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Comparisons of Water Quality near Cage Culture Sites in Batang Ai Reservoir, Sarawak, Malaysia

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ABSTRACT

New development and expansion of cage culture at Batang Ai Reservoir would require investigation of the water quality. Therefore, the objective of this study was to determine the water quality at three existing aquaculture sites, one abandoned site, and one station without cage culture at three different depths. This study was carried out in October 2013 during the rainy season. Water quality was measured *in-situ* and water samples were collected and analyzed according to standard methods. Results showed that dissolved oxygen concentrations at the surface is sufficient for healthy aquatic organisms. However, dissolved oxygen at 10 m is not suitable for healthy aquatic organisms. All aquaculture sites showed significantly higher conductivity and ammonia-nitrogen at 20 m depth than the station without aquaculture. The aquaculture site that has been abandoned for nine months still showed higher 20 m chlorophyll-*a* and surface phosphate. Elevated surface, biochemical oxygen demand, phosphate and nitrate were observed at the largest and oldest aquaculture site. Based on the Chl-*a* concentration, the stations are classified as mesotrophic. This study showed that cage culture activities at Batang Ai Reservoir has impacted the water quality. Hence, further monitoring of water quality in the reservoir needs to be carried out.

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INTRODUCTION

World aquaculture is a growing industry due to the demand for protein which natural catch could not fully supply. Among the aquaculture products, fish is an important source of protein as shown by the consumption statistics that 86.5% of the world fish supply in 2010 was used for human consumption [1]. Therefore, as human population keeps growing the demand for fish also increases. In Malaysia, aquaculture is also an alternative source of fish products especially when weather condition limits the natural supply all year round. However, aquaculture activities also introduce nutrients into a water body which is a concern especially in the lentic environment due to the potential for eutrophication which can cause oxygen depletion or diseases. For example, high phosphorus and nitrogen discharged from aquaculture site had caused water quality deterioration in Fangbian Reservoir [2] and unsustainable cage culture in reservoirs in Indonesia, namely Saguling, Cirata had caused fish kills [3].

In Malaysia, Batang Ai Reservoir has been chosen as a fish production site via cage culture project since 1993 [4]. Good water quality is required for sustainable cage culture for long term social benefit and to meet the needs of local market [5]. Although previous studies have been carried out on the water quality in Batang Ai Reservoir [4, 5, 6, 7], there have been new development, expansion of cage culture activities and abandonment of cage culture in the reservoir that require further investigation. It has been shown in a study in 2009 that to a certain extent, aquaculture activities have an impact on the water quality of the reservoir [4]. Therefore, the objective of this study was to document the water quality at three existing cage culture sites, an abandoned

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aquaculture site and a non-aquaculture site so that the impact of aquaculture activities could be determined.

MATERIALS AND METHODS

This study was conducted at the Batang Ai Reservoir which is located in the Sri Aman division, Sarawak, about 275 km from Kuching, Sarawak in October 2013. The reservoir has a water surface area of 84 km^2 and a water volume of 750 million m^3. The depth ranged from 14 to 63 m with a mean depth of 44 m. The Batang Ai and Engkari River are the two rivers that flow into the reservoir (Figure 1). The study was conducted at five stations in Batang Ai Reservoir where Station 1 is located near a small scale aquaculture site, station 2 is located at an abandoned aquaculture site, station 3 at a new aquaculture site, station 4 at an older large scale aquaculture site and station 5 is near the water intake of power house which also act as a control (Figure 1).

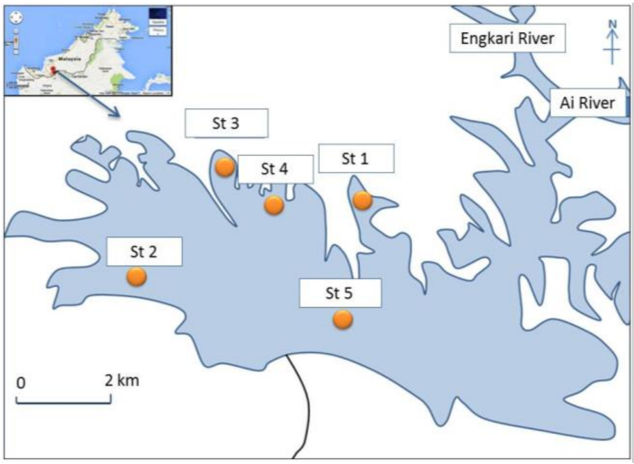

Figure 1. Location of the sampling stations at Batang Ai Reservoir

Water quality parameters studied include temperature, pH, dissolved oxygen (DO), water transparency, electrical conductivity, water depth, five-day biochemical oxygen demand (BOD_5), nitrate-nitrogen (NO_3^--N), nitrite-nitrogen (NO_2^--N), soluble reactive phosphorus (SRP) and ammonia-nitrogen (NH_3-N). At each station, data were collected in triplicates at three different depths; surface, 10 and 20 m of the reservoir which would include all the three zones, namely, epilimnion, thermocline and hypolimnion. The depth of water column at each station was determined by using a depth finder (Speedtech Instruments 67505). The water transparency was measured by using Secchi Disc (KAHLSICO, WA1088). At the surface, the water sample was taken directly into a 2L sampling bottle. For water sample collection at 10 m and 20 m, a Wildco van Dorn water sampler was used where a volume of 2L was collected. Water temperature and conductivity at each station were measured by using a conductivity meter (Lutron CD 4303). DO and pH were measured using a DO meter (SPER SCIENTIFIC) and a pH meter (Ecosan EUTECH instruments) respectively.

BOD_5 was analyzed according to APHA [8] where the initial DO reading was taken immediately in the field before the BOD bottle was capped for five days incubation. Filtered water samples were used for nitrate-nitrogen (NO_3^--N), nitrite-nitrogen (NO_2^--N), soluble reactive phosphorus (SRP) and ammonia-nitrogen (NH_3-N) analyses. Chlorophyll-*a* (Chl-*a*) analysis was conducted according to APHA standard method [8].

One litre of the water sample was filtered using a clean glass fibre paper (GF/F) and pigment extraction was carried out in subdued light before spectrophotometric determination. All the extinction values were corrected for a small turbidity blank by subtracting the 750 nm from 663, 645 and 630 nm absorptions. The concentrations of Chl-*a* were determined by inserting the corrected optical densities in equation 1 [9].

$$\text{Chl-}a = (11.64\,(OD_{663}) - 2.16\,(OD_{645}) + 0.10\,(OD_{630}))\,V_e/V_s \quad (1)$$

where Chl-*a* is chlorophyll *a* concentrations in µg/L, OD_{663}, OD_{645} and OD_{630} are the corrected optical density (with a 1 cm light path) at 663, 645 and 630 wavelengths respectively, and V_e and V_s are extract volume (mL) and volume of the sample (L), respectively.

After filtering through a glass filter of 1.2 µm retention (Sartorius, MGC), NO_3^--N, NO_2^--N and SRP were analyzed according to cadmium reduction method, diazotization method and ascorbic acid method, respectively [10]. The concentration of ammonia-nitrogen was determined by distillation and further analyzed according Nessler Method [10].

Water quality was classified according to National Water Quality Standards for Malaysia (NWQS). Significant difference for each parameter among the stations and among the depths were analyzed by using one-way ANOVA. When there was a significant difference among the means, pair-wise comparisons were made using Tukey's method. All data analyses were carried out using the SPSS version 22.0 package.

RESULTS

Depth and Transparency

Measurement shows that the deepest area was at station 4 while the shallowest at station 3 (Table 1). Transparency in both stations 3 and 4 were significantly lower than the other stations (p=0.005) whereas transparency of station 5, located near the dam water intake, was significantly higher than all the other stations (p≤0.05).

Table 1. Depth and mean and standard deviation of transparency at the five different stations

Station	Depth	Transparency
1	24.5	2.65 ± 0.12^{aI}
2	27.3	2.75 ± 0.13^{a}
3	21.2	1.87 ± 0.04^{b}
4	39.3	1.49 ± 0.10^{c}
5	25.0	3.24 ± 0.09^{d}

[I]Means in the same column with the same superscript are not significantly different at 5% significant level.

Temperature

There is a general trend of decrease in temperature as depth increases and the decrease was more from 10 to 20 m depth than from 0 to 10 m depth except station 5 where 10 m temperature was 0.13 ºC higher than 0 m (P<0.05) (Figure 2).

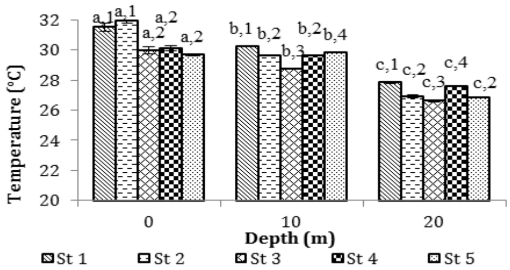

Figure 2. Temperature at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

Temperature at 0 m depth ranged from 29.67 ºC to 31.90 ºC. The highest temperature was recorded at station 2 and the lowest at station 5. At 0 m, temperature of station 2 was significantly higher than station 3 and station 4 (P=0.001). At 10 m, temperature ranged from 28.77 to 30.20 ºC with the highest temperature recorded at station 1 while the lowest at station 3. At 20 m depth, temperature was lower than shallower regions, ranging from 26.63 to 27.83 ºC where the highest was also recorded at station 1 while the lowest at station 3. As depth increased, temperature decreased significantly (P=0.001).

pH

pH at 0 m ranged from pH 5.29 to 6.87 with the highest pH recorded at station 1 and the lowest at station 5 (Table 2). At 0 m, pH of station 1 was significantly higher than station 5 (P=0.001). At 10 m, pH ranged from pH 6.19 to 7.00 with the highest pH recorded at station 5 while the lowest was at station 3. At 20 m depth, pH ranged from pH 6.27 to 6.75 where the highest pH was recorded also at station 5 whereas the lowest was at station 3. In all stations, pH at 0 m of aquaculture stations (stations 1, 3 and 4) were significantly higher than 10 m and 20 m depth (P=0.001). Among the aquaculture stations, station 3 showed the lowest pH at all depths.

Table 2. pH values at the stations at three different depths

Depth (m)	St 1	St 2	St 3	St 4	St 5
0	6.87 $\pm0.06^{a1}$	6.74 $\pm0.12^{a1}$	6.28 $\pm0.01^{a2}$	6.72 $\pm0.04^{a1}$	5.29 $\pm0.02^{a3}$
10	6.70 $\pm0.01^{b12}$	6.78 $\pm0.20^{a13}$	6.19 $\pm0.02^{b4}$	6.53 $\pm0.01^{b2}$	7.00 $\pm0.01^{b3}$
20	6.56 $\pm0.01^{c1}$	6.46 $\pm0.13^{a1}$	6.27 $\pm0.01^{a2}$	6.55 $\pm0.01^{b1}$	6.75 $\pm0.03^{c3}$

The same alphabet superscripts at same column or the same number superscripts at same row shows no significant difference at 5% significant level.

Conductivity

The 0 m and 10 m depths were lower in conductivity than 20 m depth with values ranging from 17.50 to 18.23 µS/cm (Figure 3). The highest conductivity was recorded at station 3 while the lowest at station 2. Among stations, 0 m conductivity at station 3 (new aquaculture site) was significantly higher than station 1 (small aquaculture site), 2 (abandoned aquaculture site) and 4 (old large aquaculture site) (P≤0.007). At 10 m, conductivity ranged from 17.43 to 19.40 µS/cm. The highest conductivity was recorded at station 2 while the lowest at station 5. At 20 m depth, conductivity ranged from 22.17 to 63.60 µS/cm and there were significant differences in conductivity among all stations where the highest conductivity was recorded at station 3. In all stations, water conductivity was significantly higher at 20 m depth than at 10 m depth and 0 m level (P=0.001).

Dissolved Oxygen

The DO at 0 m ranged from 6.93 to 7.81 mg/L whereas at 20 m depth, DO ranged from 0.26 to 1.47 mg/L. There was a large difference between the 0 m and 10 m except at station 5 and between 0 m and 20 m at every station (Figure 4).

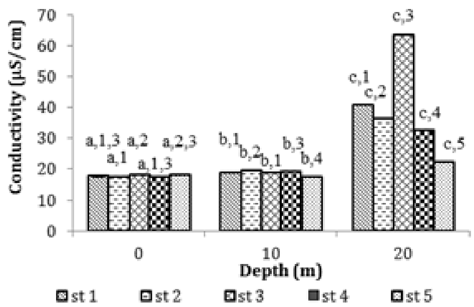

Figure 3. Water conductivity at the five stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

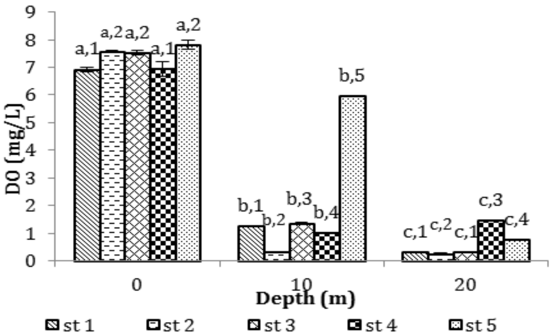

Figure 4. Dissolved oxygen at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

Among the stations, DO at surface of station 5 was significantly higher than station 1 and station 4 (P=0.001). At 10 m, DO ranged from 0.32 to 5.97 mg/L with the highest observed at station 5 and it was significantly higher than all the other stations.

In addition, at 10 m, DO concentrations were significantly different among stations with the lowest at station 2. At 20 m depth, the lowest was also recorded at station 2 while the highest was at station 4. In all the stations, DO at 20 m depth was significantly lower than 10 m depth and 0 m level ($P \leq 0.023$).

BOD_5

The highest BOD_5 occurred either at the 0 m or at 10 m depth of each station (Figure 5). The surface BOD_5 ranged from 0.60 to 2.98 mg/L and the highest value was observed at station 4 whereas the lowest at station 1. At 0 m, BOD_5 of station 4 was significantly higher than all the other stations ($P<0.05$). At 10 m, BOD_5 ranged from 0.25 to 3.17 mg/L with the highest BOD_5 recorded at station 3 while the lowest at station 4. BOD_5 concentration at station 3 (new aquaculture site) was significantly higher than station 1 (small aquaculture site) and station 4 (old large aquaculture site) (P=0.001). At 20 m depth, BOD_5 ranged from 0.33 to 2.42 mg/L. The highest BOD_5 was recorded at station 3 while the lowest at station 1. At stations 1 and 4, BOD_5 at the 0 m were significantly higher than 10 m depth and 20 m depth ($P \leq 0.033$). However, at stations 2 and 3, the concentrations at 10 m and 20 m depths were significantly higher than at 0 m ($P<0.05$).

Chlorophyll-a

The highest Chl-a occurred at 20 m depth of stations 1, 2 and 4 and the difference with other depths were significant ($P \leq 0.026$) while the other two stations showed no significant difference among depths (Figure 6).

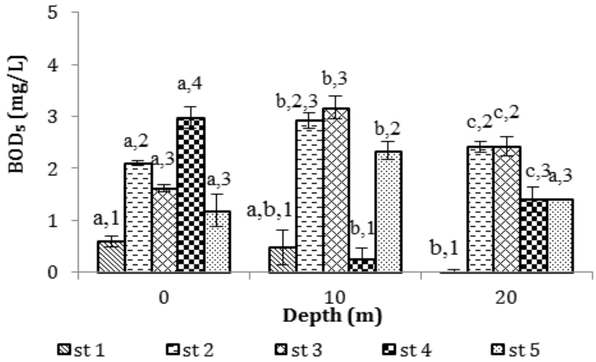

Figure 5. Biochemical oxygen demand (BOD_5) at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

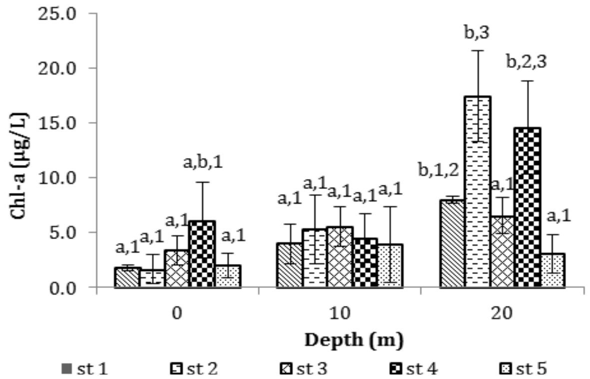

Figure 6. Chlorophyll-*a* (Chl-*a*) at the stations at sub-surface, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

Chl-a at surface ranged from 1.66 to 6.15 µg/L with the highest concentration at station 4 (old large aquaculture site) while the lowest was at station 2 (abandoned aquaculture site). No significant difference in Chl-a was recorded among stations at 0 m and also at 10 m depth where concentration ranged from 3.95 to 5.56 µg/L. At 20 m, the range of concentration was from 3.07 to 17.44 µg/L with the value at station 2 (abandoned aquaculture site) significantly higher than station 1 (small aquaculture site), station 3 (new aquaculture site) and station 5 (further from aquaculture site) ($P \leq 0.016$).

NO_3^--N

The NO_3^--N at 0 m ranged from 0.023 to 0.097 mg/L (Figure 7). The highest NO_3^--N was recorded at station 4 and the lowest at station 3. Among stations, surface NO_3^--N of station 4 was significantly higher than other stations (P=0.001). At 10 m, NO_3^--N range from 0.020 to 0.043 mg/L. NO_3^--N concentration were significantly different among stations where the highest NO_3^--N was recorded at station 2 while the lowest at station 1. At 20 m depth, NO_3^--N ranged from 0.000 to 0.037 mg/L. The highest NO_3^--N was recorded at station 4 while the lowest at station 3. Within station 3 (new aquaculture site), NO_3^--N at 20 m depth was significantly lower than 10 m depth and 0 m level (P=0.005). The concentration of NO_3^--N at 20 m depth of station 2 and station 4 were significantly lower than the 0 m and the undetectable nitrate at 20 m of statio.

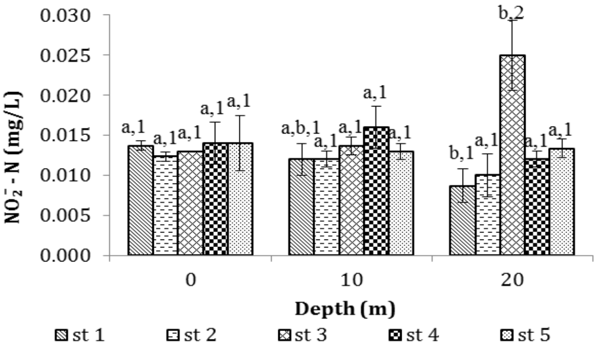

Figure 7. Nitrate-nitrogen (NO_3^--N) at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

NO_2^--N

The highest and the lowest mean NO_2^--N both occurred at the 20 m depth (Figure 8).

The NO_2^--N at 0 m ranged from 0.012 to 0.014 mg/L and there was no significant difference among the stations. Similarly, at 10 m, NO_2^--N ranged from 0.012 to 0.016 mg/L and the station means were not significantly different. At 20 m depth, NO_2^--N ranged from 0.009 to 0.025 mg/L. The highest NO_2^--N was recorded at station 3 while the lowest at station 1. NO_2^--N at station 3 was significantly higher than other stations (P≤0.002). Within station 1, NO_2^--N at 20 m depth was significantly lower than 0 m level (P≤0.023) while in station 3, NO_2^--N at 20 m depth was significantly higher than 0 m level (P=0.003).

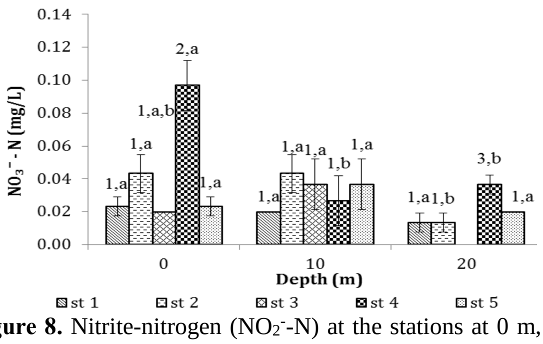

Figure 8. Nitrite-nitrogen (NO_2^--N) at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

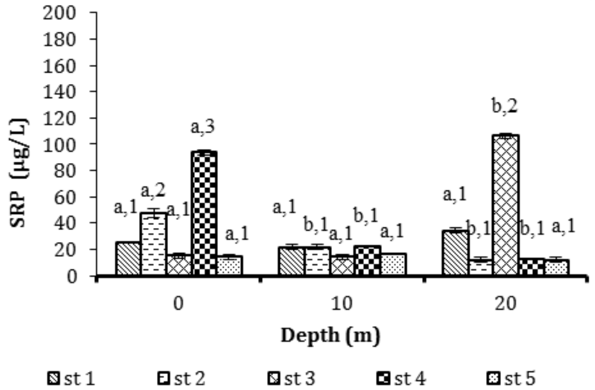

Figure 9. Total ammonia-nitrogen (NH_3-N) at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

NH_3-N

Figure 9 shows NH_3-N concentrations at the three depths with 20 m showing the highest concentration for all stations except station 5. The concentrations at 0 m ranged from 0.017 to 0.053 mg/L with the highest NH_3-N recorded at station 2 and the lowest at station 1. At 10 m, NH_3-N ranged from 0.020 to 0.057 mg/L with the highest NH_3-N concentration recorded at station 4 while the lowest occurred at station 3. At 20 m depth, NH_3-N ranged from 0.030 to 0.567 mg/L. At that depth, the highest NH_3-N was recorded at station 3 while the lowest at station 5. Cultured stations has significantly higher NH_3-N concentrations than station 5 which is further from aquaculture (P=0.0001). In fact, concentration at that 20 m depth was 6-28 times that of

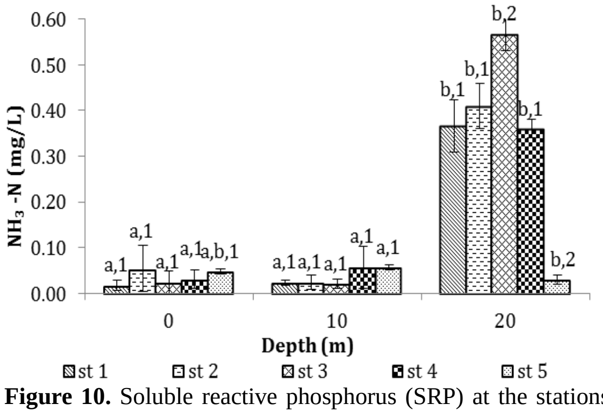

Figure 10. Soluble reactive phosphorus (SRP) at the stations at 0 m, 10 m and 20 m depths in October 2013. Means with the same alphabet at the same station or the same number at the same depth are not significantly different at 5% level

0 m and 10 m depths. Among all stations, NH_3-N at 20 m depth was significantly higher than 10 m depth and 0 m (P=0.0001).

SRP

The highest SRP was recorded at station 3 at 20 m followed by station 4 at 0 m (Figure 10). The SRP at 0 m ranged from 13.0 to 87.0 µg/L with the lowest observed at station 5 and at 0 m, and stations 2 and 4 were significantly higher than the other stations (P=0.000). At 10 m, SRP ranged from 14.1 to 26.1 µg/L and there were no significant differences among the stations (P>0.05). At 20 m depth, SRP ranged from 14.1 to 101.1 µg/L with station 3 showing significantly different concentration from the other stations. SRP at station 4 was significantly higher at 0 m than at 10 m and 20 m (P=0.0001).

Water Quality Classification

Classification of water quality parameters according to National Water Quality Standards for Malaysia (NWQS) is shown in Table 3. Among the aquaculture stations, station 3 showed the lowest pH at all depths and it falls in Class II of NWQS.

The mean pH values at 0 m depth of station 5 fall into Class III (5 - 9) of NWQS whereas the others fall in Class I. All DO values at 10 m and 20 m did not comply with Class II of NWQS for sensitive aquatic organisms except at 10 m of station 5 which was near the water intake. Ammonia-nitrogen at 0 m and 10 m depths complied with Class I. However, at 20 m depth only non-aquaculture station complied with Class I; the other stations at that depth fall in Class III of NWQS. BOD_5 at 10 m depth of station 3 fall in Class III whereas the others fall in Class I or II.

TABLE 3. Classification of water quality parameters according to NWQS

Parameter	Depth	St 1	St 2	St 3	St 4	St 5
pH	0	I	I	II	I	III
	10	I	I	II	I	I
	20	I	II	II	I	I
DO	0	II	I	I	I	I
	10	IV	V	IV	IV	II
	20	V	V	V	IV	V
EC	0	I	I	I	I	I
	10	I	I	I	I	I
	20	I	I	I	I	I
BOD_5	0	I	II	II	II	II
	10	I	II	III	I	II
	20	I	II	II	II	II
NH_3-N	0	I	I	I	I	I
	10	I	I	I	I	I
	20	III	III	III	III	I

DISCUSSION

The decrease in temperature with depth at stations 1-4 is due to the solar radiation imparting heat to the surface layer and stratification acts as a barrier to vertical mixing [11]. The reverse trend of pH and temperature where 0 m values were lower than 10 m depth at station 5 with no nearby aquaculture activities was due to its proximity to the water intake. It is attributed to overturns caused by water intake for power generation when the turbine began the day's operation shortly before sampling was conducted at that site. This also explains the higher DO observed at 10 m depth at that station which was not observed at other stations at that depth. The low DO at the deeper region is due to lack of reaeration and consumption of oxygen during decomposition of organic matter that is at the bottom of reservoir. This is similar to the observation conducted there previously [4].

BOD_5 values indicate the amount of organic matter in the water. Eventhough station 2 is an abandoned aquaculture site, the BOD_5 still ranked the second highest at 0 m and 10 m and the highest together with station 1 at 20 m. In addition, it still showed the lowest DO at 10 and 20 m, the highest chlorophyll-a at 20 m depth and significantly higher soluble reactive phosphorus than three other stations at 0 m. Though abandoned, phosphorus from fish feed and waste adsorbed onto sediment at the aquaculture site could continue to load internally. Studies have shown that under anoxic condition sedimentary phosphorus is highly available as reported [12, 13, 14, 15]. In addition, it has been estimated that anoxic sediment released 7.1 $mgP/m^2/day$ into the reservoir during stratification [16]. This explains the significantly highly soluble reactive phosphorus observed at the 0 m of abandoned station. At this station where cage culture was abandoned for 9 months, compared to previous studies, BOD_5 fall in the range of 1.80-3.07 mg/L in April 2012 which was 3 months after ceasation of aquaculture but is lower than 3.80-4.40 mg/L in November of 2011 when aquaculture was still active [7]. Near each aquaculture site, the highest BOD_5 was observed either at 0 m or 10 m depth as the source of organic matter is uneaten feed and fish waste which begin its journey from the cages in the zone of 0-3.5 m deep. BOD_5 at station 1 was the lowest as the aquaculture operation was the smallest in size and thus the input of organic matter from fish feed and fish waste was also less. The fluctuation of BOD_5 in different depths are due to dispersion process which depends on the current direction and flow rate.

Additionally, ammonia-nitrogen and soluble phosphate are the products of mineralization of organic matter. In Batang Ai Reservoir, at aquaculture sites the sources of organic matter are uneaten fish feed, urine and faeces. In low oxygen condition of the deeper region, little is oxidized to nitrate through nitrification.

Instead, ammonia accumulates at the deep region which explains the significantly higher values at all aquaculture sites at 20 m depth compared to the station without aquaculture nearby. This observation of higher ammonia-nitrogen at deeper region at aquaculture site was observed at two aquaculture stations in September of 2009 [4]. A number of studies reported the contribution of nutrients from aquaculture cages to the surrounding water. Abery et al. [3] reported nutrient loading estimated at 3.2, 15.2 and 3.1 t of nitrogen and 134, 636 and 128 kg of phosphorus per year in cage culture of three reservoirs in Indonesia. Guo et al. [17] reported that diet utilization rates were 14.8% N and 11.0% P resulting in loadings to the surrounding water of 0.160 kg total nitrogen and 0.035 kg TP per kilogram of fresh fish produced. In addition, studies in Lake Malawi shows that nutrient losses from tilapia cages to the surrounding environment was between 81 and 91% for C, 59 and 80% for N and 85 and 92% for P were lost [18]. This also explains the observation at Station 4, the largest and oldest aquaculture site where it showed the lowest in transparency, the highest and significantly higher BOD_5 at surface, soluble reactive phosphorus and 0 m and 20 m nitrate. In addition to the fish feed and fish waste at station 4, waste from fish on-site processing may have added organic matter and nutrients loading to the surrounding water. And even the new aquaculture site showed significantly higher 20 m soluble reactive phosphorus and 10 m biochemical oxygen demand than other sites. Deeper region has significantly higher 20 m conductivity at all aquaculture sites than the non-aquaculture site due to ions originating from fish waste and extra fish feed that moved downward and this was also observed by Nyanti et al. [4]. The significantly lower transparency observed near to aquaculture stations when compared to the non-aquaculture station of station 5 was due to the particulate matter such as uneaten fish feed and solid waste from the aquaculture site.

Corresponding to the 20 m high Chl-a at stations 2 and 4, there were low values of SRP due to the uptake of this nutrients for phytoplankton growth. The signiicantly higher 20 m maximum Chl-a observed at stations 1, 2 and 4 is similar to the observations of Barbiero and Tuchman [19] who reported that deep Chl-a maximum was observed in Lake Superior where in most cases the deep Chl-a maximum was located below the metalimnion. Previous studies at Batang Ai Reservoir also reported that maximum Chl-a was observed at 20 m depth at some stations in October 2011 and April of 2012 [7]. Based on the Chl-a concentration, according to Carlson classification of trophic state [20], the stations are classified as mesotrophic (Chl-a: 2.6-20 µg/L).

CONCLUSIONS

The dissolved oxygen concentration decreased with depth at all aquaculture sites and the values at 10 m depth were below 2 mg/L which is anoxic. The biggest and oldest aquaculture operation showed the lowest transparency, the highest 0 m BOD_5 and the highest 0 m SRP. In addition, electrical conductivity at 10 m and 20 m and ammonia at 20 m depth of the aquaculture stations were significantly higher than the station without aquaculture. BOD_5 at surface and SRP at 20 m depth were the highest at the new aquaculture site. BOD_5 at the surface falls in Class III. Abandoned aquaculture site still show the lowest DO at 10 m and 20 m, the second highest BOD_5 at 0 m and 10 m, the highest BOD_5 at 20 m, the highest Chl-*a* at 20 m depth and significantly higher SRP than three other stations due to internal loading of phosphorus. The lower DO concentrations at and below 10 m depth and high 20 m ammonia-nitrogen at all stations may affect aquaculture activities if overturrn of the water occurs. Water quality near the sites of existing and abandoned cage culture at Batang Ai Reservoir are impacted and continued monitoring of water quality in the reservoir needs to be carried out.

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Persian Abstract

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چکیده

پیشرفت¬های جدید و توسعه محیط بسته مخزن باتانگ به بررسی کیفیت آب نیاز خواهد داشت. بنابراین هدف این مطالعه بررسی کیفیت آب در سه سایت موجود آبزی پروری، یک سایت رهاشده و یک سایت بدون محیط بسته در سه عمق مختلف بود. این مطالعه در اکتبر دو هزار و سیزده در طول فصل بارانی انجام شد. کیفیت آب در محل اندازه گیری شد و نمونه های آب با توجه به روش استاندارد، جمع آوری و تجزیه و تحلیل شد. نتایج نشان داد که غلظت اکسیژن محلول در سطح، برای موجودات آبزی سالم کافی است. با این حال، اکسیژن محلول در ده متر برای موجودات آبزی سالم، کافی ومناسب نیست. همه¬ی سایت¬های آبزی-پروری به طور قابل ملاحظه ای هدایت و آمونیاک-نیتروژن بالاتری نسبت به سایت¬های بدون آبزی پروری، در عمق بیست متری نشان دادند. سایت¬های آبزی پروری که به مدت نه ماه متروکه شده بودند باز هم در عمق بیست متری، کلروفیل آ و فسفات سطحی بالاتری نشان دادند. شفافیت سطح بالا، نیاز به اکسیژن بیوشیمیایی، فسفات و نیترات در بزرگترین و قدیمی ترین سایت آبزی پروری مشاهده شد.براساس غلظت کروفیل آ، ایستگاه¬ها به عنوان mesotrophic طبقه بندی می¬شوند. این مطالعه نشان داد که فعالیت های محیط بسته در مخزن بتانگ، روی کیفیت آب اثر می¬گذارد. از این رو، نیاز است نظارت بیشتری بر کیفیت آب مخزن صورت بگیرد.