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Water and Sediment Quality Near Shrimp Aquaculture Farm in Selang Sibu River, Telaga Air, Sarawak, Malaysia

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Abstract: Shrimp farms are commonly located in the estuaries where it supplies the brackish water needed. World-wide, there have been reports of environmental degradation due to loadings of pollutants from shrimp farms. Therefore, the objective of this study was to determine the water and sediment quality near a shrimp farm discharge area. Water and sediment samples were collected at six stations near the discharge. Results of the study show that temperature ranged from 29.2-31.2°C and mean salinity ranged from 19-22 PSU. Water transparency was significantly lower and ammonia-nitrogen was significantly higher near the shrimp farm discharge station when compared to all the other stations. When there was discharge, water transparency was lower and ammonia-nitrogen was higher at all stations along the 3 km distance. In the sediment, total organic carbon ranged from 3.17-4.79% and total nitrogen of the stations ranged from 458.7 to 543.9 mg/kg. Total organic carbon, total nitrogen and total phosphorus of sediment at stations within 1.5 km of the shrimp farm discharge point were significantly higher than stations beyond that indicating that the impact of shrimp discharge on the sediment appears to be within 1.5 km from the discharge point.

Key words: Sibu Laut River · Sediment quality · Nutrients · Aquaculture

INTRODUCTION

Aquaculture is predicted to overtake capture fisheries as a source of aquatic food as global production from capture fisheries has leveled off and therefore unlikely to be able to meet the demand for aquatic food [1]. Shrimp aquaculture provides one of the aquatic products that are in high demand. In Malaysia, cultured shrimp are not only an important source of revenue but also an important source of protein for local populations. Shrimp farms are located in the estuaries where it supplies the brackish water needed and it also receives the discharge of the pond effluent during harvesting. World-wide, there have been reports of environmental degradation due to loadings of pollutants from shrimp farms. These include eutrophication due to the discharge of high nutrient pond water during pond harvesting which has an impact on the aquatic organisms and thus fisheries [2]. In addition, the occurrence of shrimp disease has been linked to the enriched estuarine water due to the loading from shrimp farms [3].

In Sarawak, one of the estuaries where shrimp farms are located is the Sibu Laut Estuary. It is a tidal river located about 25 km to the north-west of Kuching City and it also forms the western boundary of the Kuching Wetlands National Park (KWNP). The economic importance of KWNP is valued at about US$25 million per annum from marine fisheries, timber products and tourist industry [4] and eco-tourism industry based on wildlife alone contributed RM6 million per annum [5]. The ecological importance of mangrove includes being an area for feeding, breeding, nursery and shelter for many species of aquatic life. Previous studies of fish diversity in a similar estuary forming the eastern boundary of the Kuching Wetlands National Park showed that most of the individuals of fish caught from the area were small-sized

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indicating the importance of the area as nursery, feeding, breeding and shelter areas for many species of fish [6]. Therefore, it is important that the water and sediment quality of the area be monitored. Studies on sediment quality of the Semariang River and Sampadi River have been conducted [7, 8]. As for the water quality, studies have been conducted near shrimp aquaculture areas in the Santubong River [9] and bottom water of the Sibu Laut River [10]. However, detail study of water and sediment quality near the shrimp culture area of the Sibu Laut River is still lacking. Shrimp pond effluent was reported to be high in total suspended solids, biochemical oxygen demand, chemical oxygen demand, ammonia-nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus and chlorophyll-*a* [11, 12]. Therefore, the objective of this study was to determine the water and sediment quality as a function of distance from a shrimp farm in a tributary of the Sibu Laut River.

MATERIALS AND METHODS

The area studied was the Selang Sibu River, a tributary of the Sibu Laut River located north-west of Kuching City in the state of Sarawak of Malaysia. Three trips were made from August 2010 to January 2011 to collect samples and conduct *in-situ* measurements at six selected stations (S1, S2, S3, S4, S5 and S6) as shown in Fig. 1. Station S1 was located at a tributary of Selang Sibu River and it received effluent from the shrimp farm. Station S2 is upstream of station S1 and station S3 is downstream of Station S1. Station S6 is the nearest to the estuary. Water samples were collected from the subsurface using 1-L polyethylene bottles. Prior to samplings, the bottles were soaked in 10% nitric acid overnight and washed with deionized water and dried. Sediment samples were collected from the intertidal zone during low tide and were placed in plastic bags. Both water and sediment samples were packed in the cooler box with ice before being transported to the laboratory for analyses. All samples were analyzed in triplicates.

For *in situ* measurements, dissolved oxygen (DO) was measured using a DO meter (Cyberscan 100^{DO}), pH and temperature were measured using pH meter (Thermo Orion), salinity using portable refractometer (Apago), depth of water using a depth finder (PS-7, Hondex) and the transparency of water using a secchi disc. Water samples were filtered using glass fibre filter (Advantex GA-100) and analyzed for ammonia-nitrogen according to the phenate method [13]. Twenty millilitres of water sample was transferred in a 50 mL test tube. The sample was added with 1 mL phenol solution, 1 mL sodium nitroprusside solution and 2.5 mL oxidizing solution which was a mixture of alkaline citrate and sodium hypochlorite. The sample was covered with plastic paraffin film. The color was allowed to develop at room temperature in subdued light for at least one hour. The absorbance was measured at 640 nm for single wavelength. The concentration of ammonia-nitrogen was determined by a prepared standard curve of absorbance readings against ammonia concentration of standards.

The sediment samples were air dried for one week before being grounded using mortar and pestle in preparation for analyses. Sediment samples were analyzed for organic matter (OM), total Kjeldahl nitrogen (TKN) and total phosphorus (TP) contents and the weight expressed as mg/kg dry weight. Organic matter (OM) analysis was carried out according to the Loss-On-Ignition method and total organic carbon (TOC) was taken to be 0.58 times that of OM [14]. For sediment phosphorus content, digestion was carried out using perchloric acid method and the phosphorus concentration was determined by using the ascorbic acid method [15]. The digestion involved adding 30 mL of 70 % perchloric acid to 2 g of air-dried soil and heating until dark colour due to organic matter disappeared. The absorbance was measured at 880 nm and the phosphorus concentration was determined by a prepared standard curve of absorbance against phosphorus concentration of standards.

Sediment TKN was determined by using Kjeldahl method [16]. Digestion was conducted by adding potassium sulphate, catalyst and concentrated H_2SO_4 and heated. When frothing has ceased, the heat was increased until digest cleared. The mixture was boiled gently for 5 hours. After digestion was completed and the mixture has cooled, 20 mL of water was slowly added. The digested sample was distilled by using Buchi AutoKjeldahl Unit (K-370). The distillate was collected in 20 mL boric acid and titrated with 0.02*M* HCI with methyl-red and bromocresol green indicators. Significant difference of each water quality variable among the stations was analyzed using two-way ANOVA. For each trip, comparisons among stations were made using one-way ANOVA. Tukey's test was used for multiple comparisons among stations. All data were analyzed using SPSS 17.0 software.

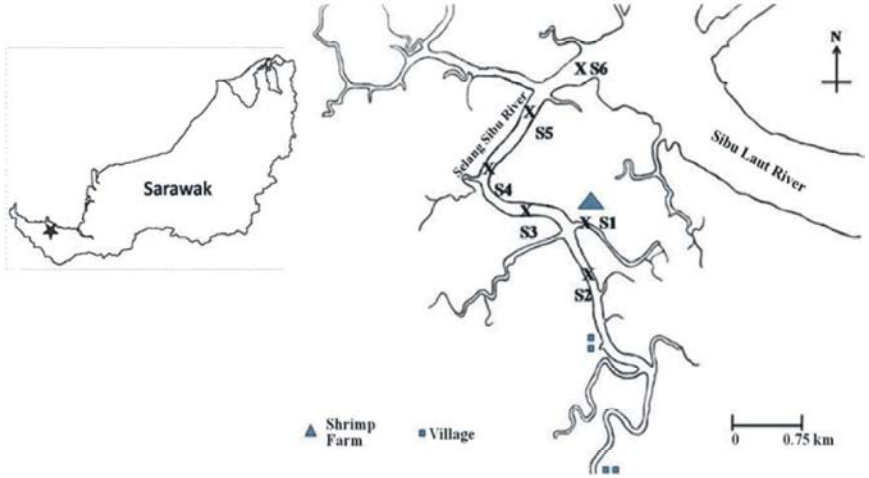

Fig. 1: The six sampling stations in Selang Sibu River

RESULTS AND DISCUSSION

Water quality variables at the six stations are given in Table 1. Mean temperature ranged from 29.2 to 31.2°C which is typical of the estuarine water of a tropical country. The range of pH was 7.30-7.50 and the values increased from S2 to S6, that is, in seaward direction. The alkaline values observed were due to natural buffering by carbonates and bicarbonates in the water and the range of pH falls in the range preferred by most estuarine organisms (6.5-8.5) [17]. The highest temperature occurred at station S1 due to its shallowness and exposure to solar radiation. Salinity was the lowest at S2 as it is the most upstream station among all stations and it receives input of fresh water from the watershed upstream.

Mean transparency of the river water was the lowest at the discharge station S1 (23.3 cm) and it was significantly lower than all the other stations. In terms of trips, transparency was the lowest during the third trip (Fig. 2a). Tukey's test showed that mean transparency of the trips were in decreasing order of Trip 1 (75.7 cm) > Trip 2 (64.7 cm) > Trip 3 (45.3 cm) and they were significantly different (P=0.02). Since the depth of the water at all the sampling stations during the second and the third trip were equal, the lower transparency at all stations of the third trip (Fig. 2a) were most likely due to the suspended solids which included sediment, detritus and phytoplankton which could have been discharged from the shrimp ponds as Nyanti *et al*. [12] reported that harvesting pond discharge contained total suspended solids and chlorophyll-*a* of 33-173 mg/L and 61-112 µg/L respectively. In another study, Ling *et al*. [11] reported 123.4-317.6 mg/L of total suspended solids and 190-284 µg/L of chlorophyll-*a* in pond effluent during harvesting. At all stations, DO comply with the standard of 4 mg/L of the mangrove and river mouth water quality criteria of Malaysia Marine Water Quality Criteria and Standard (MMWQCS) [18].

Ammonia-N in the water in the first trip ranged from 0.009-0.061 mg/ and in the second trip, it ranged from 0.006-0.102 mg/L with station S1 showing the highest value in both trips. In the third trip, ammonia-N ranged from 0.022 to 0.363 mg/L and was significantly higher than the first two trips (P<0.001). This concurred with the low transparency of the third trip indicating the recent discharge of effluent from shrimp aquaculture farm. For the third trip, from stations S2 to S3, the value of ammonia-N increased from 0.030 mg/L to 0.053 mg/L (Fig. 2b) showing the impact of inflow from the shrimp farm discharge and Tukey's test showed that that increase was significant (P=0.002). From the studies of loading of pollutants from shrimp farms, Ling *et al*. [11] and Nyanti *et al*. [12] reported that high loads of ammonia-nitrogen were released from the ponds during harvesting.

Overall, mean ammonia-N near the discharge point, S1, was the highest among all the stations and was significantly higher than other stations (P<0.0005). Even when there was no harvesting effluent, the high ammonia-N values at S1 were likely due to regular water exchange as reported by Lorenzen [19] that most of the nitrogen that were not deposited in sediment were discharged with routine water exchange in commercial intensive shrimp farms studied. The observation of higher ammonia-N at station S1 in first and second trip is in agreement with

Table 1: Mean values of water quality variables at the six stations

St	Temperature (°C)	pH	Salinity (PSU)	Transparency (cm)	DO (mg/L)	Depth (m)
1	31.2±0.4^b	7.50±0.25^c	22±4^b	23±8^a	6.02±0.39^a	0.9±0.4^a
2	29.8±0.7^a	7.30±0.02^a	19±4^a	67±14^b	5.88±1.23^a	3.0±0.6^b
3	29.7±0.8^a	7.36±0.09^{ab}	22±3^b	70±16^b	5.88±1.30^a	3.4±0.3^b
4	29.2±0.8^a	7.36±0.11^{ab}	22±3^b	67±10^b	6.08±1.40^a	5.7±0.4^c
5	29.4±0.3^a	7.38±0.13^{ab}	22±2^b	74±17^b	5.47±1.63^a	2.6±0.4^b
6	29.7±0.4^a	7.42±0.14^{bc}	22±2^b	70±13^b	5.89±1.30^a	3.3±0.7^b

*Means in the same column with the same letters are not significantly different at 5% level

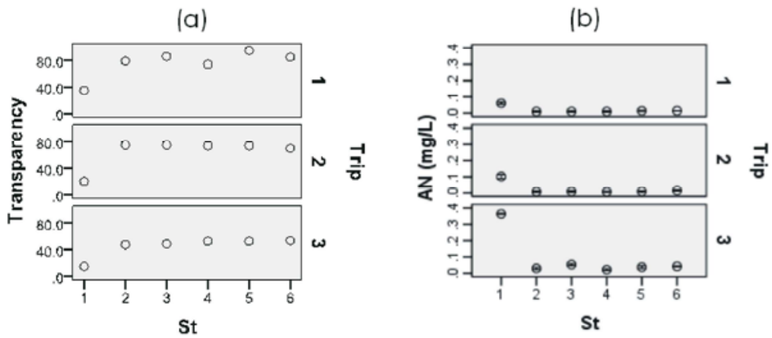

Fig. 2: Transparency and ammonia-nitrogen (AN) of the water samples at the sampling stations during the three trips

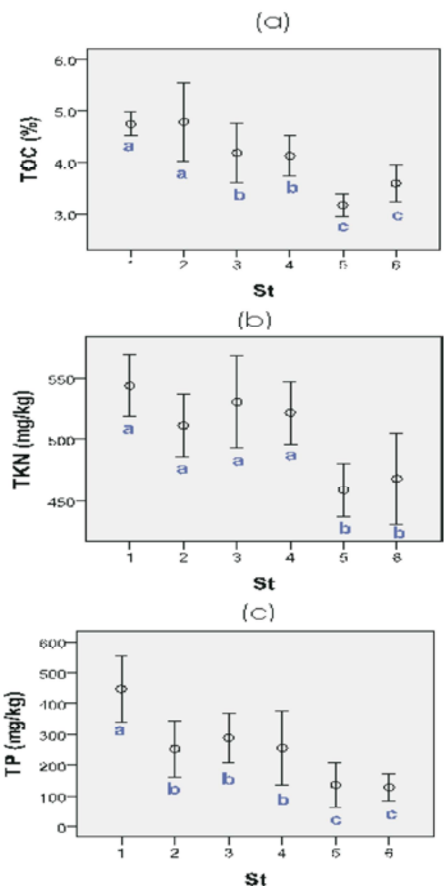

Fig. 3: Total organic carbon (TOC), total Kjeldahl nitrogen (TKN) and total phosphorus (TP) of the sediment at the six sampling stations

Trott and Alongi [20] who reported that water quality and phytoplankton biomass were within ambient levels within 1 km downstream of discharge site. The highest concentration of ammonia-N (0.363 mg/L) at S1 occurred during the third trip with temperature of 31°C and pH of 7.3. That value is equivalent to unionized ammonia value of less than 11 µg/L, which is below the standard of 70 µg/L unionized ammonia of MMWQCS [18].

In the sediment, mean TOC at the stations ranged from 3.17-4.79% (Fig. 3a). There was no significant difference in mean TOC between stations S1 and S2 (P=1.0) and stations S1 and S2 were significantly higher than all the other stations ($P \leq 0.03$). As we move further from the farm, mean TOC decreased. Station S5 and S6 were furthest from the shrimp farm and they showed the lowest values. TOC of station S2 was the highest followed by station S1. The lowest station was station S5. The source of TOC at stations nearer shrimp farm was due to the organic particulates discharged during regular water exchange, during draining of pond water at harvesting and the flushing of pond bottom to remove the sediment from the ponds. The mean TOC of the present study falls in the range of TOC of pond bottom soil, that is, 0.58-11.6%, calculated from organic matter of 10,000-20,000 mg/kg, as reported by Avnimelech and Ritvo [21].

Mean TKN of the sediment of the stations ranged from 458.7 to 543.9 mg/kg with station S1 showing the highest. Mean TKN increased from Station S2 to S3 after receiving discharge from station S1 and then decreased from S3 at S5. The sources of nitrogen in shrimp effluent are inflow water, uneaten feed and excretion. High amount of N from the feed was found to be not consumed and wasted. Jackson *et al*. [22] reported that only 22% of input N was converted to harvested shrimp and 14% deposited in the sediment and 57% discharged to the environment. In addition, outflow water of a semi-intensive farm accounted for 36.7% of the total nitrogen [23]. Furthermore, previous studies on shrimp pond effluent during harvesting showed that shrimp pond effluent was high in total nitrogen [12]. Therefore, regular water exchange, effluent during harvesting and pond flushing after harvesting potentially move the nitrogen from the pond systems to the nearby water and sediment.

Mean TP in the sediment of stations ranged from 128.1 mg/kg at station S6 to 447.3 mg/kg at station S1. Mean TP at S1 was significantly higher than all the other stations ($P \leq 0.001$). There was an increase in TP as we move from station S2 to S3 after passing the discharge. However, the increase is insignificant ($P=0.907$). The lowest mean TP values were found in the sediment samples that were located at S5 and S6 near the mouth of the Selang Sibu River which was the farthest from the shrimp farm. The contribution of phosphorus from shrimp farm is mostly due to the uneaten feed as shrimp is a poor eater and studies has shown that only 6.1% of input phosphorus was in the harvested shrimp and 63.5% found accumulated in the sediment and 30.3% in the outlet water [23]. Thakur and Lin [24] reported that 39 - 67% of the TP input in shrimp culture was accumulated in the sediment. Therefore, after shrimps are harvested and the ponds flushed, the phosphorus is transported to the nearby water bodies. Therefore, the sediment showed very high concentrations, more than four times that of the station that is farthest from the farm. The observation of highest TP at station S1 is similar to the report of Ling *et al*. [25] that near a shrimp farm of the Santubong River, the total phosphorus concentration of the sediment was the highest compared to other stations.

Overall, Fig. 3 shows that TOC, TKN and TP at stations near to shrimp farms, that is, S2-S4 were significantly higher than S5 and S6 which were further away. This indicates the impact of shrimp farm effluent on the sediment within 1.5 km from the discharge site.

CONCLUSIONS

Transparency of the water was the lowest and ammonia-N was the highest at the station near the discharge point for all trips. When there was discharge, the transparency of the water decreased and ammonia-nitrogen increased at all the stations within 3 km distance from the discharge point. TOC, TKN and TP in sediment were significantly higher at the station near discharge than the stations downstream of it. The impact of shrimp farm effluent on the sediment was within 1.5 km from the discharge site.

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