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Fish Diversity and Water Quality during Flood Mitigation Works at Semariang Mangrove Area, Kuching, Sarawak, Malaysia

(Kepelbagaian Ikan dan Kualiti Air semasa Kerja Mitigasi Banjir di Kawasan Paya Bakau Semariang, Kuching, Sarawak, Malaysia)

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ABSTRACT

This study aimed to document the fish diversity and water quality at Semariang mangrove area, Kuching, Sarawak, which is located at the eastern part of Kuching Wetland National Park. Field samplings were carried out in 2009 during the construction of the flood mitigation channel at the eastern part of the park. A total of 21 families represented by 37 species of fish were caught from the area. The six dominant families in terms of the number of individuals caught were Mugilidae *(16%),* Leiognathidae *(16%),* Ambassidae *(11%),* Ariidae *(9%),* Lutjanidae *(8%) and* Plotosidae *(6%). In terms of the percentage of six dominant genera based on the number of individuals caught, 16% was represented by* Valamugil, *11% by* Ambassis, *10% by* Gazza, *9% by* Arius, *8% by* Lutjanus *and 6% by* Plotosus. *The values of diversity and richness indices were lower at stations located close to the flood mitigation channel. Similarly, the concentrations of dissolved oxygen were lower and total suspended solids were significantly higher at stations close to the channel and sand mining area. Therefore, fish fauna and water quality at Semariang mangrove area were affected during the construction of the flood mitigation channel.*

Keywords: Fish diversity; flood mitigation channel; Semariang mangroves; water quality

ABSTRAK

Kajian ini bertujuan untuk mendokumentasi kepelbagaian ikan dan kualiti air di kawasan paya bakau Semariang, Kuching, Sarawak, yang terletak di bahagian timur Taman Negara Tanah Lembab Kuching. Kerja lapangan telah dijalankan pada tahun 2009 semasa kerja membina saliran mencegah banjir dilakukan di bahagian timur kawasan taman. Sebanyak 21 famili ikan yang mewakili 37 spesies ditangkap di kawasan ini. Enam famili ikan yang paling banyak daripada segi bilangan individu yang ditangkap ialah Mugilidae *(16%),* Leiognathidae *(16%),* Ambassidae *(11%),* Ariidae *(9%),* Lutjanidae *(8%) dan* Plotosidae *(6%). Enam genus ikan yang paling banyak daripada segi bilangan individu yang ditangkap ialah* Valamugil *(16%),* Ambassis *(11%),* Gazza *(10%),* Arius *(9%),* Lutjanus *(8%) dan* Plotosus *(6%). Bagi stesen-stesen yang terletak berhampiran dengan saliran mencegah banjir, nilai indeks kepelbagaian dan kekayaan adalah lebih rendah, kandungan kepekatan oksigen terlarut juga lebih rendah dan pepejal terampai adalah lebih tinggi secara signifikan. Oleh itu, fauna ikan dan kualiti air di kawasan paya bakau Semariang telah dipengaruhi semasa kerja pembinaan saliran mencegah banjir.*

Kata kunci: Kepelbagaian ikan; kualiti air; paya bakau Semariang; saliran mencegah banjir

INTRODUCTION

Mangroves are characteristic features of most tropical and subtropical estuaries. The low-energy intertidal zone encourages the development of this ecosystem (Twilley et al. 1996) and is commonly associated with soft and muddy substrate. Mangrove forests are highly productive and valuable ecosystems (Sasekumar et al. 1992). They are important detritus contributor for the ecosystem food webs, which also benefit the estuarine and near shore fisheries. They also act as nursery, feeding, breeding and shelter areas for many species of aquatic life. In Sarawak, mangrove forest covers an area of approximately 174,000 hectares and occupies about 60% of the 800 km length of its coastline. Mangrove forests are located mainly along the sheltered coastlines and estuaries within the major bays of Kuching Division, Sri Aman Division, Rajang Delta and Limbang Division (Chai 1982). Over the past thirty years, the State of Sarawak had lost approximately 24% of its pristine mangrove forests (Anon 2008) due to conversion into various types of land use including oil palm plantation, aquaculture, housing estate and other development projects.

Traditionally, mangrove forests have been an essential resource for communities living in coastal areas and contribute high economic values in term of forest products, fisheries, aquaculture and eco-tourism. Bennett and Reynolds (1993) reported that the Sarawak Mangrove Forest Reserve, of which Kuching Wetland National Park is part of, contributed about US$25 million to the State's revenue per annum from marine fisheries, timber products and tourism industry. Tuen et al. (2008) reported eco-tourism industry based on wildlife alone in Kuching Wetland National Park contributed RM6 million per year. The Kuching Wetland National Park (KWNP) covers an area of approximately 6,610 hectares and was gazetted in October 2002. The park was subsequently declared as a Ramsar site in November 2005. The area is drained by two major rivers, namely Sungai Sibu Laut in the west and Sungai Semariang in the east. In between these two major rivers are numerous channels and creeks. The importance of KWNP mangrove areas as feeding, breeding, nursery and shelter areas for many species of aquatic life and fisheries was reported by CTTC (2010a). However, the impact of the on-going flood mitigation works at one of the tributaries of Semariang River on fish fauna and water quality at Semariang mangrove area was unknown. Therefore, the objectives of this study were to investigate the composition and diversity of fish fauna as well as the status of the water quality during construction of the flood mitigation channel at Semariang mangrove area.

Materials and Methods

Fish Fauna

Field samplings of the fish fauna were carried out at six stations in 2009 during the on-going flood mitigation works at Semariang mangrove area. The six sampling stations are Lemidin Besar River (S1), Lemidin Kecil River (S2), Semariang River (S3), Mangkuang River (S4), Pergam Besar River (S5) and Pergam Kecil River (S6), respectively (Figure 1).

Fish sampling methods used were monofilament gill net, three-layered net and cast net. Each fishing method was employed in a similar manner in all the stations. When monofilament gill net was employed, fishes were sampled using nets of different mesh sizes (mesh size, depth × length) - 2.5 cm, 1.2 m × 6 m; 5.0 cm, 2.0 m × 30.0 m; 7.5 cm, 2.0 m × 30.0 m and 10.0 cm, 2.5 m × 45.0 m). Three-layered net with mesh sizes of 15.0 cm, 2.5 cm and 7.5 cm, depth of 2.5 m and length of 50.0 m were also employed. At each station, three sets of three-layered net and each set of monofilament net with different mesh sizes were placed at 45 degrees to the bank of the river. All nets were set in late afternoon during low tide and left overnight to be checked in the morning. When cast net was employed, thirty throws were made at each station. Fish species were identified in the laboratory. The specimens were placed in a cooler box with ice before they were brought back to the laboratory for preservation in 10% formalin for about a week. Subsequently, these specimens were transferred to 70% ethanol. Fish identification followed those of Atack (2006), Kottelat et al. (1993), Lim and Gambang (2009), Mansor et al. (1998), Matsuda et al. (1984) and Mohammed Shaari (1971). The standard length, total length and weight of each individual fish caught were measured and recorded. At each station, the diversity

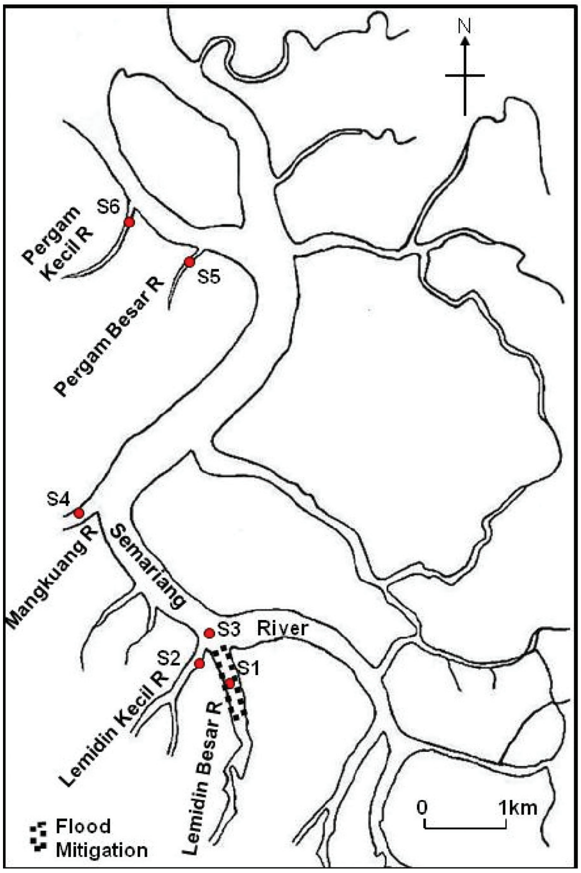

FIGURE 1. Location of sampling stations at Sungai Semariang mangrove area

(Shannon & Weaver 1963), evenness (Pielou 1996) and richness (Margalef 1968) indices were calculated based on (1), (2) and (3) respectively.

$$H = \frac{n \log_{10} n - \sum f_i}{n}. \quad (1)$$

$$J = \frac{H}{\ln S}. \quad (2)$$

$$D = \frac{S-1}{\log_{10} N}, \quad (3)$$

where H is the diversity index, n is the sample size, f_i is the number of individual for each species, J is the similarity index, S is the total number of species, D is the richness index and N is total number of individuals.

Water Quality

Water quality samplings were carried out in 2009 concurrently with the fish fauna samplings. Values of dissolved oxygen, temperature and pH were measured using the multi-parameter Sonde model YSI 6820 V.2. Water samples were analyzed for five-day for biochemical oxygen demand (BOD_5), chlorophyll-*a* (Chl-*a*), total ammonia-nitrogen (TAN) and total suspended solids (TSS). All parameters were measured in triplicates at three different depths; subsurface, mid-depth and bottom except for Chl-*a* which was measured at the subsurface in triplicates. BOD_5 and TSS were performed according to Standard Methods (APHA 1998). Chl-*a* was determined by spectroscopic measurements using trichromatic methods (Aminot & Rey 2000). One liter sample was filtered using 0.7 μm pore size micro-glass fibre paper. The pigments were then extracted by grinding the filters in 90% acetone. The ground filter and acetone were then centrifuged for 10 min at 3,000 rpm, after which the optical density (absorbance) were determined at 750 nm, 664 nm, 647 nm and 630 nm using a spectrophotometer and the concentration computed. Water samples were filtered before analysis for total ammonia nitrogen (TAN) and their concentrations were determined using colorimetric method (Hach 1996). TAN was analyzed using Nessler Method where mineral stabilizer, Polyvinyl Alcohol Dispersing Agent and Nessler Reagent were added into 25 mL of the samples. Concentrations of TAN were determined by using a spectrophotometer Hach Odyssey 2500.

STATISTICAL ANALYSIS

Significant difference of each water quality parameter among the stations was analyzed using two-way ANOVA. Tukey's method was used for multiple comparisons. At each depth, water quality parameters among stations were also compared using one-way ANOVA and subsequently Tukey's test. All data analyses were conducted using SPSS version 17.0 package. For water quality parameters with no significant difference among depths, the mean value among the three depths were computed and presented in the results.

RESULTS

FISH FAUNA COMPOSITION

Fish families, species, number of individuals caught and their presence and absence in each of the sampling station are given in Table 1.

A total of 10 families represented by 13 species were caught from S1. The dominant family is Engraulidae, comprising 21% of all the number of individuals caught. At S2, 11 families represented by 16 species were caught and the dominant family is Ariidae comprising 21% of the total number of individuals caught. At S3, only 4 families represented by 4 species were caught. Fifteen families represented by 19 species were caught at S4 and the dominant family is Mugilidae representing 32% of all the numbers of individuals caught. At S5, 9 families represented by 10 species were caught. The dominant family is Mugilidae, comprising 33% of all the number of individuals caught. At S6, 7 families represented by 9 species were caught. The dominant family is Apogonidae, comprising 40% of all the number of individuals caught. The total number of individuals caught in all the study station for each species as well as their standard length, total length and weight is also shown in Table 1. Some of individuals from the families Lutjanidae and Serranidae were small in size and the juvenile stage. However, many of the individuals caught were adult but were small in size.

A total of 231 individuals from 21 families and 37 species were caught from all the six stations. In terms of the percentage of six dominant families based on the number of individual caught, 16% was represented by the family Mugilidae, 16% by Leiognathidae, 11% by Ambassidae, 9% by Ariidae, 8% by Lutjanidae and 6% by Plotosidae (Figure 2(a)). The rest of the 15 families make up about 34% of the total number of individuals caught. In terms of the percentage of six dominant genera based on the number of individuals caught, 16% was represented by the *Valamugil*, 11% by *Ambassis*, 10% by *Gazza*, 9% by *Arius*, 8% by *Lutjanus* and 6% by *Plotosus* (Figure 2(b)). The rest of the 24 genera make up about 40% of the total number of individuals caught.

DIVERSITY, RICHNESS AND EVENNESS INDICES

The values of species diversity, richness and evenness indices for each of the six stations are shown in Table 2. The value of diversity index ranged from 0.60 at S3 to 0.91 at S1, richness index ranged from 6.52 at S5 to 11.75 at S4 and evenness index ranged from 0.64 at S4 to 1.00 at S3.

WATER QUALITY

The mean values of water quality parameters at each station did not show significant difference among depths (Table 3). Water temperature ranged from 27.98 to 30.23°C and temperature increased seaward. pH of S1 and S3 were slightly below 7 whereas other stations recorded pH values of above 7. DO at all stations were below 4 mg/L (2.4 to 3.8 mg/L) with S1, S2 and S3 showing the lowest DO values. DO at S5 and S6 were significantly higher than stations 1, 2 and 3 ($p \leq 0.021$). BOD_5 was the highest at S2 (9.5 mg/L) followed by S3 (8.8 m/L). The lowest BOD_5 was at S5 with a value of 7.4 mg/L. Chl-*a* measured at subsurface ranged from 2.62 μg/L (S6) to 4.57 μg/L (S2) and there was no significant difference among the stations (p=0.806). TAN values ranged from 0.08 to 0.49 mg/L and S2 showed the highest value followed by S4.

Table 4 shows the TSS values at three different depths at the six stations. The highest value of TSS occurred at the bottom water of station S3 with a mean value of 655.2 mg/L and the lowest occurred at mid-depth of station S6 with a mean of 51.0 mg/L. At station S2, mid-depth and bottom water have significantly higher TSS than the subsurface level ($p<0.0005$). At station S3, the bottom water has significantly higher TSS than the shallower levels (p=0.005, 0.035). At stations S1, S4 and S6, there were no significant difference in TSS among the depths (p=0.051, 0.232, 0.521). At station S4, TSS was high at all depths ranging from 102.4 to 267.9 mg/L.

Overall, comparisons among depths showed that TSS values increased from subsurface to the bottom with the bottom TSS significantly higher than the subsurface

TABLE 1. Fish family, species, number of individual caught from each station and absence (-), total number of individuals caught from all stations (N) and their standard length (SL), total length (TL), weight (WT) and standard deviations (SD)

Family	Species	Station						N	SL ± SD	TL ± SD	WT ± SD
		1	2	3	4	5	6				
Ambassidae	*Ambassis macracanthus*	2	7	-	14	2	-	25	4.1 ± 1.3	5.3 ± 1.6	2.3 ± 2.9
Apogonidae	*Apogon hyalosoma*	-	-	-	1	1	6	8	9.2 ± 1.9	11.0 ± 2.3	27.3 ± 15.4
Ariidae	*Arius sagor*	-	7	-	3	-	-	10	17.7 ± 3.0	19.7 ± 6.5	106.8 ± 86.4
	Arius sona	-	9	-	-	-	-	9	16.6 ± 2.5	20.1 ± 2.7	83.6 ± 42.9
	Arius venosus	-	1	-	-	-	-	1	6.3	7.9	3.8
Carangidae	*Carangoides malabaricus*	-	-	-	1	1	-	2	8.0 ± 0.1	9.5 ± 0.1	9.2 ± 0.9
	Pseuocaranx dentex	-	-	-	-	-	1	1	11.1	13.5	17.9
Clupeidae	*Anodontostoma chacunda*	-	-	-	5	-	-	5	5.1 ± 0.4	6.2 ± 0.4	2.4 ± 0.5
	Tenualosa macrura	-	-	-	-	2	1	3	5.64 ± 0.3	7.6 ± 0.6	3.3 ± 0.6
	Butis melanostigma	-	-	-	-	-	1	1	9	11.4	12.9
Engraulidae	*Coilia dussumieri*	-	-	1	1	-	-	2	9.8 ± 0.2	10.8 ± 0.1	4.4 ± 0.1
	Coilia macrognathus	6	-	-	1	-	-	7	9.0 ± 0.4	10.0 ± 0.4	3.4 ± 0.5
	Thryssa hamiltonii	-	-	-	1	-	-	1	9.9	12.2	12
Gerreidae	*Gerres abbreviatus*	3	-	-	1	1	1	6	5.0 ± 0.9	6.5 ± 1.2	3.6 ± 2.9
	Gerres filamentosus	-	-	-	2	-	-	2	4.8 ± 0.1	6.3 ± 0.1	3.4 ± 0.1
Gobiidae	*Parapocryptes serperaster*	-	-	-	2	-	-	2	8.2 ± 1.7	10.4 ± 2.8	11.1 ± 6.9
Haemulidae	*Pomadasys kaakan*	-	1	-	-	-	-	1	1.4	1.9	0.3
Leiognathidae	*Gazza minuta*	3	7	-	13	-	-	23	3.9 ± 1.2	4.9 ± 1.4	1.4 ± 1.3
	Leiognathus eguulus	2	1	1	-	1	1	6	7.7 ± 1.0	9.7 ± 1.5	14.6 ± 8.9
	Leiognathus splendens	-	-	-	-	6	-	6	6.3 ± 2.1	8.1 ± 2.8	10.5 ± 11.5
	Secutor ruconius	-	-	-	-	-	1	1	3.7	4.7	0.8
Lutjanidae	*Lutjanus fulviflamma*	-	7	-	-	-	-	7	13.6 ± 1.1	16.6 ± 1.1	74.6 ± 17.3
	Lutjanus johnii	1	8	-	1	1	-	11	11.9 ± 2.9	14.6 ± 3.5	68.6 ± 44.0

(continue)

Continue TABLE 1.

Family	Species	Station						N	SL ± SD	TL ± SD	WT ± SD
		1	2	3	4	5	6				
Mugilidae	*Valamugil engeli*	1	2	1	25	8	-	37	7.0 ± 2.2	8.6 ± 2.5	11.5 ± 15.9
Platycephalidae	*Platycephalus indicus*	-	-	1	2	1	1	5	8.7 ± 0.7	10.5 ± 0.8	7.2 ± 2.2
Plotosidae	*Plotosus canius*	-	13	-	-	-	-	13	30.9 ± 6.6	32.2 ± 6.6	250.7 ± 161.4
Pristigasteridae	*Ilisha melastoma*	-	-	-	-	-	2	2	8.6 ± 0.1	10.9 ± 0.1	7.3 ± 0.2
Scatophagidae	*Scatophagus argus*	-	4	-	-	-	-	4	6.3 ± 2.0	7.9 ± 1.8	15.0 ± 10.3
Sciaenidae	*Johnius belangerii*	2	2	-	3	-	-	7	11.9 ± 3.7	14.3 ± 4.2	39.6 ± 28.9
	Johnius dussumieri	-	2	-	1	-	-	3	11.8 ± 0.8	14.3 ± 1.3	35.7 ± 10.9
	Paranibea semiluctuosa	2	-	-	-	-	-	2	7.2 ± 1.1	9.3 ± 1.1	7.9 ± 4.2
Scorpaenidae	*Synanceja verrucosa*	-	3	-	1	-	-	4	12.3 ± 0.7	14.7 ± 0.9	51.8 ± 8.2
	Vespicula trachinoides	1	-	-	-	-	-	1	5.7	7.0	5.8
Serranidae	*Epinephelus malabaricus*	-	-	-	1	-	-	1	9.2	11.0	13.0
Tetraodontidae	*Chelonodon patoca*	3	-	-	-	-	-	3	6.6 ± 2.3	8.4 ± 2.8	21.6 ± 17.1
	Tetraodon nigroviridis	1	7	-	-	-	-	8	3.7 ± 2.8	4.7 ± 3.3	9.1 ± 20.0
Toxotidae	*Toxotes chatareus*	1	-	-	-	-	-	1	6.0	7.3	6.7

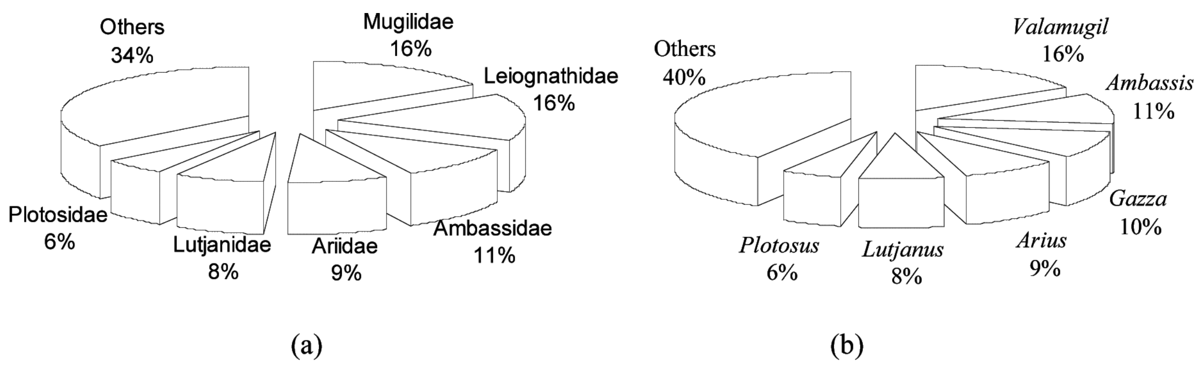

FIGURE 2. The percentage of six dominant (a) families and (b) genera caught from the study area

TABLE 2. Values of diversity (*H*), richness (*D*) and evenness (*J*) indices in each of the station

S	Location	H	D	J
1	Lemidin Besar River	0.91	9.22	0.81
2	Lemidin Kecil River	0.87	8.83	0.73
3	Semariang River	0.60	4.98	1.00
4	Mangkuang River	0.82	11.75	0.64
5	Pergam Besar River	0.83	6.52	0.83
6	Pergam Kecil River	0.82	6.80	0.86

TABLE 3. Mean values of water quality variables at all the sampling stations

S	Temperature (°C)	pH	DO (mg/L)	BOD_5 (mg/L)	Chl-*a* (µg/L)	TAN (mg/L)
1	27.98 ± 0.09^{a}	6.93 ± 0.04^{a}	2.36 ± 0.39^{a}	7.8 ± 0.9^{ac}	4.47 ± 1.74^{a}	0.28 ± 0.28^{ab}
2	28.97 ± 1.32^{ab}	7.15 ± 0.16^{b}	2.46 ± 0.48^{a}	9.5 ± 0.7^{b}	4.57 ± 2.70^{a}	0.49 ± 0.31^{a}
3	28.32 ± 0.40^{a}	6.87 ± 0.03^{a}	2.42 ± 0.16^{a}	8.8 ± 1.3^{bd}	2.95 ± 0.40^{a}	0.26 ± 0.06^{ab}
4	28.74 ± 1.03^{a}	7.15 ± 0.02^{b}	2.95 ± 0.27^{abc}	8.6 ± 0.9^{ad}	2.91 ± 1.98^{a}	0.32 ± 0.32^{ab}
5	29.15 ± 0.42^{ab}	7.31 ± 0.05^{bc}	3.33 ± 0.10^{cd}	7.4 ± 0.4^{c}	4.06 ± 2.59^{a}	0.08 ± 0.04^{b}
6	30.23 ± 0.12^{b}	7.34 ± 0.01^{c}	3.78 ± 0.04^{d}	8.1 ± 0.7^{acd}	2.62 ± 0.82^{a}	0.25 ± 0.17^{ab}

*Means in the same column with the same superscript given by letters were not significantly different at 5% level

TABLE 4. Mean values of total suspended solids (TSS) at different depths of the sampling stations

S	Subsurface	Mid-depth	Bottom	Mean
1	$122.1 \pm 6.1^{1*}$	246.3 ± 94.2^{1}	254.2 ± 28.5^{1}	$207.5 \pm 80.9^{ab**}$
2	98.1 ± 22.1^{1}	409.7 ± 47.1^{2}	387.6 ± 40.4^{2}	298.5 ± 154.2^{a}
3	25.6 ± 12.2^{1}	249.3 ± 10.9^{1}	655.2 ± 255.5^{2}	310.0 ± 304.6^{a}
4	267.9 ± 188.9^{1}	102.4 ± 12.5^{1}	180.0 ± 3.0^{1}	183.4 ± 118.8^{ab}
5	55.1 ± 0.1^{1}	73.1 ± 12.0^{2}	96.3 ± 0.6^{3}	74.8 ± 18.8^{b}
6	60.5 ± 10.3^{1}	51.0 ± 1.4^{1}	83.8 ± 59.5^{1}	65.1 ± 33.6^{b}
Mean	104.9 ± 104.6^{a}	188.6 ± 135.0^{ab}	276.2 ± 223.4^{b}	189.9 ± 174.2

*Means in the same row with the same superscript given by numbers were not significantly different at 5% level
**Means in the same row or column with the same superscript given by letters were not significantly different at 5% level

(p=0.001). Overall, among the stations, mean TSS values at stations S2 and S3 were significantly higher than S5 and S6 ($0.005<p<0.013$). TSS of station S4 was not significantly different from that of the other stations.

DISCUSSION

In this study, a total of 37 species of fish from 21 families were reported from Semariang mangrove area. The number of fish species present in this study was lower than those reported for other mangrove areas. In Inanam Mangrove area in Sabah, Kueh (1991) reported the presence of 57 species of fish from 31 families, 70 species of fish from 40 families in Paloh mangroves (Nyanti et al. 2005) and 121 species of fish from 44 families from the whole area of Kuching Wetland National Park (CTTC 2010a). The diversity and richness indices at stations close to the construction of the flood mitigation channel also recorded lower values compared with well developed mangrove areas in Sarawak such as Paloh mangrove area (Nyanti et al. 2005) and also to an earlier study done at the same stations before the commencement of the flood mitigation works. However, stations located farther from the flood mitigation channel showed no difference in the values of diversity and richness indices before and during the flood mitigation works (CTTC 2010a).

Mangroves have complex habitat structures that attract many species of fishes to utilize the area as their breeding and nursery ground for their juveniles. The roots of mangrove trees are a suitable and complex habitat for fishes and also reduced the risk of them being eaten by piscivorous predators (Laegdsaard & Johnson 2001; Robertson & Duke 1987; Thayer et al. 1987). The abundance of food supply was also one of the reasons for the high diversity of fish in mangrove areas. Studies in Paloh mangrove carried out using small trawler showed large quantities of detritus found at the bottom of the estuaries (Nyanti et al. 2005). Although similar structures were also observed in mangroves along Semariang River bordering the eastern part of the park and along the extensive network of marine waterways and tidal creeks within the sampling area, the number of fish species and values of indices recorded were lower at stations close to the flood mitigation works indicating the negative impact of flood mitigation works on fish fauna.

In Paloh mangrove area, large numbers of individuals caught were marine migrants mainly from the families of Lutjanidae, Leiognathidae and Ariidae (Nyanti et al. 2005). Similar results were also reported by (Blaber 1997; Chong et al. 1990; Khoo 1989; Sasekumar et al. 1994) at Matang mangrove system in Peninsular Malaysia. According to Day et al. (1981), marine migrant fishes are the largest group in subtropical and tropical estuaries. They may occur in the estuaries both as adults and juveniles (Yasuki 2003). The juvenile stage came to mangrove area to look for food and shelter. These fishes spend their early juvenile stage in mangrove (as a nursery ground) before moving into the coast and sea to spend their juvenile and successive adult stages (Saifulhak & Yasuki 2003). In this study, juveniles from the families Lutjanidae and Serranidae were also caught.

Stations S1, S2 and S3 which are close to the flood mitigation channel showed the lowest water quality among all stations; S1 showed the lowest DO and the second highest Chl-*a*, S2 showed the highest BOD_5 and TAN and S3 showed the lowest pH, the second lowest DO, the second highest BOD_5 and the highest Chl-*a*. The pH values at stations S1 and S3 were significantly lower than those at the other stations before the flood mitigation works. The difference between DO at S1, S2, S3 and S6 in the present study is much higher. Furthermore, it was reported that BOD_5 and Chl-*a* at S6 was the highest (Buda et al. 2008) whereas in the present study, BOD_5 and Chl-*a* was the highest at S2. The decrease in water quality at S1, S2 and S3 could be attributed to the current activities in the area, namely, the flood mitigation works. During the mitigation works, the temporary settlement may have contributed to wastewater with high BOD_5 and low DO which impacted the water quality around stations S1, S2 and S3 as shown by studies of household wastewater in several residential areas in Kuching (Ling et al. 2010a). The dredged materials that are deposited inside or in the immediate vicinity of the park area are rich in sulfide and thus could have developed acidic conditions under oxidizing environment lowering the pH and DO values. DO values at all stations were lower than the Class E (Mangroves, Estuarine and River-mouth Water) standard of the Malaysia Marine Water Quality Criteria and Standard (MMWQCS) of 4 mg/L (DOE 2010).

S6 has high BOD_5 and TAN due to the input from Kampung Salak which is located on Salak Island. Studies conducted on Santubong River also showed high BOD_5 and TAN near residential areas (Ling et al. 2010b). In addition, the on-going construction of the diversion channel near the three sampling stations (S1-S3) where dredging was carried out could lead to resuspension of the sediment, as shown by the high TSS values at S1, S2 and S3, leading to higher oxygen demand in the water. This could have led to lower DO in the water column. Sediment is normally a sink for phosphorus and organic matter and when resuspended, phosphorus became available for algal bloom. The death of algae could have contributed to the high oxygen demand and low DO and decaying organic matter in the sediment leading to lower pH. At station S4, TSS was high at all depths due to sand mining activities that caused resuspension of the sediment. Comparing the TSS values of this study with that of the MMWQCS, TSS values at stations S1, S2, S3 and S4 exceeded the Class E standard of 100 mg/L (DOE 2010). Calculation of unionized ammonia, the toxic form of ammonia, from the TAN values showed that the values were less than 0.004 mg/L which is much lower than the MMWQCS standard of 0.07 mg/L (DOE 2010).

As Semariang mangrove area is part of the Kuching Wetland National Park and is one of the few remaining large and productive mangrove areas in Kuching that support substantial number of fish species as well as important commercial and recreational fishing grounds, it is crucial that the mangrove be managed properly. Environmental degradation, in terms of changes in water quality and habitat modification and loss, has been documented in many Asian countries and this is likely to be a contributing factor for the decline in fisheries resources (Stobutzki et al. 2006). Although there are some indirect existing pressure on the fish fauna and fisheries, direct existing pressure on fish fauna and fisheries at present is minimal. However, there are a number of potential pressures that could degrade the mangrove ecosystem at KWNP such as large input of freshwater into mangrove area especially at the area near Sungai Lemidin Kecil and Sungai Lemidin Besar once the flood mitigation channel is completed. Presently, there is very little input of freshwater into the rivers and salinity values range between 31.1 to 31.8 psu (CTTC 2010b). Even during high rainfall, the dilution effect on the salinity is reported to be minimal (CTTC 2010c). Therefore, a large fluctuation in salinity would change the fish fauna composition and species diversity. In their study on the effects of flood mitigation structures on the quality of estuarine and freshwater fish habitats in the lower Clarence River system of south-eastern Australia, Pollard & Hannan (1994), reported that both total and commercial fish species numbers generally declined with decreasing salinity; input of sewage from the nearby housing area and nutrients from agriculture and aquaculture activities (CTTC 2010d). With an increase in the population of Kuching city, more houses would be built to cater for the demand. A large input of sewage and nutrients from the nearby area could potentially cause eutrophication of the water bodies in the area; acidic runoff from acid sulfate soils of the dredged material of the flood mitigation channel. Acid sulfate soils could have destructive effects on fish fauna due to increased incidences of disease outbreaks, loss of spawning ground and in extreme cases fish kills; loss of mangrove area either due to harvesting or effects of other physical development. Loss of mangrove areas would mean reduction in input of detritus into the rivers which resulted in the loss of food sources to the ecosystem. Mangroves are highly productive systems and the export of organic and inorganic nutrients from these forests can considerably affect the biogeochemical cycles of coastal regions (Alongi et al. 1989; Rivera-Monroy et al. 1995) and overfishing if there is a lack of control on the number of fishing vessels operating in the park area.

CONCLUSIONS

The number of fish species present in Semariang mangrove area is comparable or even higher than those reported for other mangrove areas and the area is an important nursery ground. Stations near the flood mitigation works showed the lowest water quality among all stations in terms of pH, DO, BOD_5, Chl-*a,* TAN and TSS. Although the mangroves are facing a number of threats due to many developments outside the immediate vicinity of the area such as clearing for human settlements and infrastructure and illegal extraction of mangrove poles, the greatest threats would be due to the flood mitigation works where once the flood mitigation channel is operational, large volume of freshwater will be discharged into the area. This will reduce the salinity of the water and alter the fish fauna composition in the immediate vicinity of the mangrove area.

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