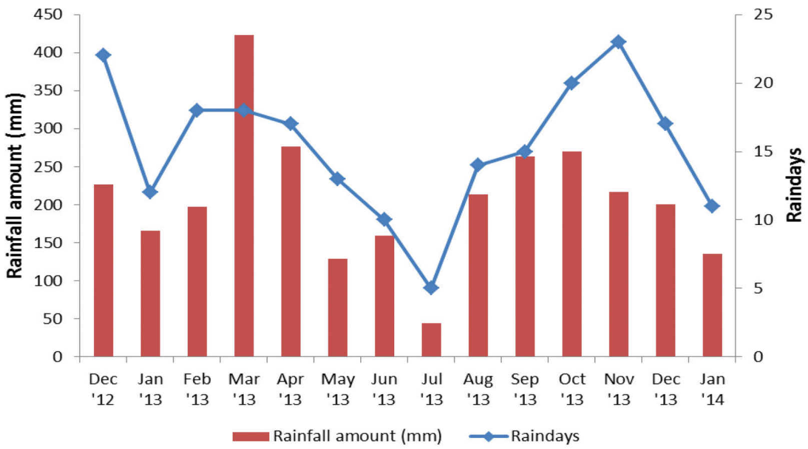
RESULTS

HYDROLOGICAL DATA

Figure 2 shows the fluctuations of rainfall data, mean water level based on reservoir level (RL) and water flow of the BMR that was supplied by the Department of Irrigation and Drainage (DID). The highest rainfall amount was recorded in March 2013 (423.5 mm) while the lowest amount was recorded in July 2013 (44 mm). Based on rainy days, the highest occurrence was recorded in November 2013 (23) while in July 2013 the rainy days were the least (5). River discharge that was recorded at the Inlet of Sungai Kurau has increased from April to May 2013 and September to November 2013, ranging from 4.32 to 9.38 m^3/s while other months were ranged from 0.66 m^3/s (December 2013) to 2.26 m^3/s (June 2013). The reservoir had the lowest mean water level based on RL with the value of 6.71 m (June 2013) and the highest was recorded in February 2013 (8.86 m).

TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL AND NUTRIENT ANALYSES

Figures 3 and 4 show average readings of all sampling stations by month of physico-chemical and nutrient



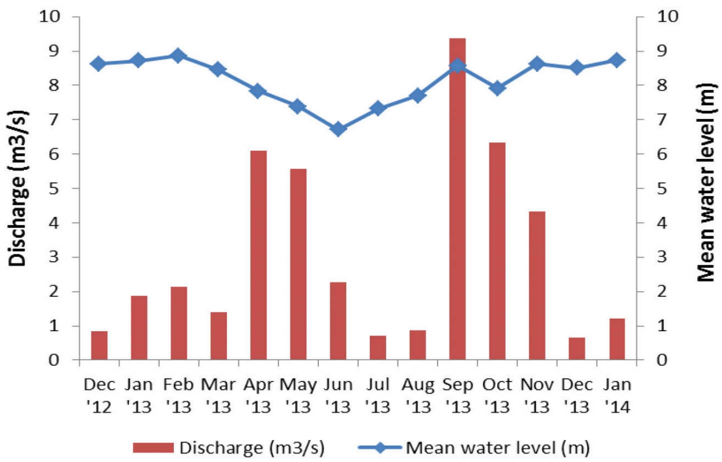


FIGURE 2. Temporal variations of actual rainfall data (above), water discharge from the Inlet of Sungai Kurau and mean water level (below) of Bukit Merah Reservoir, Malaysia. Data were obtained from the Kerian Department of Irrigation and Drainage

parameters of the BMR. Mean concentration of DO ranged from 5.3 ± 0.501 to 6.71 ± 0.239 mg/L, which the values had significant difference among months (F (11,33) = 5.57, p< 0.05) (Figure 3). Mean water temperature had the lowest values of 24.7 ± 0.349°C and 25.2 ± 0.781°C, respectively, while other months had less variation in the values, ranging between 27 ± 0.8°C and 30.6 ± 0.204°C. The mean water temperature had significant difference of F (11,33) = 6.122, p < 0.05 (Figure 3).

Mean values of pH had no significant difference as the values were consistent every month (5.8 ± 0.135 – 8.0 ± 0.153) (Figure 3). Water conductivity values has significant differences between December 2012 and March 2013; and April 2013 and January 2014 (Kruskal-Wallis χ^2 = 30.34, p < 0.05) where the values increase from 16.0 ± 0.408 to 26.3 ± 0.854 μS/cm. Mean TDS had significant difference among months although the values did not vary much (13.75 ± 0.35 – 15.5 ± 0.5 mg/L) (Figure 3).

Water clarity based on secchi depth value was inconsistent every month, with the lowest light penetration was recorded in June 2013 (0.18 ± 0.016 m) and the deepest light penetration was recorded in February 2013 (0.87 ± 0.12 m), thus the variation of the light availability was significant (F (11,33) = 3.348, p < 0.05) (Figure 3). The TSS concentrations has no significant differences among months (F (11,33) = 1.283, p > 0.05). The mean concentrations reached the peak in April and September 2013 with the values of 31.67 ± 14.607 and 22.67 ± 4.514 mg/L, respectively. Other values ranged from 6.50 ± 0.645 (February 2013) to 18.90 ± 12.945 mg/L (March 2013). There was a significant difference in the mean concentration of TP between December 2013 and September 2013 (0.0452 ± 0.0006 and 0.092 ± 0.0087 mg/L, respectively). Generally, mean concentrations for all nutrient parameters had significant values temporally (p < 0.05) (Figure 4). Mean concentration of orthophosphate

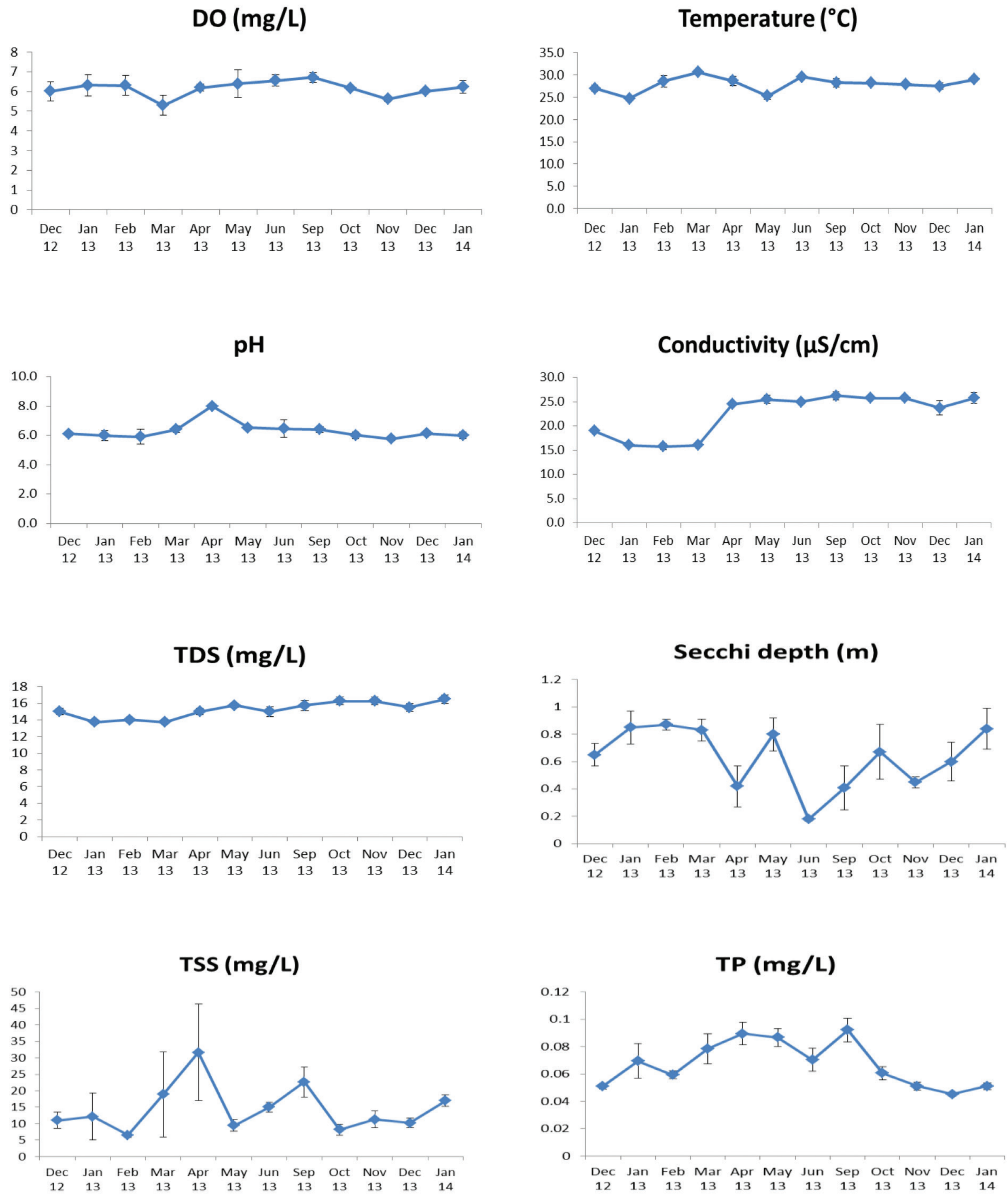


FIGURE 3. The average reading of all sampling stations by month (± s.e) of physico-chemical parameters such as DO, temperature, pH, conductivity, TDS, secchi depth, TSS and TP of Bukit Merah Reservoir, Malaysia

(PO_4^-) was higher in January, February, June, September and December 2013 (0.047 ± 0.0008 mg/L, 0.047 ± 0.0008 mg/L, 0.0463 ± 0.008 mg/L, 0.0473 ± 0.0044 mg/L and 0.0452 ± 0.0006 mg/L, respectively) (Figure 4). Mean concentration of NO_2^- increased drastically in February and October 2013 with the value of 0.0077 ± 0.0002 mg/L and 0.0075 ± 0.0006 mg/L, respectively, from 0.0021 ± 0.0006 mg/L (January 2013) and 0.0048 ± 0.0003 mg/L (September 2013). The lowest mean concentration was recorded in December 2013 (0.0017 ± 0.0006 mg/L). The mean concentrations of NH_4^+ showed descending trends from January to October 2013 with the highest mean value recorded in January 2013 (0.1215 ± 0.018 mg/L) while the lowest was recorded in October 2013 (0.058 ± 0.003 mg/L) (Figure 4). However, there was an uneven pattern showed by the mean concentration of NO_3^-, they ranged between 0.047 ± 0.0018 mg/L (June 2013) and 0.093 ± 0.013 mg/L (January 2013). The mean concentration of chlorophyll-*a* was less varied, ranging from 0.1192 ± 0.001 µg/L (December 2012) to 0.2069 ± 0.0655 µg/L (February 2013), resulting in no significant difference among months ($p > 0.05$). The net primary productivity was raised in February 2013 (0.0964 ± 0.0075 mgC/L/h) before it fell to 0.0117 ± 0.0024 mgC/L/h in April 2013 and raised again in May 2013 (0.0742 ± 0.0205 mgC/L/h), resulting in a significant difference among months (F (11,33) = 8.580, $p < 0.05$) (Figure 4).

SPATIAL VARIATIONS OF PHYSICO-CHEMICAL AND NUTRIENT ANALYSES

Table 2 shows the spatial of physico-chemical and nutrient parameters from four sampling stations of the BMR. Mean concentration of DO content in the water oscillated between 5.451 ± 2.483 mg/L (S2) and 5.904 ± 0.236 mg/L (S3). The homogeneous values of this parameter resulted to no significant difference among sampling stations ($p > 0.05$). Mean water temperature showed no significant difference among sampling stations ($p > 0.05$). The lowest value of water temperature was 26.68 ± 0.469°C (S1) while the highest value was recorded in S4 (27.582 ± 0.336°C). Mean water pH showed less variation from 6.222 ± 0.162 (S4) to 6.573 ± 0.166 (S2) with no significant difference among sampling stations ($p > 0.05$). Mean water conductivity and TDS were low with a range of between 22.533 ± 0.712 µS/cm and 15.3 ± 0.378 mg/L to 23.167 ± 0.805 µS/cm and 15.9 ± 0.205 mg/L, respectively, resulting in no significance difference among sampling stations ($p > 0.05$) There was a significance increase of the TSS as

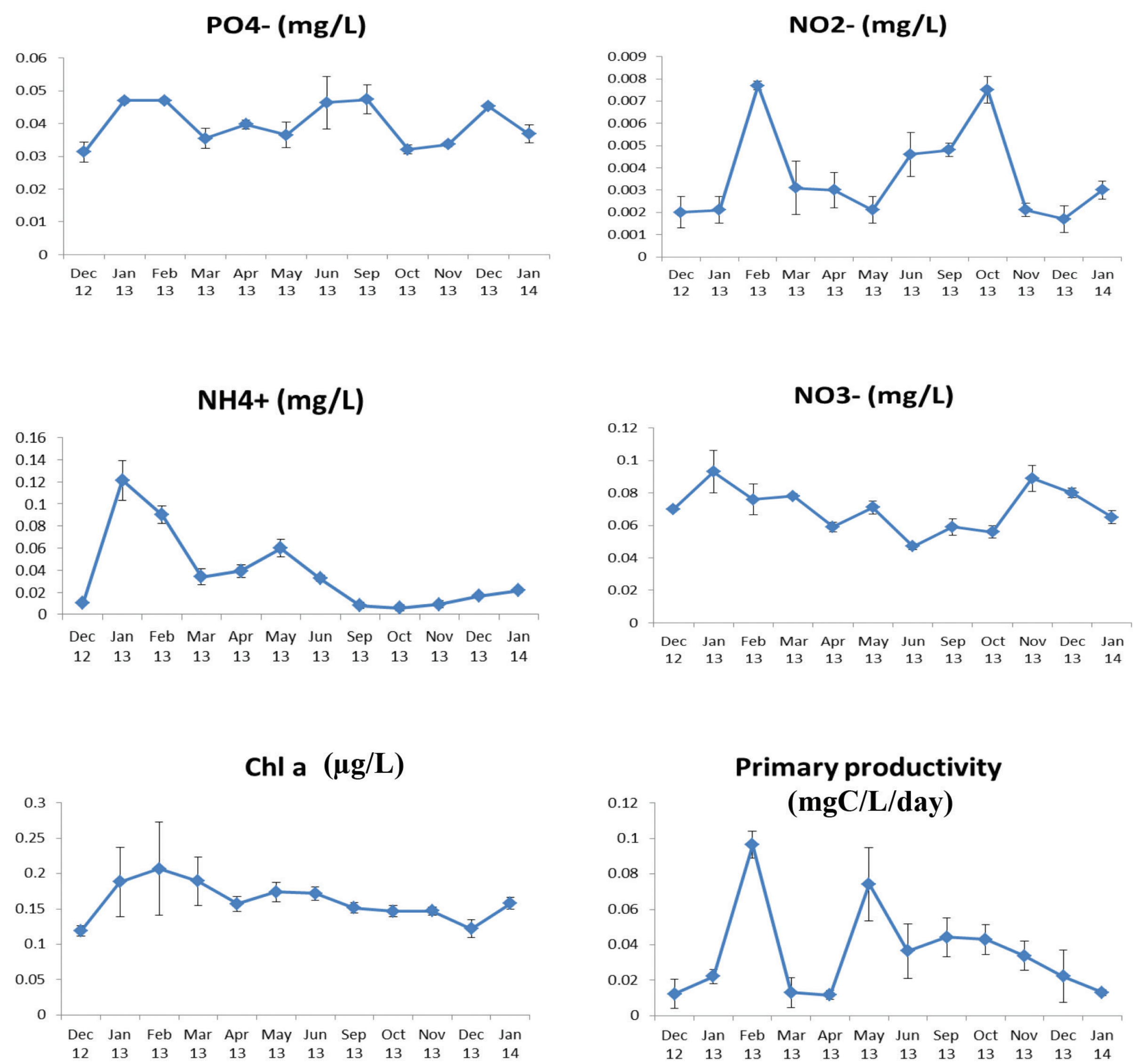


FIGURE 4. The average reading of all sampling stations by month (± s.e) of PO_4^- (mg/L), NO_2^- (mg/L), NO_3^- (mg/L), NH_4^+ (mg/L), chlorophyll-*a* (μg/L) and net primary productivity (mgC/L/day) of Bukit Merah Reservoir, Malaysia

TABLE 2. Spatial of physico-chemical and nutrient parameters (mean ± s.e.) with their range (minimum – maximum) from four sampling stations of the BMR

	S1	S2	S3	S4
DO (mg/L)	5.837 ± 0.283	5.451 ± 2.483	5.904 ± 0.236	5.687 ± 0.257
Range (min – max)	(4.6 – 8.6)	(4.3 – 8.2)	(4.82 – 7.9)	(4.03 – 8.02)
Temperature (°C)	26.68 ± 0.469	27.539 ± 0.433	27.38 ± 0.406	27.582 ± 0.336
Range (min – max)	(21.6 – 31.2)	(23.4 – 27.1)	(22.8 – 30.8)	(23.9 – 30.5)
pH	6.27 ± 0.157	6.573 ± 0.166	6.301 ± 0.169	6.222 ± 0.162
Range (min – max)	(5.19 – 8.27)	(4.5 – 8.5)	(5.1 – 8.4)	(5.2 – 8.0)
Conductivity (μS/cm)	23.167 ± 0.805	22.6 ± 0.846	22.767 ± 0.95	22.533 ± 0.712
Range (min – max)	(16 – 29)	(15 – 32)	(14 – 29)	(16 – 27)
TDS (mg/L)	15.9 ± 0.205	15.3 ± 0.378	15.5 ± 0.283	15.533 ± 0.14
Range (min – max)	(14 – 19)	(13 – 24)	(12 – 18)	(14 – 19)
TSS (mg/L)	19.18 ± 3.765	8.58 ± 0.978	9.81 ± 1.093	12.23 ± 1.274
Range (min – max)	(3 – 75)	(2 – 15)	(3 – 20)	(4 – 24)
Secchi depth (cm)	37 ± 4.953	79.65 ± 7.171	75.019 ± 6.834	61.75 ± 6.993
Range (min – max)	(11 – 74)	(11 – 107)	(21 – 109)	(19 – 105)
TP (mg/L)	0.0777 ± 0.04	0.0649 ± 0.003	0.0672 ± 0.003	0.0693 ± 0.003
Range (min – max)	(0.044 – 0.109)	(0.042 – 0.107)	(0.044 – 0.105)	(0.04 – 0.103)
PO_4^- (mg/L)	0.0454 ± 0.002	0.0405 ± 0.001	0.0399 ± 0.001	0.0353 ± 0.002
Range (min – max)	(0.034 – 0.072)	(0.026 – 0.052)	(0.03 – 0.048)	(0.025 – 0.059)
NO_2^- (mg/L)	0.004 ± 0.414	0.0031 ± 0.462	0.0026 ± 0.336	0.0038 ± 0.4
Range (min – max)	(0.001 – 0.009)	(0.006 – 0.009)	(0.003 – 0.007)	(0.008 – 0.009)
NO_3^- (mg/L)	0.074 ± 3.725	0.065 ± 3.151	0.064 ± 2.987	0.069 ± 3.66
Range (min – max)	(0.074 – 0.126)	(0.039 – 0.098)	(0.039 – 0.104)	(0.035 – 0.103)
NH_4^+ (mg/L)	0.055 ± 8.957	0.031 ± 4.377	0.036 ± 6.693	0.041 ± 6.268
Range (min – max)	(0.013 – 0.19)	(0.003 – 0.085)	(0.003 – 0.145)	(0.003 – 0.145)
Chlorophyll-*a* (μg/L)	0.1378 ± 0.005	0.2011 ± 0.013	0.1671 ± 0.006	0.1376 ± 0.006
Range (min – max)	(0.086 – 0.168)	(0.114 – 0.39)	(0.107 – 0.232)	(0.084 – 0.225)
Net primary productivity (mgC/L/day)	0.0301 ± 0.012	0.0298 ± 0.011	0.0294 ± 0.012	0.0223 ± 0.011
Range (min – max)	(0.012 – 0.115)	(0.017 – 0.083)	(0.015 – 0.11)	(0.013 – 0.11)
TSI	51	48	47	48

the distance from the inlet decrease (Kruskal-Wallis $\chi^2 = 11.302$, $p < 0.05$). The mean concentration of TSS was higher in S1 (19.18 ± 3.765 mg/L) than in S2 (8.58 ± 0.978 mg/L). In contrast, secchi depth in S2 (79.65 ± 7.171 cm) was significantly higher than the Inlet of Sungai Kurau, S1 (37 ± 4.953 cm) (Kruskal-Wallis $\chi^2 = 19.466$, $p < 0.05$). Nutrient analyses showed that the mean concentration of PO_4^-, NO_2^- and chlorophyll-*a* had significant different among sampling stations ($p < 0.05$) except for TP, NO_3^-, NH_4^+ and net primary productivity ($p > 0.05$). The highest mean concentration of TP, PO_4^-, NO_2^-, NO_3^-, NH_4^+ and net primary productivity was recorded in S1 (0.077 ± 0.04, 0.0454 ± 0.002, 0.004 ± 0.414, 0.074 ± 3.725, 0.055 ± 8.957 and 0.0301 ± 0.012 mgC/L/h, respectively), indicating that these concentrations has been influenced by the catchment areas. Trophic state index (TSI) of all sampling stations were considered as mesotrophic with the score ranged between 47 (S2) and 51 (S1).

Based on correlation analysis (Table 3), the amount of rainfall and rain days has positively correlated with river discharge ($r = 0.433$, $p < 0.01$) but they had negatively correlated with secchi depth ($r = -0.383$, $p < 0.01$) and chlorophyll-*a* ($r = -0.262$, $p < 0.01$) (Table 3). The water level had significantly decreased the value of the temperature, pH, conductivity, TP and NO_2^- in the reservoir with the correlation values (r) of -0.281, -0.458, -0.463, -0.288 and -0.572, respectively and it had positive correlation with NO_3^- ($r = 0.359$, $p < 0.01$) and NH_4^+ ($r = 0.338$, $p < 0.01$) (Table 3). Discharged from Sungai Kurau increased the value of conductivity ($r = 0.400$), TSS ($r = 0.290$), TP ($r = 0.306$) and NO_2^- ($r = 0.308$) as a result from runoff and erosion, thus decreasing the secchi depth values ($r = -0.444$), NO_3^- ($r = -0.304$) and NH_4^+ ($r = -0.280$).

DISCUSSION

Almost all lowland reservoirs are irrigation reservoirs and their hydrological regimes are significantly influenced by irrigation of agricultural lands (Sahoo & Smith 2009). The BMR is subjected to periodic fluctuations in water levels, due to rain, temperature changes and how they are operated for their functional role. There was no stratification occurred in the BMR due to its shallowness (< 5m) and short retention time resulted from development cycle of

TABLE 3. Correlation between physico-chemical parameters and nutrients of the BMR. All parameters were analysed using Pearson correlation. (**) = Correlation is significant at $p < 0.01$ level

	Raindays	Rainfall	Water level	Discharge	DO	Temp.	pH	Cond.	TDS	Secchi depth	TSS
Raindays		0.567**		0.433**						-0.383**	
Rainfall											
Water level						-0.281**	-0.458**	-0.463**			
Discharge								0.400**		-0.444**	0.290**

TABLE 3. *Continued*

	TP	PO_4^-	NO_2^-	NO_3^-	NH_4^+	Chl-*a*	Pn
Raindays						-0.262**	
Rainfall							
Water level	-0.288**		-0.572**	0.359**	0.338**		
Discharge	0.306**		0.308**	-0.304**	-0.280**		

the rice crops imposes a regular pattern of variation in reservoir volume and depth (Duncan & Kubečka 1995; Kah Wai & Ali 2001).

The DO concentrations in the BMR were in Class II based on Water Quality Index (WQI) and lie within the optimum level of fish health (> 5 mg/L), though it had fluctuated during the study (Alabaster & Lloyd 1982; DOE 2009; Jain et al. 1977; Othman et al. 2002). The DO concentration in the BMR was regulated by the process of diffusion of oxygen from the atmosphere, photosynthetic activity, respiration and decomposition of aquatic organisms (Mollah et al. 2011). There was no significant difference in the concentration of DO among sampling stations because of the same water bodies and geographical area. The primary production in tropical reservoirs is normally within the range of one to five gmC/L/day (Costa & de Silva 1978; Sreenivasan 1974). Thus, the primary productivity in this reservoir was low throughout the study period (0.012 mgC/L/day).

The water temperature in the BMR was consistent throughout the year and between stations, although a drop in the temperature was observed in certain months. Cloudy and rainfall that occurred during the sampling influenced the reading of the water temperature (Pedrazzi et al. 2013). Similar water bodies and geographical area are the reason of less variation in the water temperature among sampling stations (Sreenivasan 1974). The shallowness of the water (3 - 5 m) and wind mixing result in no vertical stratification of the water during the study period (Kah Wai & Ali 2001). The values of pH for both spatial and temporal were consistent throughout the study, fell around six to seven (neutral) hence suitable for most aquatic organisms. Generally, pH is almost the same in every layer of the BMR due to shallowness of the reservoir (DOF 1993; Sarnita 1976). pH is a very important factor of water body for the fish culture as it controls the amount of soluble ions in the water (Mollah et al. 2011). An acidic pH of water reduces the growth rate, metabolic rate and other physiological activities of fishes (Swingle 1967), thus suggested that pH values varying from 6.5 to 9.0 as suitable for the normal growth of fishes. Range for pH values during the present study is classified in Class II, desirable for municipal uses (Akinbile et al. 2013).

Based on the results, water discharge from Sungai Kurau had positively correlated with the concentrations of TP, NO_2^-, water conductivity, TSS and TDS indicates that most of the nutrient concentrations, dissolved and particulate substances in the BMR derived from the catchment basin sources or known as allochthonous input while the remaining sources came from within the reservoir (autochthonous). In addition, the highest concentration values of conductivity, TDS, TP, PO_4^-, NO_2^-, NO_3^- and NH_4^+ that were recorded in S1 prove that the catchment basin plays an important role in influencing the water quality in the BMR. These results were supported by the previous studies, claiming that 93% of the sediment input and nutrients came from Sungai Kurau (Hasan et al. 2012; Ismail & Najib 2011; Shuhaimi-Othman et al. 2010). Higher flow rates can support a higher concentration of suspended solids, which mean the higher the flow volume, the more it will carry the sediment load from the river into the reservoir (Chapman 1996; Meybeck et al. 1990). Dissolved solids present in clay and limestone soils could directly influence water conductivity (Lawson 2011). Most of the suspended sediment including nutrients present in water bodies come from runoff and erosion (Durand et al. 1994; Hasan et al. 2012; Stottlemyer & Troendle 1992). Erosion can influence water quality because it is a major source of sediment, nutrients and pesticides in water from catchments areas (Baker 2003; Prosser et al. 2003; Quinn et al. 1997). Soil erosion that caused by land development, either from agricultural or construction, disturbs and loosens soil, often has a higher concentration of nutrients and dissolved solids that can influence conductivity (Durand et al. 1994; Hasan et al. 2012; Meybeck et al. 1990; Prosser et al. 2003; Stottlemyer & Troendle 1992).

Although water conductivity increased with higher water discharge, its concentration was balanced by rainfall and water level because during the rainy season, the increasing of water volume and level due to the rainfall can lower the conductivity values as it dilutes the water source. The TDS in the reservoir is in Class I, ranging from 10 to 31 mg/L (DOE 2009; Siti Hidayah 2012; Sumayyah 2010).

The values of secchi depth were negatively correlated with two factors; rain days and water discharge ($p < 0.01$). High concentrations of dissolved and particulate substances (eroded soils and nutrients) that were transported from the surrounding catchment into the reservoir after rainfall has been reducing light transmission and water clarity (Akinbile et al. 2013). Spatial distribution showed that the S1 had the lowest secchi depth values among all sampling stations. Dredging projects or removal of built-up sediment near the Inlet of Sungai Kurau, are one of the main sources of re-suspended sediments in the surrounding reservoir (Siti Fadzilatulhusni et al. 2012) thus resulting an increase of the TSS concentrations in the S1. Dredging can cause high turbidity levels and reducing water clarity because it disturbs large amounts of settled sediment such as silt and sand. Meanwhile, rainfall can increase reservoir water level and stream flow rate, which can re-suspend bottom sediments and erode riverbanks hence raising TSS concentrations (Hasan et al. 2012; Siti Fadzilatulhusni et al. 2012). Increasing of suspended solids may destroy fish habitats and suffocate benthic organisms and fish eggs (Wetzel 2001). However, the TSS in the BMR is still classified in Class I. The presence of floating curtains that act as a silt and floating plants barrier helped to reduce the impact of those activities on the TSS concentrations in the reservoir. The secchi depth values are associated with most of aquatic plants because the chlorophyll content inside them are depending upon light availability, temperature and nutrients (Edmondson 1980; Wetzel & Likens 2000). The concentrations of TP, NO_2^-, NO_3^- and NH_4^+ were varied during the study. Instead of water level fluctuations, the allochthonous sources that came from the Sungai Kurau apparently were the main contributors of nutrients concentrations in the BMR and this situation was verified by Ismail and Najib (2011) and Siti Hidayah (2012) who found that the highest concentrations of nutrients were in the reservoir inlet from Sungai Kurau catchment area. Ismail and Najib (2011) found that there was a positive relationship between sedimentation and phosphorus concentrations in the BMR.

From a study conducted by Akinbile et al. (2013), the amount of TP contained in the BMR ranged from 0.001 to 0.053 mg/L. The present study recorded higher than the previous study, with mean the values ranged from 0.0452 ± 0.0006 to 0.092 ± 0.0087 mg/L. According to Chapra (1997), human activities (human and animal waste, fertilizers and erosions) were the main factors increasing the concentration of the phosphorus in the water bodies. Based on the correlation, the concentration of phosphate increased when the water level had decreased due to wind-induced resuspension between sediment and overlying water in the BMR which is considered as a shallow reservoir (Ismail & Najib 2011), significantly affect the sediment phosphate release (Hamilton & Mitchell 1997; Ismail & Najib 2011; Kristensen et al. 1992). This situation has also been verified by Lee et al. (1977) and Welch and Cooke (1995) who found that the contact between sediment depth and the lake water are dependent on lake morphology, sediment characteristics and wind exposure. The decreasing of TP was probably due to the decreased of microbial activity (Ismail & Najib 2011).

Unlike phosphorus, nitrogen is more abundant as it exists in the atmosphere and be removed from the aquatic ecosystem through denitrification (Chapra 1997; Jensen et al. 1990). Ismail and Najib (2011) found that nitrate and nitrite inputs were retained in the reservoir except for ammonia and phosphate inputs which were released from the reservoir. Ismail and Najib (2011) described that the fluctuation of the nitrogen concentrations in the reservoir were influenced by the uptake of vegetation, sedimentation and denitrification. The results showed that the concentration of nitrate and ammonium, except nitrite had positive correlation with the water level; indicate that nitrification probably occurred during that period. Ammonia may have been converted into organic compound, released from the bottom sediments and discharged from the lake (Ismail & Najib 2011).

The TSI for all the stations were less varied and belong to the same trophic state due to located in the same water bodies, geographical areas and were sampled at the same day. The TSI showed that the BMR was in mesotrophic state, which was similar to Sumayyah (2010) who conducted a study of water quality in Bukit Merah Reservoir during a period of April 2008 to April 2009. The result indicated that the BMR has an intermediate level of productivity. Although BMR can still be classified as mesotrophic, there is a trend towards becoming eutrophic due to human settlement and enlarging rivers especially in Sungai Kurau and Sungai Ara.

The water quality status of the BMR has not changed since 1980s (Yap 1982), which is classified as clean and requires minor purification (Class II), although Akinbile et al. (2013) classified it as slightly polluted (Class III). Other researchers who reported similar results with the present study are DoF (1993), Ismail and Najib (2011), Siti Hidayah (2012) and Sumayyah (2010). However, Shuhaimi-Othman et al. (2010) reported that the water quality in this reservoir was in Class I, except for DO and pH.

Conclusion

The concentration of dissolved oxygen (DO), water temperature, conductivity, TDS, TP, PO_4^-, NO_2^-, NO_3^-, NH_4^+ and net primary productivity had variations temporally. Meanwhile, the TSS, secchi depth, PO_4^-, NO_2^- and chlorophyll-*a* had variations in mean reading among the sampling stations. The water quality of the BMR is classified in Class II and TSI indicates that the BMR has an intermediate level of productivity (mesotrophic) and meets the objective of this reservoir which is to provide water for paddy irrigation.

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