Water Quality Study Using Macrobenthos as Bioindicator and Impact of Flood at Dabong, Kelantan

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Abstract. In 2014 and 2015, floods have affected Malaysia and more than 200,000 people were affected while 21 were drown.This flood has been described as the worst floods in decades. Disturbances from flood is one of the factors that affect the habitat or fish communities in the river. It also may affect the quality of water in terms of physical, biological or chemical. Most people do not notice the impact of flood towards changes of water quality due to the lack of exposure in this field. They consider river water quality remains the same and can ne use as normal. Polluted water consumed may contain pathogens or toxic matter that can bring harm to human health even affect living organisms. This study was conducted to determine the water quality level using Water Quality Index analysis and Biological Water Quality Index analysis by considering macrobenthos as bioindicator and both result will be compared and also will be compared with the water quality before the flood event to see the impact of flood toward river water quality. In this study, there are six parameters involved to analyse the water quality of river which is Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), pH, Dissolved Oxygen (DO) and Total Suspended Solids (TSS). The sub-index values of each parameterare calculated to obtain water quality index. Besides that, there is alternative method conducted by using macrobenthos as a bioindicator based on Biological Water Quality Index (BWQI). Macrobenthos obtained will be analysed and the score will be calculated to determine the status of river. A total of 3 stations and 2 points at each station were selected for macrobenthos and water quality analysis sampling which were taken three times on 5 June 2015, 7 August 2015 and 30 September 2015 which were at Sungai Jelawang, Sungai Lah and Sungai Kenerong. The result showed that, WQI for Sungai Jelawang is 90.41±0.45 which can be categorised as Class II (Rather Clean). Same as Sungai Lah, the WQI is 83.89±1.43, Class II (Rather Clean). While Sungai Kenerong, the WQI is 92.55±0.99 which can be categorised as Class I (Clean). For BWQI, the collected and calculated data shows BWQI for Sungai Jelawang is 6.11 (Level II) which can be categorised as Rather Clean. However, BWQI for Sungai Kenerong was 8.28 (Level I) which can be categorised as Clean. On the other hand, result for BWQI was recorded as 6.60 (Level II, Rather Clean) for Sungai Lah. Overall, when comparing both results WQI and BWQI showed the consistencies between these two methods which both gave the similar results. This study suggests that benthic macroinvertebrate can be used as indicators of water pollution with having the advantages of low cost, easy identification and it provides a better reflection of water quality than using physicochemical parameters alone.

Introduction

Flood can be defined as a body of water that rise and overflow over a surface which was not covered with water before. It also can be defined as overflowing of the bank of a stream, lake or drainage system of water onto adjacent land as an effect of storm, snow and channel obstruction. Flooding is a common and expected occurrence in Malaysia's east coast. That is why many houses in areas near rivers are built on stilts. But the relentlessness of the rains, strong winds and the breadth of the areas affected have taken many by surprise. There are many impact of flood which can be positive or negative and there are differences of water quality before and after flood. Water quality in river changes because it affected by many factors including domestic and industrial waste water, sewage discharge, fuel product or pesticide from agriculture area. Rivers and streams are the main sources and play an important role in providing water that support living things, ecosystem survival, health and especially human. The quality of river water also govern the extent to which essential to be used as water supply for industries and domestic uses; recreational usage such as swimming and fishing; transportation mode in early civilisation, for navigational purposes and other numerous activities.

The quality of river water is directly affected by the amount of waste discharged into the river and its assimilative capacity. The factors contributing to the river pollution in Malaysia are because of the increase in the number of polluting sources such as sewage treatment plants, poultry farms, industrial wastewater, which were not managed properly and effectively. The decreasing number of clean raw water is concerning us due to increasing of number of population, which tend to increase water demand. Disturbances from flood is one of the factors that disturb the habitat or fish communities in the river. It also may affect the water quality of river in terms of physical, biological or chemical. Many people do not notice the impact of flood toward changes of water quality because less of exposure in this field. They consider river water quality to remain the same and thus can be used as usual. Polluted water may contain pathogens or toxic that can bring harm to human health even affect living organisms. In order to avoid this from happening, this study was conducted to determine the water quality level by using Water Quality Index analysis and Biological Water Quality Index analysis by using macrobenthos as bioindicator and both result will be compared and also will be compared with the water quality before the flood event to see the impact of flood toward river water quality. The WQI and BWQI sampling were taken three times which were on 5 June 2015, 7 August 2015 and 30 September 2015 at three stations which is Sungai Jelawang, Sungai Lah and Sungai Kenerong.

Previous Studies

From previous studies, there were positive and negative impact of flood which can affect the area or river. Some of the positive impact of flood is it can enrich and rejuvenating certain factor of biodiversity in the flood plain, replenishes land with nutrient rich soil that good for agriculture. The negative impact of flood is flooding can threaten lives, destroy properties and can also affect the water quality of river [1].

The impact towards water quality is one of the negative impact. Water quality after the flood usually is changing because of the surface runoff water where usually it comes from nearby land use which can be agricultural activities, animal waste, industrial area and logging activities. All these activities affect the nutrient and river water properties. Previous studies found water quality changes from flooding have shown the declines in BOD, coliform bacteria and fecal coliform bacteria [2]. River water overflowing onto the floodplain will increase the availability of shelter and allochthonous food sources and enrich the water with nutrients carried down from slopes or nutrients present in flooded organic or inorganic materials [3]. However, the large input of organic matters to aquatic floodplain habitats may reduce dissolved oxygen and result in the emigration or death of a great number of fishes [4].

Macrobenthos are organisms that more than 1mm in size and are large enough to be seen with the naked eyes. They inhabit all types of running waters, from fast flowing mountain streams to slow moving river even at or below seafloor. Biosurveys and habitat assessments can be used for many purposes because macrobenthos are stationary and are sensitive to different degrees of pollution; changes in their abundance and variety vividly illustrate the impact pollution on the stream. Previous study shown using the macrobenthos as a biological indicator is another way in determining the class and status of river [5]. By using Biological Water Quality Index (BWQI), water quality trends can be identified whether there are increasing or decreasing over year [6].The community structures of benthic fauna in all rivers also can be influenced by the flood. Benthic fauna responds directly to the flood [7]. The flood obviously alters species composition in the high gradient portion of the stream, increasing numbers of some, reducing numbers of other, and probably eliminating several species [8]. Floods also can increase the abundance and richness of fish assemblages in streams by temporary connecting isolated pools and creating potential movement opportunities previously impeded by barriers [9].

Methodology

This chapter discuss on the implementation methods that have been used in order to achieve the objectives stated for this study. The methods required to be followed before on the site to make sure the information obtained from the right sources and make the process of study on data that will assemble later easy. The objectives of the study have been determined based on six parameters which are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS) Ammonical Nitrogen (AN), pH, Dissolved Oxygen (DO) by referring to Water Quality Index (WQI) through field and laboratory analysis. Laboratory analysis will be conducted at Environmental Laboratory, Faculty of Civil Engineering, while observation of invertebrates and aquatic life will be conducted on site. To make sure the precision and effectiveness of study, research methodology must be conducted in details.

Area of Sampling Station

This study was located in Kelantan which involved several rivers in Dabong District. Figure 1 shows the location of the area of sampling stations which were very important for domestic uses that cover the residential area in Dabong and as a habitat and bio-diversity protection. Sampling were conducted three times in June, August and September 2015. Field samplings were carried out from 3 stations which were tributaries of Sungai Galas namely Jelawang, Kenerong, and Lah. Three sampling stations were established with 2 points at each station for water quality and biological sampling respectively.The coordinates of location at Dabong are shown in Table 1.

Figure 1: Location area of sampling station, Dabong

Sampling Method

Water sample were taken from the station or site selected at location area. This were taken at upstream and downstream of the river and will be tested at the laboratory. There were several factors that need to be considered while sampling. The bottle for the sampling need to be rinsed to avoid any reaction from particle or contamination from previous work and need to be marked to avoid any mistake or confusion. Sample taken need to be tested and analysed at the laboratory.

Table 1: Coordinates Location of Sampling

No.	Site	Main River	Point	Longitude	Latitude
1	Sg. Jelawang	Sg. Galas	1	5.34387°N	101.98347°E
2	Sg. Jelawang		2	5.34369°N	101.98136°E
3	Sg. Lah		1	5.15234°N	101.97446°E
4	Sg. Lah		2	5.15374°N	101.97475°E
5	Sg. Stong/Kenerong		1	5.29127°N	101.98444°E
6	Sg. Stong/Kenerong		2	5.29104°N	101.98325°E

In Situ Analysis Method

In-situ measurement of water quality have been made for parameters of dissolved oxygen (DO), pH, temperature and conductivity using a YSI ProPlus meter, whereas other parameters such as total suspended solid (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and ammoniacal-nitrogen (NH_3N) were determined by APHA standard method procedures [10]. Determination of water quality index (WQI) according to the equation from Malaysian Department of Environment (DOE) was calculated based on Eq. (1).

$$WQI = 0.22(SIDO) + 0.19(SIBOD_5) + 0.16(SICOD) + 0.15(SIAN) + 0.16(SITSS) + 0.12(SIpH) \quad (1)$$

where,
SI = Sub-index for each parameter

Laboratory Testing

This study needs an analysis from laboratory to determine the quality of water and benthic life at the river. Laboratory testing for Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solid, and Ammoniacal Nitrogen were conducted by following the standard method shown in Table 2. Analysis were conducted at the Environmental Laboratory at Faculty of Civil Engineering, UTM.

Table 2: Standard Method

Parameter	Standard Method
Biochemical Oxygen Demand (BOD)	APHA 52210-B
Chemical Oxygen Demand (COD)	APHA 5220-C
Ammonial Nitrogen (NH_3N)	HACH Standard Procedure 8038
Total Suspended Solid (TSS)	APHA 2540-D.

Macrobenthos Analysis

Macrobenthos analysis is a biological analysis method that can be used to determine the water quality using Biological Water Quality Index (BWQI). It is easy to be conducted compared to conventional method and needed only minimum time of training. Furthermore, it does not need any chemicals and will not harm or pollute the ecosystem of the river while study is being carried out. This method is an alternative method to determine the quality of water or level of water pollutant despite using the conventional method which is costly, take a long time, required a skilled person to using high technology equipment and dangerous chemicals [11].

Basics Equipment Used in Macrobenthos Method. The equipment for this method was easy to use and perform. This is listed in Table 3 shown below. A macrobenthos sampling was taken using large square dip net. A dip net was placed on the shallow running water substrate against the water flow. Then, the substrate was disturbed and boulders in that area were rubbed gently to dislodged the organisms into the net. Samples collected were rinsed using 300µm sieve to remove the sediments and leaving behind any invertebrates and kept in a bottles filled with 70% ethanol for temporary preservation before being analysed in laboratory.

Table 3: Equipment used for BWQI Method

Equipment	Function
Large Square Net	Taking a sample of macrobenthos
Universal Bottles	Placing the macrobenthos
Forceps	Taking a sample of macrobenthos from square net and put into another bottles or tray
Brochure	Identify a sample of macrobenthos
Lens	Larger and clear an image of macrobenthos
Spoon	Transfer sample from another bottles or tray
Stick Current Meter Digital	Measuring river current and height of river water level
Pipette	Sucking/ Inhaling tiny objects

Analysis of Macrobenthos. Macrobenthos will be placed in universal bottles in certain duration for the process of recognition and identification based on guidelines given by Department of Irrigation and Drainage. Identification of macroinvertebrates was performed using a stereo microscope. References used to assist the identification process are from [12]. Score for every type of macrobenthos will be recorded in Biological Water Quality Index Score Form and were calculated for BWQI using Eq. (2).

$$\text{Biological Water Quality Index (BWQI)} = \frac{\text{Score of macrobenthos}}{\text{Types of macrobenthos}} \quad (2)$$

Chart Score of Macrobenthos. Score of macrobenthos can be determined by distributing each macrobenthos into their categories or class, and were marked even the if the number of that category is only one. Each type only can be counted once. The score for each category will be added after an ammonals has been found and the score will be divided by types of macrobenthos that have noted in the table to measure the average. Determining the average is very important to subtract any error that may have made from sampling. The result of Biological Water Quality Index can be evaluated base on Table 4 below.

Table 4: Biological Water Quality Index (BWQI)

Score	Water Quality	Level Condition
7.6 – 10	Very Clean	Level I
5.1 – 7.5	Rather Clean	Level II
2.6 – 5.0	Rather dirty water sewage	Level III
1.0 – 2.5	Dirty	Level IV
0.0 – 0.9	Very dirty	Level V

Data Collection Method

Data for this study were taken by in-situ analysis and manual method to analyse macrobenthos. Data for in-situ analysis which is parameter for water consist of pH, temperature, turbidity which is taken directly using portable equipment turbidity meter and YSI Proplus. In–situ data were taken three times to avoid any parallax error. In – situ data then recorded into a form for the purpose of monitoring the physical condition of the river and to determine Water Quality Index. While, macrobenthos observed score were taken and being calculated for the final reading for water quality analysis based on Biological Water Quality Index.

Results and Discussions

In this study, the analysis made on site and laboratory from data obtained at Sungai Jelawang, Sungai Kenerong and Sungai Lah which were Sampling 1, Sampling 2 and Sampling 3 shows a result of WQI and BWQI. Both result from WQI and BWQI were compared to see the relevance of macrobenthos as bioindicator of water quality. The data also will be compared with the WQI data before the flood event obtained from Department of Irrigation and Drainage.

Water Quality

Comparison of mean values of parameters are given in Table 5 and comparison of parameters between stations in Figure 2 while comparison of Water Quality Index (WQI) for each sampling at each station in Figure 3. In general, physical and chemical parameters measured varied from Class I to IV of WQI. Some parameters were found to have a constant reading and some not consistent.Parameter that showed significant differences were BOD_5, COD, TSS and NH_3N. High concentration of TSS was observed at station Sg. Lah with an average value is 30.17±9.98 mg/L, while high content of NH_3N was also recorded at station Sg. Lah with an average value is 0.51±0.05 mg/L. Both readings are in class II (TSS) and V (NH_3N) according to the Malaysian DOE-WQI Classes [13]. In all stations, DO readings are uniform and showed high values, put the study area in a Class I according to the National Water Quality Standards (NWQS). According to [14], aquatic organisms are very sensitive to changes in pH and can live well in the range of 6.0 to 8.5 and all station seem to be in good pH value which is neutral. High concentration of certain parameters was believed to occur due to the river receiving high runoff during the flood. While, TSS will generally give a higher reading during the rainy season because of runoff during rainfall has high erosion and cause high rate of soil erosion. This contributes to the increase of suspended solids in the flat lands which were particularly vulnerable due to the land-based activities [15].

Beside suspended solid, soil erosion tends to increase biochemical oxygen demand and chemical oxygen demand which both of these elements contributed to the degradation of water quality, all of which can affect downstream users of drinking water [16]. Many studies have proven that the huge or drastic impact on natural habitat has led to major changes in physical and chemical properties of water body. Deforestation for instance, always been associated with changes in pH, DO, and temperature of the water, as well as habitat degradation and stream communities [17].The use of water quality index (WQI) is a conventional method for monitoring and assessment of river status in Malaysia. Calculation of WQI for 3 sampling stations at Galas river systems has been done as shown in Table 6. As a result, the WQI ranged from 86.35 to 91.55 and classify the study area into Class II.Class II of WQI indicate good water quality and suitable for multiple uses such as recreational with body contact and requires conventional treatment for drinking water supply. There also suitable for all type of fish.

Table 5: Comparison of mean values of water quality parameters

Station	Water Quality Parameter					
	pH	DO (%)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	NH_3N (mg/L)
Jelawang	6.77±0.13	8.85±0.90	5.50±0.43	8.17±0.70	7.33±1.36	0.13±0.01
Kenerong	6.69±0.08	8.57±0.61	4.17±0.48	7.17±0.60	6.00±0.82	0.07±0.03
Lah	6.78±0.003	8.70±0.72	6.83±0.40	10.67±0.61	30.17±9.98	0.51±0.05

Table 6: WQI from all stations and WQI for Sungai Galas

Station	WQI	Class	Category	Mean	WQI Sg.Galas
Sg. Jelawang	90.41 ± 0.45	II	Clean		88.95±2.60
Sg. Kenerong	92.55 ± 0.99	I	Very Clean	88.95	II
Sg. Lah	83.89 ± 1.43	II	Clean		(Good)

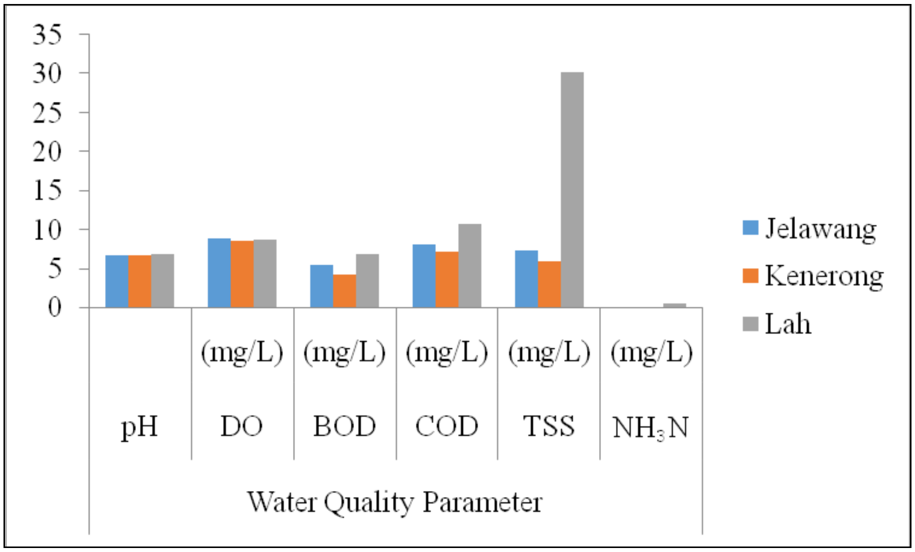

Figure 2: Comparison average value of parameters between each station

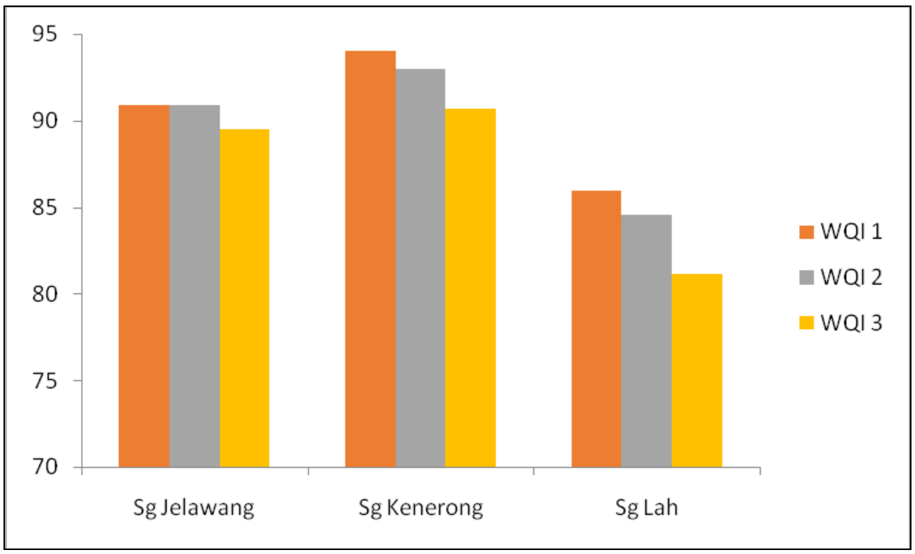

Figure 3: Comparison of WQI for each sampling and station

Benthic Macroinvertebrates

Figure 4, 5 and 6 showed the types of macrobenthos that were obtained from the analysis and each station has some different types of macrobenthos. This was because the factor of weather and time macrobenthos found in the water. Invertebrates analysis were conducted from morning until afternoon to get precise results. From the analysis, macrobenthos that were collected form the sample is the type of nymphs, larvae, insects, crustacean, and molluscs. The animals usually live in clean water and demand a lot of oxygen. From the bar graph, it showed that the macrobenthos mostly found was from the nymphs and followed by insects as the second common and there were also larvae, crustacean and molluscs. Nymph group animal found was Stonefly nymphs, flattened mayfly, prong-grilled mayfly, dragonfly nymphs and damselfly nymphs. Insects group animal found were long mouthed saucer bugs and other water bugs. From molluscs group, animal found was pea cockles and other common snails. While from crustacean group, animal found was freshwater shrimps. This group of macroinvertebrates was fairly adapted to tolerate a broad range of environmental conditions to cope with decline in the water quality [18]. The mayflies were categorised as a primitive winged insect. Their larval can adapt from tranquil river to fast-flowing water [19]. Caddisfly is one of the largest group of aquatic insects [20] inhabiting aquatic ecosystem from moderately poor to good water quality. Their larval stage can be found in rivers and lakes, and are highly specialized in food acquisition [21].

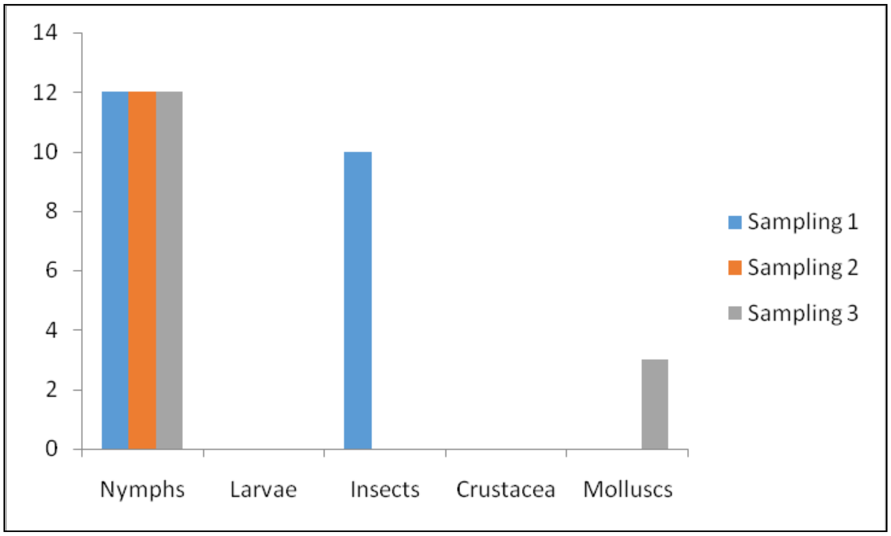

Figure 4: Composition of Macrobenthos at Sungai Jelawang

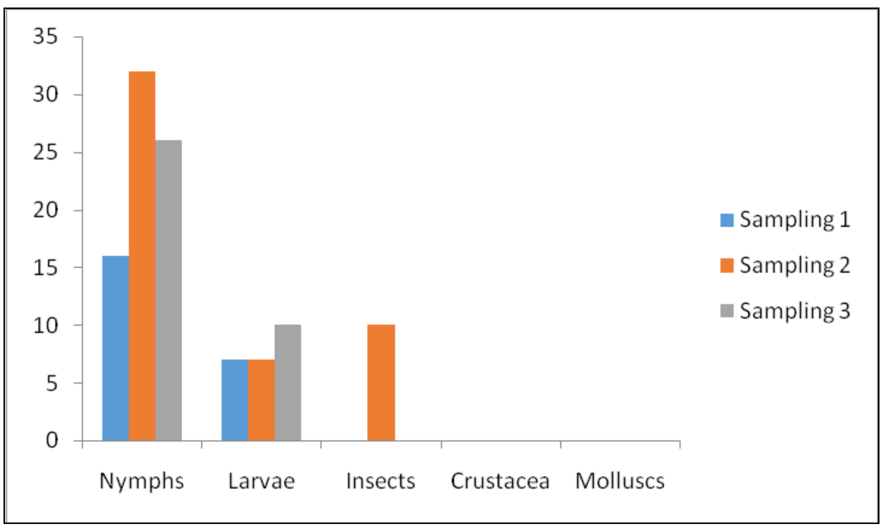

Figure 5: Composition of Macrobenthos at Sungai Kenerong

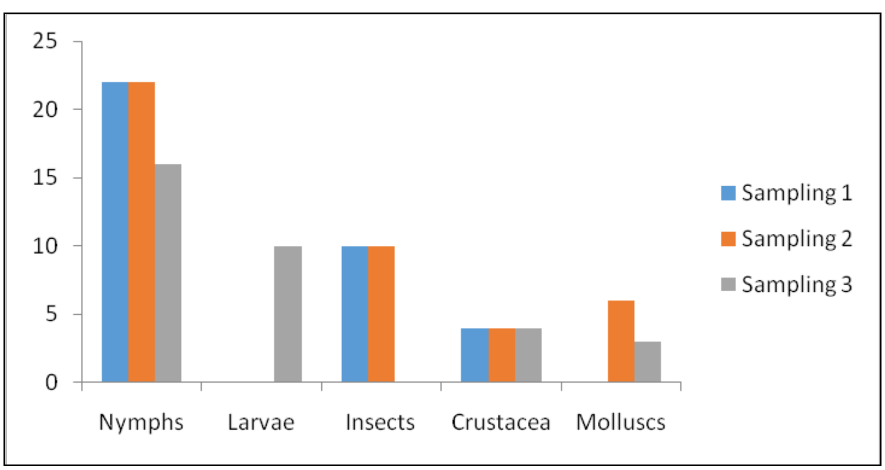

Figure 6: Composition of Macrobenthos at Sungai Lah

With regards to Biological Water Quality Index (BWI), in A Guide to Freshwater Invertebrates of Ponds and Streams in Malaysia, all stations were classified as very clean water (Class A) to rather clean water (Class B) is shown in Table 7. The highest BWQI mean value was observed in station Sg. Kenerong (8.28). Two other stations Jelawang and Lah was classified into class B (range score 5.1 - 7.5) with score observed (6.11) and (6.60) respectively.

Table 7: BWQI score and water status for each stations

Animal	Station								
	Jelawang			Kenerong			Lah		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Total Score	22	12	15	23	49	36	36	42	33
Number of animal types	3	2	3	3	6	4	5	7	5
Biological Water Quality Index (BWQI)	7.33	6.00	5.00	7.67	8.17	9.00	7.20	6.00	6.60
Average BWQI	6.11			8.28			6.6		
Category	B			A			B		
Water Quality	Rather Clean			Very Clean			Rather Clean		

Comparison between WQI and BWQI

Based on Table 8, the study of which can be seen using laboratory analysis and biological indicator gave similar results. It can be seen that the result of the classification of all rivers is in class I and II for both types of tests respectively. This study showed that using both methods acceptably can provide the same classification of results. It also showed the level of the Water Quality Index will affect the Biological Water Quality Index because it is very sensitive to any change and pollution.

Table 8: Comparison between WQI and BWQI

Station	Water Quality Index		Biological Water Quality Index	
Sg Jelawang	II	Clean	II	Rather Clean
Sg Kenerong	I	Very Clean	I	Very Clean
Sg Lah	II	Clean	II	Rather Clean

Comparison WQI Pre-Flood and Post-Flood

The water quality index of major rivers such as Sungai Galas same level from 2013 to 2015. It can be seen in Table 9, where the level of classification of water quality in Sungai Kelantan same from 2013 to 2015, but the score decreased slightly in 2014 which is 83. This is because at the end of December 2014 experienced a major flood. This change is important for the life of the river and others, especially in aquatic life.

Table 9: The Comparison Water Quality Index Between Laboratory Analysis and DOE Major River Results

Major River	2013			2014			This Study (2015)		
	Score	**Class/ Category**		**Score**	**Class/ Category**		**Score**	**Class/ Category**	
Sg Galas	88	II	C	83	II	C	89	II	C

**C - Clean*

Conclusions

Conventional method and biological analysis to identify the level of water quality based on biotic and diversity indices showed the recent phenomenon of flood event in Galas river system is not severely impact the water quality and bio-indicators organisms, as the studied area are generally categorized as clean. However, regular surveillance and supervision by the local authorities in relation to sustainable land use activities that can be implemented to ensure the quality of the environment at a good level. Both analyses for the three rivers show the index and status of water quality is in good and excellent condition. It is because those rivers are located on the eastern side of the main range, which the majority of the catchment area is steep mountainous and hilly area.. Hence, the surrounding of those rivers is less from human activities or pollutant. This can be concluding that human activities are the cause of the pollution in the river.

Macrobenthos as a biological indicator use to determine the water quality of the river. This process depends on how many organism or living invertebrates are found and collected in the river at certain amount of water. Based on the analysis done, many organisms can be collected at Sungai Jelawang, Kenerong and Sungai Lah. This shows that the water is in clean condition or pristine because types of organisms collected mostly from the category nymphs, insects, crustacea, molluscs which are this species cannot tolerance with pollution. This shows that macrobenthos can be used as biological indicator as it gives the same result as water quality index. Further research and studies need to be carried out to produce a better management planning and understanding as a preparation for worst case of flood scenario in the future.

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