WWF

REPORT

MALAYSIA

2016

Water Quality Monitoring in Sugut River and its Tributaries

WWF-Malaysia Project Report

February/2016

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By

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Report Produced Under Project ST01081R
HSBC Bank Malaysia

February 2016

Acknowledgements

The authors of this report would like to thank the Sabah Forestry Department staff of Trusan-Sugut Forest Reserve for providing accommodation, transport and assistance in carrying out this project. Thanks also to WWF-Malaysia for providing us the opportunity to carry out the work.

This project was funded by HSBC Bank Malaysia.

Executive Summary

WWF-Malaysia initiated the water quality monitoring using physic-chemical and biological parameters along the lower Sugut River and its tributaries to monitor the status of water quality in the area, especially in areas surrounded by oil palm plantations. A total of 12 sampling stations were selected at four tributaries of Sugut River based on agreement with WWF staff members and Sabah Forestry Department (SFD) officer. The four tributaries were Sabang river (next to oil palm mill), Sugut river (next to oil palm plantation), Wansayan river (next to secondary forest) and Kepilatan river (next to Nipah forest). Fieldwork started in August 2015 and ended in November 2015, with a total of four samplings.

The results showed that the Water Quality Index (WQI) classified Sg. Sabang as very polluted, while Sg. Sugut, Sg. Wansayan and Sg. Kepilatan were slightly polluted. In accordance to INWQS, parameters TSS, DO and BOD for all tributaries were classified in Class III and IV. Table 3 summarizes the mean concentrations for each physico-chemical parameter at each tributary. Parameters TSS, TDS, COD, ammonia nitrogen, conductivity and salinity were found the highest at Sg. Sabang, followed by Sg. Kepilatan, which could be due to salinity effect. It also possibly caused by accumulation of sediments and nutrients, as estuary area has been reported constantly receives organic matter from inflowing tributaries (Day et al., 2007). COD was the highest at Sg. Sabang, and this parameter is known to represent total organic matter in water bodies (Hur & Cho, 2012).

The monitoring work presented in this report represents a baseline data on the water quality of Sugut River basin by using physico-chemical and biological parameters. It is recommended that development in the upper reaches of the Sugut river should be monitored to ensure that the quality of the river does not get worse. The next step would also be to engage with the oil palm plantation companies along the river to look at ways to mitigate river pollution.

1.0 Introduction

Healthy and functioning freshwater ecosystems are essential for water security and human well-being. A principal threat affecting the health of freshwater ecosystems is water pollution caused by land based sources or pollutants and human activities. Recognizing this fact, WWF-Malaysia promotes improved management of freshwater systems in key river basins in Sabah's terrestrial landscape.

Sugut River is one of WWF-Malaysia's four priority river systems identified through a Priority Conservation Mapping exercise. At approximately 178km long, the Sugut is the largest river in northeast Sabah, flowing from its high altitude origins in the Crocker Range through an extensive alluvial plain before draining into the Sulu Sea. In the river basin, a diverse range of forest types, including mixed dipterocarp forest, kapur forest, kerangas forest, freshwater swamp forest, peat-swamp forest, and mangrove forest occurs.

The Sugut River basin comes under the administration of the Beluran and Ranau districts. Records from the Beluran district office indicate that there are 1,730 people living in villages located along the lower Sugut River and they depend directly on the river. The local community here is principally involved in agriculture (palm-oil, paddy, fruit trees), aquaculture and capture fisheries in the rivers.

WWF-Malaysia initiated the water quality monitoring along the Sugut River and its tributaries to monitor the status of water quality in the area, especially in areas surrounded by oil palm plantations. The results will be used to strengthen WWF-Malaysia's advocacy work to reduce river pollution in the Sugut River Basin and work with oil palm companies for improvement of the river health.

Water quality physico-chemical and biological parameters have been extensively used to assess and monitor the status and quality in various water bodies (Spieles & Mitsch, 2000). However, in Malaysia, very few studies had emphasized the potential of benthic macroinvertebrates as bioindicators to evaluate the water quality of polluted rivers (Azrina et al., 2006). Therefore, this study presents the monitoring work of Sugut River basin and its tributaries to achieve the objectives: i. to systematic monitor water quality using physical, chemical and biological parameters in Sugut River and its tributaries; ii. to evaluate the status of ecosystem health of the Sugut River and its tributaries using water quality as the indicator; iii. to determine if oil palm plantation and mill activities in the surrounding land are polluting the Sugut river; and iv. to determine the possible sources of pollutants in the Sugut river from the water quality parameters.

2.0 Material and Methods

2.1 Study Area

Study area was located at Sugut Forest Reserve, which comprised of natural vegetation such as freshwater swamp forests, riverine forests, dry land forest on sandstone hills and also oxbow lakes. This area plays significant ecological functions for example providing habitat to several species of hornbills, proboscis monkeys, long-tailed and pig-tailed macaques, silvered langurs and numerous birds (Wong, 1998).

2.2 Sampling Design

A total of 12 sampling stations have been selected at four tributaries of Sugut River based on agreement with WWF staff members and Sabah Forestry Department (SFD) officer during the survey. The distance from each sampling station was within 100-300m, depending on the accessibility. Fieldwork campaign started in August 2015 and ended in November 2015, with a total of four samplings. Locations of sampling stations has been determined and recorded by using a global positioning system (GPS). Figure 1 exhibits the map of Sugut River and the tributaries in this study.

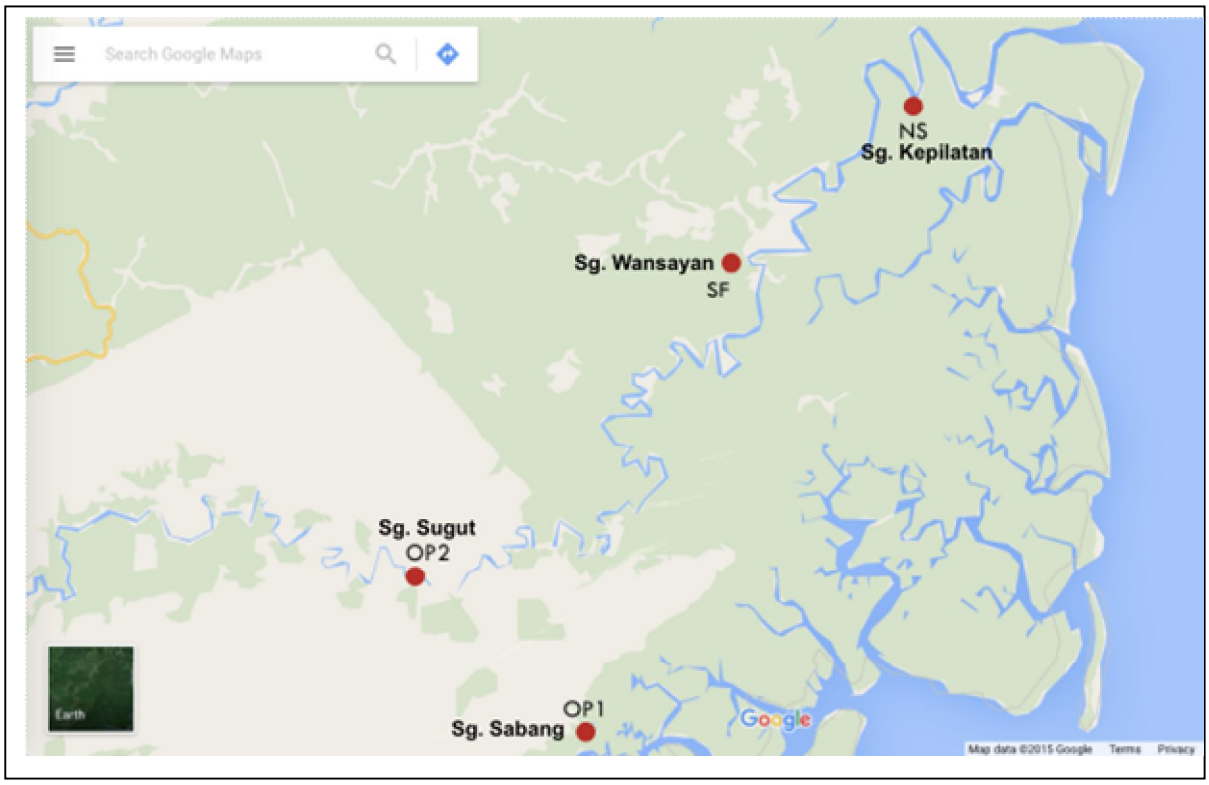

Figure 1 Map of Sugut River and its tributaries in this study. OP1 and OP2: oil palm plantation, SF: secondary forests, NS: nypa swamps.

2.2.1 Sg. Sabang

Sg. Sabang was an estuary with GPS coordinate 06°13.105' N and 117°34.019' E. IJM palm oil depot and staff settlement were built near to the river. Mangrove forests were the natural vegetation in this area. Photos 1 and 2 show the IJM palm oil depot and mangrove forests at the Sg. Sabang. The average width and depth of this station was 120-150m and 3-7m respectively.

Photo 1 IJM palm oil depot at the Sg. Sabang.

Photo 2 Mangrove forests at the Sg. Sabang.

2.2.2 Sg. Sugut

Sampling stations at Sg. Sugut were located along the tributary within housing settlements and oil palm plantation. The plantation was visible from the river, as shown in Photos 3 and 4. The GPS coordinate for Sg. Sugut was 06° 16.295' N and 117° 31.347' E. The average width and depth of this station was within 60-80m and 1-4m respectively.

Photo 3 A metal bridge that is being used by the locals.

Photo 4 Oil palm plantation (circled in red) that was visible from the river view.

2.2.3 Sg. Wansayan

The GPS coordinate of sampling stations at Sg. Wansayan was 06° 21.988' N and 117° 36.630' E. Secondary forests were the main natural vegetation at this area (Photo 5). The average width and depth of this station was within 70-90m and 5-6m respectively.

Photo 5 Secondary forests at Sg. Wansayan.

2.2.4 Sg. Kepilatan

Sampling stations at Sg. Kepilatan were located at GPS coordinate 06° 24.769' N and 117° 40.183' E. Nipah and secondary forests were the main vegetation in this area (Photo 6), with mixture of saline waters. The average width and depth of this station was within 50-60m and ~3m respectively.

Photo 6 Nipah and secondary forests at Sg. Kepilatan.

2.3 Water Quality

Water samples were collected near the surface of river and streams, and stored in 250 ml high-density polyethylene (HDPE) bottles pre-washed with 10% hydrochloric acid (HCl) and deionized water. *In situ* parameters such as temperature, pH, conductivity, salinity, dissolved oxygen (DO) and ammonia nitrogen were determined by using YSI water quality multiparameter (Photo 7). Samples were brought to Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah (UMS) for laboratory analysis: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), while total coliforms (TC) was analyzed by Chemsain Sdn Bhd. Interim National Water Quality Standards (INWQS) is a set of standards to indicate beneficial uses of water for each water quality parameter (Appendix 1). Water Quality Index (WQI) was then calculated to classify the river water quality (Appendix 2).

Photo 7 YSI water quality multiparameter.

2.3.1 Analytical Procedures

i. Biochemical oxygen demand (BOD)

Biochemical oxygen demand (BOD) is a parameter to determine the amount of dissolved oxygen used by the microorganisms such as aerobic bacteria to break down organic material present in a water sample. This parameter was analyzed at the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah (UMS) by using MERCK Pharo 100.

ii. Chemical oxygen demand (COD)

Chemical oxygen demand (COD) analysis was carried out by using USEPA Reactor Digestion Method (HACH DR900). Analysis was conducted at the ITBC, UMS.

iii. Total suspended solids (TSS)

Total suspended solid (TSS) was conducted in the lab by following Gravimetric Method and Photo 8 shows the filtration set for the TSS analysis:

i. Whatman glassfibre GF/C filter with 47mm diameter and 0.45mm pore size was placed

in clay dish and dried in drying oven at least for 1-2 hour at 103-105°C.

ii. The filter later was left to cool in desiccator for 1 hour.
iii. The initial weight was recorded (B) on an analytical balance.
iv. The filter was then placed on the filter holder, which has been assembled in the suction flask apparatus (connected and applied to vacuum source).
v. Water sample is then shook vigorously and then measured about 100ml in a 100ml volumetric flask.
vi. This portion of sample was poured carefully into the filter funnel.
vii. If the sample is very low in suspended material, larger volume of sample is used.
viii. When filtration is complete, the filtration is complete, the filter is then remove carefully with tweezers. It was then placed in clay dish and dried in drying oven at least for 1-2 hour at 103-105°C.
ix. The filter later was left to cool in desiccator for 1 hour.
x. The final weight was recorded (A) on an analytical balance.
xi. Total suspended solid was calculated by using following equation:

$$\text{Total suspended solid (TSS)} = \frac{A - B}{C} \times 10^6 \text{ mg/l}$$

where,

A = weight of filter disc + solids (g)
B = weight of filter disc (g)
C = volume of sample (ml)

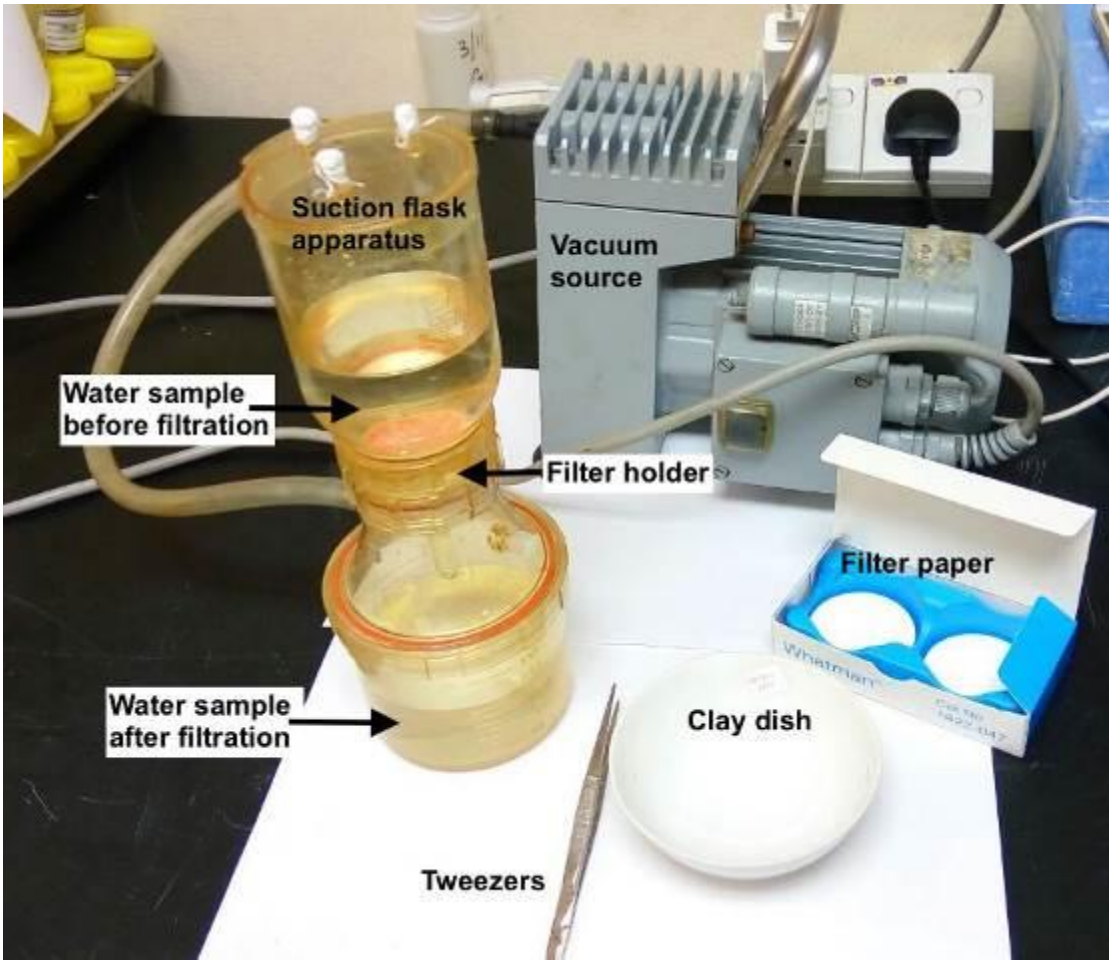

Photo 8 Filtration set for total suspended solids analysis.

2.4 Macroinvertebrates

Macroinvertebrates were collected from the riverbanks by using a D-frame net (mesh size 250 mm) with dipping technique for 2-minute duration. The leaf packs and macrophytes were washed into the net and then placed into a white pan and all the leaves, twigs and other large

debris were washed off and discarded. Macroinvertebrates then placed in universal bottle with 90-95% ethyl alcohol.

Specimens were sorted during the field and later preserved in 80% ethyl alcohol (Merritt & Cummins, 1984). The identification level was done until genus level and using key identification of Morse et al. (1994), and Yule and Yong (2004). All samples were labeled with date of sampling, location and brief description of the habitat type.

2.4.1 Biotic Indices

A biotic index is used to calculate habitat quality (water or sediment) based on measures of the relative abundance of different taxa present at site and the associated tolerance value of these taxa mixed to generate a numerical score (Canfield *et al.,* 1998). In this study, Biological Monitoring Work Party (BMWP) and Family Biotic Index (FBI) were used to calculate the biotic indices for the macroinvertebrate community in the streams of the Sugut River basin.

i. Biological Monitoring Work Party (BMWP)

The Biological Monitoring Work Party (BMWP) index is calculated by adding the individual tolerance values of all indicator organisms present (family level, except order Oligochaeta) (Friedrich *et al.,* 1996). This index summarizes presence/absence of families. For example, if the aquatic insects families were Gerridae, Corixidae and Coenagrionidae, the BMWP index is 16 (5+5+6), which categorized as moderate water quality. This index is based on a scale of 0 to 150 which above 150 indicates high water quality and 0 reflects poor water quality (Table 1).

Table 1 Scores of Biological Monitoring Work Party (BMWP)

Range of Species	**Water Quality Description**
> 151	Very high/good water quality
101 – 150	High water quality
51 – 100	Good water quality
15 – 50	Moderate water quality
0 – 10	Poor water quality

Source: Armitage *et al.* (1983)

ii. Family Biotic Index (FBI)

Family Biotic Index (FBI) is an index used for rapid assessment of stream quality. It uses the diversity of aquatic insect species as biological indicator. This index is based on a scale of 0-10 whereby 10 indicates very poor water quality and 0 indicates excellent water quality (Table 2):

$$FBI= \sum(x_i t_i)/(n)$$

Where, xi= number of individuals within a taxon
Ti= tolerance value of a taxon
N=total number of organism in the sample

Table 2 Scores of Family Biotic Index (FBI)

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

3.0 Results and Discussion

The Water Quality Index (WQI) classified Sg. Sabang as very polluted, while Sg. Sugut, Sg. Wansayan and Sg. Kepilatan were slightly polluted. In accordance to INWQS, parameters TSS, DO and BOD for all tributaries were classified in Class III and IV. Table 3 summarizes the mean concentrations for each physico-chemical parameter at each tributary. Parameters TSS, TDS, COD, ammonia nitrogen, conductivity, salinity were found the highest at Sg. Sabang, followed by Sg. Kepilatan, which could be due to salinity effect. It also possibly caused by accumulation of sediments and nutrients, as estuary area has been reported constantly receives organic matter from inflowing tributaries (Day et al., 2007). COD was the highest at Sg. Sabang, and this parameter is known to represent total organic matter in water bodies (Hur & Cho, 2012). In addition, a study by Harun et al. (2016) at the Lower Kinabatangan River catchment also indicated accumulation of dissolved organic matter (DOM) in Kg. Abai (estuary area).

Table 3 Summary of physico-chemical parameters at Sugut River basin.

Parameter	Sg. Sabang (OP1)	Sg. Sugut (OP2)	Sg. Wansayan (SF)	Sg. Kepilatan (NS)
pH	7.08	7.01	6.82	7.02
Temperature (°C)	29.65	30.33	29.6	29.15
Conductivity (µS/cm)	45574.65	155.28	180.3	4373.45
Dissolved oxygen (mg/l)	1.93	4.93	3.66	3.20
Salinity	27.29	0.07	0.11	2.22
TSS (mg/l)	141.5	100.28	82.9	59.45
TDS (mg/l)	27706.45	91.53	107.45	2669.7
BOD (mg/l)	1.27	3.19	4.01	2.49
COD (mg/l)	751.15	18.08	21.03	24.38
Total coliform	1108.28	3594.88	1753.25	3029.53
Ammonia nitrogen (mg/l)	98.44	0.52	0.7	4.75
Dissolved organic carbon (mg/l)	-	3.63	4.14	-
Water Quality Index (WQI)	**36.3** (Very polluted)	**77** (Slightly polluted)	**70.8** (Slightly polluted)	**61.8** (Slightly polluted)

The composition of macroinvertebrates captured in this study is presented in Table 4 and the images of the specimens are listed in Appendix 3. *Macrobrachium sp.* was dominant at all sampling station, with the highest number of individual found at Sg. Wansayan. It has been reported that family Palaemonidae is potentially considerable as indicators of organic pollution (Thorp et al., 2001). The second highest abundance of macroinvertebrates was the order Hemiptera from family Gerridae. The Gerrid has shown to exhibit relative tolerance to parameters COD, TSS and high temperature of streams at the Lower Kinabatangan River catchment (Harun et al., 2015), which makes the family as potential bioindicator for environmental disturbance.

Table 4 Composition of macroinvertebrates captured in Sugut River and its tributaries. OP1: Sg. Sabang; OP2: Sg. Sugut; SF: Sg. Wansayan, NS: Sg. Kepilatan.

Order	**Family**	**Genus**	**OP1**	**OP2**	**SF**	**NS**
Hemiptera	Gerridae	*Amemboa sp.*	-	-	5	52
		Cryptobates sp.	-	7	-	-
		Limnogonus sp.	3	-	-	-
Crustacea	Palaemonidae	*Macrobrachium sp.*	179	386	1847	394
	Sesarmidae	*Pseudosesarma sp.*	11	-	2	2
	Hymenosomatidae	Unknown	2	-	6	4
Odonata	Libellulidae	*Cratilla sp.*	-	-	5	-
	Calopterygidae	*Hetaerina sp.*	-	-	2	-
Coleoptera	Curculionidae	Unknown	-	-	-	1
Total			**195**	**393**	**1867**	**453**
BMWP			8.5 (poor)	9.7 (poor)	11.8 (poor)	11.8 (poor)
FBI			6 (fairly poor)	6 (fairly poor)	6 (fairly poor)	6 (fairly poor)

Figure 2 shows the cluster analysis for macroinvertebrates distribution across the tributaries in this study. Sg. Sugut and Sg. Kepilatan were found to have similar distribution of macroinvertebrates, in comparison with Sg. Sabang and Sg. Wansayan. In terms of diversity, Sg. Wansayan has the most diverse macroinvertebrates composition (Table 4). Sg. Wansayan also recorded the order Odonata, from families Libellulidae and Calopterygidae, which were not found at the other tributaries. Odonata has been found to indicate environmental disturbance, possibly pollution or logging activities (Orr et al., 2004). This is consistent with the water quality physico-chemical parameters, which indicated TSS in Class III, could be derived from logging activities or active land development in the area and at the upper part of Sugut Forest Reserve.

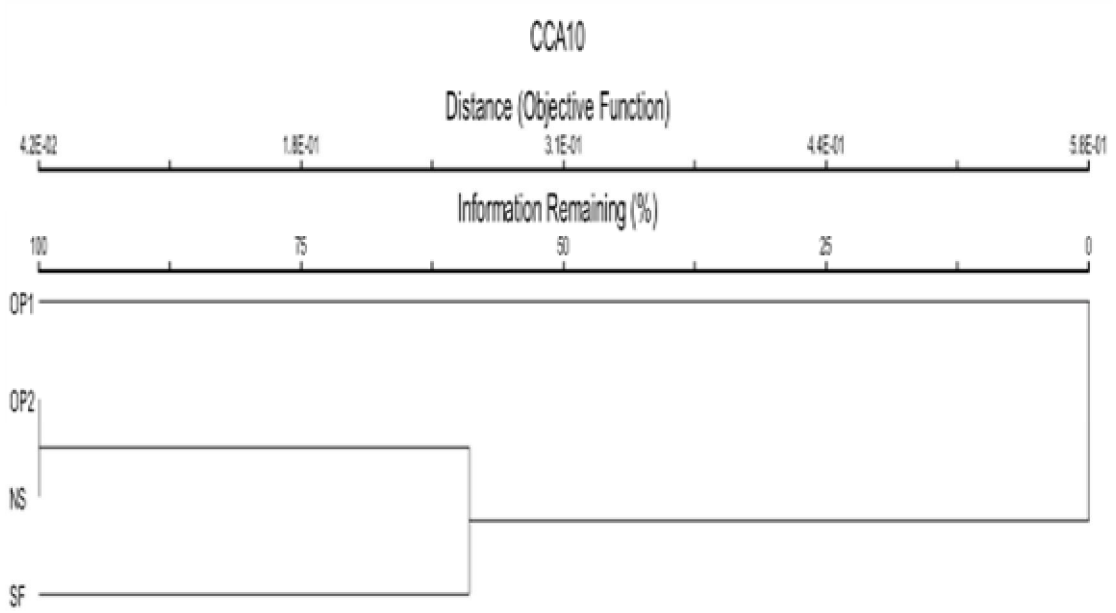

Figure 2 Cluster analysis for macroverintebrates distribution at each tributary: OP1: Sg. Sabang; OP2: Sg. Sugut; NS: Sg. Kepilatan; and SF: Sg. Wansayan.

3.1 Sg. Sabang

3.1.1 Water Quality Physico-chemical Parameters

Table 5 summarized the water quality physico-chemical parameters and the Water Quality Index (WQI) values at Sg. Sabang, which were taken from August until November 2015. The results indicated that parameters DO, COD and ammonia nitrogen were categorized in Class IV and V, which defined as very polluted, based on INWQS for Malaysia (Appendix 1). TSS was in Class IIB and III, while total coliform was categorized in Class I and IIA. This could be due to the location of Sg. Sabang at the estuary area, where there was salinity effect (Table 5).

Table 5 Physico-chemical parameters of Sg. Sabang.

Parameter	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
pH	7.11	7.05	7.13	7.03
Temperature (°C)	30.3	29.6	29.2	29.5
Conductivity (µS/cm)	42778.8	44970.6	47780.8	46768.4
Dissolved oxygen (mg/l)	2.37	1.85	1.61	1.88
Salinity	26.0	26.82	28.71	27.64
TSS (mg/l)	90.2	165.3	169.9	140.6
TDS (mg/l)	26565.5	27265.3	29001.4	27993.6
BOD (mg/l)	0.78	0.64	1.86	1.80
COD (mg/l)	1693.3	398.6	391.0	521.7
Total coliform	1.3	3633.3	363.3	435.2
Ammonia nitrogen (mg/l)	106.80	97.41	103.01	86.55
Water Quality Index (WQI)	**34** (Very polluted)	**35** (Very polluted)	**38** (Very polluted)	**38** (Very polluted)

3.1.2 Macroinvertebrates

A total of 195 individual were collected during the whole sampling campaign (Table 6), with the highest number in August 2015 and the lowest in November 2015, which the latter probably caused by precipitation event during the sampling activity. Both BMWP and FBI indices indicated that the quality of Sg. Sabang as poor and fairly poor respectively, which was consistent with the physico-chemical parameters. However, less number of macroinvertebrates found in this area also could be due to the salinity effect, as most macroinvertebrates species that serve as indicator for healthy aquatic ecosystem are not be able to survive in water bodies with high salinity (Horrigan et al., 2005).

Table 6 Macroinvertebrates found at Sg. Sabang during the sampling at Sugut River basin.

Order	Family	Genus	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
Hemiptera	Gerridae	*Limnogonus sp.*	0	0	0	3
Crustacea	Palaemonidae	*Macrobrachium sp.*	138	10	24	7
	Sesarmidae	*Pseudosesarma sp.*	0	2	8	1
	Hymenosomatidae	Unknown	0	0	2	0
Total			138	12	34	11
BMWP			8 (poor)	8 (poor)	8 (poor)	10 (poor)
FBI			6 (fairly poor)	6 (fairly poor)	6 (fairly poor)	6 (fairly poor)

3.2 Sg. Sugut

3.2.1 Water Quality Physico-chemical Parameters

Table 7 summarized the water quality physico-chemical parameters and the WQI values at Sg. Sugut. The results showed that parameters DO, BOD, total coliform, TSS and ammonia nitrogen were categorized within Class IIA to III, according to the INWQS for Malaysia (Appendix 1). The concentration of dissolved organic carbon (DOC) was consistently low during the whole sampling campaign (Table 7), compared to DOC at the Lower Kinabatangan River catchment (mean 11.38 mg/l) (Harun et al., 2016). This could reflect the low concentration of dissolved organic matter at Sg. Sugut in comparison to other area with almost similar land use type (oil palm plantation).

Table 7 Physico-chemical parameters of Sg. Sugut, Sugut River basin.

Parameter	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
pH	7.69	6.96	6.73	6.64
Temperature (°C)	32.1	30.9	29.4	28.9
Conductivity (µS/cm)	174.8	161.1	151.7	133.5
Dissolved oxygen (mg/l)	5.03	4.66	4.77	5.25
Salinity	0.07	0.07	0.06	0.06
TSS (mg/l)	69.1	80.9	127.7	123.4
TDS (mg/l)	100.0	94.0	91.1	81.0
BOD (mg/l)	4.48	3.03	3.68	1.56
COD (mg/l)	19.7	19.3	19.3	14.0
Total coliform	139.5	6400.0	640.0	7200.0
Ammonia nitrogen (mg/l)	0.44	0.54	0.59	0.50
Dissolved organic carbon (mg/l)	3.19	3.82	4.34	3.14
Water Quality Index (WQI)	**77** (Slightly polluted)	**76** (Slightly polluted)	**75** (Slightly polluted)	**80** (Slightly polluted)

3.2.2 Macroinvertebrates

A total 393 individual were found during the sampling period from September until November 2015 (Table 8), and consisted of 2 orders and 2 families. Both BMWP and FBI indices indicated that the quality of Sg. Sugut as poor and fairly poor respectively.

Table 8 Macroinvertebrates collected at Sg. Sugut during the sampling campaign.

Order	Family	Genus	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
Hemiptera	Gerridae	*Cryptobates sp.*	NA	0	2	5
Crustacea	Palaemonidae	*Macrobrachium sp.*	NA	49	156	181
Total			NA	49	158	186
BMWP			NA	8 (poor)	10 (poor)	11 (poor)
FBI			NA	6 (fairly poor)	6 (fairly poor)	6 (fairly poor)

3.3 Sg. Wansayan

3.3.1 Water Quality Physico-chemical Parameters

Physico-chemical parameters at Sg. Wansayan were characterized by DO, TSS, BOD, ammonia nitrogen and total coliform classified within Class IIA to III (Table 9) based on INWQS for Malaysia (Appendix 1). The results also showed that COD was in Class I and IIB, which indicate fairly low organic pollution. The concentration of DOC was also consistently low during the whole sampling campaign, compared to DOC at secondary forests in Lower Kinabatangan River catchment (mean 9.60 mg/l) (Harun et al., 2016). This could reflect the low concentration of dissolved organic matter at Sg. Wansayan in comparison to other area with almost similar land use type.

Table 9 Physico-chemical parameters of Sg. Wansayan.

Parameter	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
pH	6.74	7.26	7.06	6.21
Temperature (°C)	30.7	30.2	28.8	28.7
Conductivity (µS/cm)	151.6	222.5	175.3	171.8
Dissolved oxygen (mg/l)	4.18	4.08	3.19	3.20
Salinity	0.06	0.20	0.08	0.08
TSS (mg/l)	78.3	48.5	125.0	79.8
TDS (mg/l)	85.7	131.2	106.6	106.3
BOD (mg/l)	3.52	3.67	4.30	4.56
COD (mg/l)	20.7	21.7	24.7	17.0
Total coliform	217.7	2666.0	296.0	3833.3
Ammonia nitrogen (mg/l)	0.90	0.79	0.71	0.4
Dissolved organic carbon (mg/l)	3.36	3.73	4.79	4.67
Water Quality Index (WQI)	**70** (Slightly polluted)	**74** (Slightly polluted)	**69** (Slightly polluted)	**70** (Slightly polluted)

3.3.2 Macroinvertebrates

Table 10 summarized the composition of macroinvertebrates captured from Sg. Wansayan during the sampling activity. A total of 1,867 individuals representing 3 orders and 6 families were collected from the tributary. The highest number of macroinvertebrates was captured in November 2015. Both BMWP and FBI indices indicated that the quality of Sg. Wansayan was poor and fairly poor respectively.

Table 10 Composition of macroinvertebrates from Sg. Wansayan.

Order	Family	Genus	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
Hemiptera	Gerridae	*Amemboa sp.*	0	0	1	4
Crustacea	Palaemonidae	*Macrobrachium sp.*	135	290	543	879
	Sesarmidae	*Pseudosesarma sp.*	0	1	1	0
	Hymenosomatidae	Unknown	2	0	1	3
Odonata	Libellulidae	*Cratilla sp.*	2	1	1	1
	Calopterygidae	*Hetaerina sp.*	0	0	0	2
Total			139	292	547	889
BMWP			12 (poor)	10 (poor)	12 (poor)	13 (poor)
FBI			6 (fairly poor)	6 (fairly poor)	6 (fairly poor)	6 (fairly poor)

3.4 Sg. Kepilatan

3.4.1 Water Quality Physico-chemical Parameters

Parameters DO, TSS, BOD, COD, total coliform and ammonia nitrogen at Sg. Kepilatan were categorized within Class IIB until V, according to the INWQS for Malaysia (Appendix 1; Table 11), which could be due to the salinity effect at the tributary. The WQI for Sg. Kepilatan identified the tributary as slightly polluted.

Table 11 Physico-chemical parameters of Sg. Kepilatan.

Parameter	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
pH	6.81	7.16	7.16	6.94
Temperature (°C)	29.9	30.2	27.9	28.6
Conductivity (µS/cm)	5886.0	2996.0	4834.3	3777.5
Dissolved oxygen (mg/l)	2.93	3.50	2.68	3.68
Salinity	2.88	1.46	2.46	2.07
TSS (mg/l)	46.6	26.4	90.2	74.6
TDS (mg/l)	3527.4	1868.8	2986.9	2295.7
BOD (mg/l)	2.31	2.34	3.3	2.0
COD (mg/l)	20.3	25.9	29.0	22.3
Total coliform	389.7	7966.7	395.0	3366.7
Ammonia nitrogen (mg/l)	0.64	4.96	7.67	5.72
Water Quality Index (WQI)	**69** (Slightly polluted)	**63** (Slightly polluted)	**54** (Slightly polluted)	**61** (Slightly polluted)

3.4.2 Macroinvertebrates

A total of 453 individuals of macroinvertebrates from 3 orders and 5 families were captured at Sg. Kepilatan (Table 12). The highest number of individual was collected in October 2015, and the lowest in November 2015. Both BMWP and FBI indices indicated that Sg. Kepilatan was poor and fairly poor quality respectively.

Table 12 Composition of macroinvertebrates at Sg. Kepilatan.

Order	Family	Genus	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015
Hemiptera	Gerridae	*Amemboa sp.*	14	2	23	13
Crustacea	Palaemonidae	*Macrobrachium sp.*	69	116	179	30
	Sesarmidae	*Pseudosesarma sp.*	0	0	2	0
	Hymenosomatidae	Unknown	3	1	0	0
Coleoptera	Curculionidae	Unknown	1	0	0	0
Total			87	119	204	43
BMWP			13 (poor)	10 (poor)	13 (poor)	11 (poor)
FBI			6 (fairly poor)	6 (fairly poor	5.8 (fairly poor)	6 (fairly poor

4.0 Conclusion

Based on the surface water quality physico-chemical parameters, Water Quality Index (WQI) and macroinvertebrates assessments, it was concluded that the quality of Sugut River basin was in moderate level, with slight pollution. Agricultural activities i.e. fertilizers from oil palm plantations, land use development and sampling period were among the factors that play significant role in determining the quality of Sugut River basin, as reflected by parameters total suspended solids (TSS), chemical oxygen demand (COD) and ammonia nitrogen. Sg. Sabang exhibits the lowest WQI values and high values of chemical oxygen demand (COD) and ammonia nitrogen. However, it could possibly caused by interference of salt ions from the estuary.

In terms of biological parameter, Sg. Wansayan has the most diverse macroinvertebrates, which could be due to high dissolved organic matter (DOM) (provide food to the aquatic organisms), as reflected by dissolved organic carbon (DOC) and ammonia nitrogen parameters. Furthermore, there was low interference of salt ions as demonstrated by low salinity value in this area. Macroinvertebrates from order Palaemonidae has the highest abundance throughout the sampling program at all sampling stations, followed by order Hemiptera and Odonata. Palaemonidae has been indicated significant potential as bioindicators for organic pollution, with moderate tolerance to environmental disturbances. The abundance of Palaemonids possibly correlated with moderate organic pollution and active land development such as logging and agricultural activities in this area or at the upper part of Sugut Forest Reserve.

5.0 Recommendations

The monitoring work presented in this report represents a baseline data on the water quality of Sugut River basin by using physico-chemical and biological parameters. Recommendations for future river quality monitoring works include:

1. A regular monitoring program on land development such as land clearing for new plantation area and road building construction works in particular at the upper part of Sugut River basin in order to control the export of sediment into rivers/streams, as it could contribute to high suspended materials concentration in the aquatic ecosystems. High suspended materials in water bodies will lead to mortality of aquatic organisms i.e. fish, macroinvertebrates, planktons.
2. Present the findings to the IJM plantation which is the biggest oil palm plantation at the area and find ways to work with them to mitigate the worsening of the river quality of the river.
3. A frequent monitoring work of the application of fertilizers at surrounding oil palm plantations. Only environmental compliance and correct amount of fertilizers should be used, as excessive fertilizers will contribute to high concentration of dissolved nutrients, which may lead to problems such as eutrophication.
4. Develop a local sampling program, sub-sampling within the river basin, as to establish a clearer link between land use and water quality parameters; acknowledging that there is unlikely to be a clear relationship between oil palm plantations and water quality parameters i.e. fingerprints for pollutants derived from oil palm plantations/mills. For example, parameter biochemical oxygen demand (BOD) of samples from rivers/streams doesn't show absolute indication of bacterial activity derived from palm oil mill effluent (POME); or high concentration of ammonia nitrogen in any water bodies is evidently caused by fertilizers from agricultural activities. There are many other factors that need to be taken into consideration such as type of soil or leachate from groundwater from nearby land use activities.
5. Examine the water quality of tributaries at the upper areas and/or in areas of pristine rainforest as a comparison to the lower part of Sugut River basin.
6. Develop a more thorough method/protocols to analyze samples more quickly in areas with limited access to laboratory facilities.

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Appendix 1

Excerpt of Interim National Water Quality Standards for Malaysia (after Zainudin, 2010)

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
BOD_5	mg/l	1	3	3	6	12	> 12
COD	mg/l	10	25	25	50	100	> 100
DO	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH		6.5 - 8.5	6.5 - 9.0	6.5 - 9.0	5 - 9	5 - 9	-
Color	TUC	15	150	150	-	-	
Elec. Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables		NV	NV	NV	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste		NOT	NOT	NOT	-	-	-
Total Suspended Solids	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Fecal Coliform	counts/100ml	10	100	400	5000 (20000)*	5000 (20000)*	-
Total Coliform	counts/ 100 ml	100	5000	5000	50000	50000	>50000

Note :
NV = No visible floatable materials/debris NOT = No objectionable taste

Class		Definition
I	·	Conservation of natural environment.
	·	Water supply I – Practically no treatment necessary (except by disinfection or boiling only).
	·	Fishery I – Very sensitive aquatic species.
IIA	·	Water supply II – Conventional treatment required.
	·	Fishery II – Sensitive aquatic species.
IIB	·	Recreational use with body contact.
III	·	Water supply III – Extensive treatment required.
	·	Fishery III – Common of economic value, and tolerant species; livestock drinking.
IV	·	Irrigation.
V	·	None of the above.

Department of Environment (DOE) Malaysia Water Quality Index Classification (after Zainudin, 2010)

Parameters	Unit	Classes				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand (BOD_5)	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand (COD)	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	mg/l	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solids (TSS)	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)	mg/l	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Appendix 2

Formulae for Calculating Water Quality Index (WQI) In Malaysia

Subindex for DO (%)

$SIDO = 0$	$x < 8$
$SIDO = 100$	$x > 92$
$SIDO = -0.395 + 0.030x^2 - 0.00020x^3$	$8 < x < 92$

Subindex for BOD

$SIBOD = 100.4 - 4.23x$	$x < 5$
$SIBOD = 108*e^{-0.055x} - 0.1x$	$x > 5$

Subindex for COD

$SICOD = -1.33x + 99.1$	$x \leq 20$
$SICOD = 103*e^{-0.0157x} - 0.04x$	$x > 20$

Subindex for Ammonia nitrogen

$SIAN = 100.5 - 105x$	$x \leq 0.3$
$SIAN = 94*e^{-0.573x} - 5 \mid x - 2 \mid$	$0.3 < x < 4$

Subindex for TSS

$SITSS = 97.5*e^{-0.00676x} + 0.05x$	$x \leq 100$
$SITSS = 71*e^{-0.0016x} - 0.015x$	$100 < x < 1000$
$SITSS = 0$	$x \geq 1000$

Subindex for pH

$SIPH = 17.2 - 17.2x + 5.02\ x^2$	$x < 5.5$
$SIPH = -242 + 95.5x - 6.67\ x^2$	$5.5 \leq x < 7$
$SIPH = -181 + 82.4x - 6.05\ x^2$	$7 \leq x < 8.75$
$SIPH = 536 - 77.0x + 2.76\ x^2$	$x \geq 8.75$

Note: * = multiply
x = concentration in mg/l

Appendix 3

Macroinvertebrates of the Sugut River Basin

Order: Crustacea
Family: Palaemonidae
Genus: *Macrobrachium sp.*
Tributary: Sg. Sabang, Sg. Sugut, Sg. Wansayan, Sg. Kepilatan

Order: Hemiptera
Family: Gerridae
Genus: *Amemboa sp.*
Tributary:Sg. Wansayan, Sg. Kepilatan

Order: Crustacea
Family: Sesarmidae
Genus: *Pseudosesarma sp.*
Tributary: Sg. Sabang, Sg. Wansayan, Sg. Kepilatan

Order: Crustacea
Family: Hymenosomatidae
Genus: Unknown
Tributary: Sg. Sabang, Sg. Wansayan, Sg. Kepilatan

Order: Hemiptera
Family: Gerridae
Genus: *Cryptobates sp.*
Tributary: Sg. Sugut

Order: Hemiptera
Family: Gerridae
Genus: *Limnogonus sp.*
Tributary: Sg. Sabang

Order: Odonata
Family: Calopterygidae
Genus: *Hetaerina sp.*
Tributary: Sg. Wansayan

Order: Odonata
Family: Libellulidae
Genus: *Cratilla sp.*
Tributary: Sg. Wansayan

About WWF-Malaysia

WWF-Malaysia (World Wide Fund for Nature-Malaysia) was established in Malaysia in 1972. It currently runs more than 90 projects, covering a diverse range of environmental conservation and protection work, from saving endangered species such as tigers and turtles, to protecting our highland forests, rivers and seas. The national conservation organisation also undertakes environmental education and advocacy work to achieve its conservation goals. Its mission is to stop the degradation of the earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the nation's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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