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WATER QUALITY ASSESSMENT AT FRASER'S HILL AND PANGKOR ISLAND, MALAYSIA USING PHYSICO-CHEMICAL AND BIOLOGICAL METHODS

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Abstract: Water bodies are an indispensable part of human life where their quality determine human life. Monitoring the water quality in terms of water temperature, dissolved minerals and amount of bacteria present in the water is essential for healthy life. Beetle has been used as an indicator of water quality, but scarcely studied in Malaysia. This study was undertaken to determine the quality of water at Fraser's Hill and Pangkor Island using physicochemical and biological methods. Water quality assessment was carried out by measuring water temperature, pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), ammoniacal nitrogen (NH_3-N) and Total Dissolved Solids (TDS). Water Quality Index (WQI) was obtained by calculating the mean values of above measurements. All water quality measurements were analyzed using one-way analysis of variance ($p \leq 0.05$) and the levels of significance of the differences between the localities checked using ANOVA. The water quality indices (WQI) of the water bodies in Fraser's Hill (94.01) and Pangkor Island (82.21) were rated as Class I and Class II, respectively. This was confirmed by the diversity of the water beetle species (Fraser's Hill 0.69; Pangkor Island 0.52) found at these locations. The information that beetles are good indicators of pollution means that this could serve as an additional tool for rapid assessment of water quality, in addition to chemical and physical analysis.

Key words: Diversity, Fraser's Hill, Oxygen, Pangkor Island, Temperature.

INTRODUCTION

Freshwater habitats around the world are now being subjected to increasing levels of human interference and disturbance (Saunders et al. 2002). An assessment done on the status of various inland ecosystems showed that the most threatened river catchments across the globe are found in the Indian subcontinent (Groombridge & Jenkins 2000). Dudgeon (2000) stressed that identifying, monitoring and conserving important zones of biodiversity is imperative, especially in the riverine ecosystems, in the interests of long-term conservation.

Condition of an aquatic resource can be monitored and characterized by making a biological assessment of the freshwater habitat (Revenga et al. 2005, Park & Hwang 2016). The practice of monitoring water quality by observing the living organisms found in that body of water originated in Europe and has been widely used elsewhere (Revenga et al. 2005, Poikane et al. 2016, Fernandez et al. 2018). Studies conducted in the USA and European countries have revealed that the most effective way to monitor a freshwater ecosystem is by assessing the status of the benthic macroinvertebrates that inhabit it (Poikane et al. 2016, Siddiq et al. 2016, Fernandez et al. 2018). The quality of water bodies reflects living activities occurring around its area. A number of attributes such as temperature, dissolved mineral contents, and whether or not the water body is contaminated with bacteria are assessed to determine the quality of any given water body (Bhateria & Jain 2016).

The reliable monitoring of water resources is vital for the effective protection and sustainable management of water quality in aquatic ecosystems (Park 2016, Fernandez et al. 2018). Conventional practice was to depend on physicochemical measurements to judge the quality of water resources. Nevertheless, they have a fundamental drawback in covering the entire water systems, especially with regard to ecosystem health and integrity (Park & Chon 2015). Lately, a number of new approaches have become available to assess water quality and ecosystem health, which are applied at different levels of the biological hierarchy, from gene level to ecosystem level (Park & Hwang 2016).

Freshwater bodies can be monitored by the physiochemical parameters. However, macroinvertebrates are the most common for bioassesment as they provide a much more reliable assessment for a long term ecological changes in the aquatic quality compared to physio-chemical parameters which have rapidly changing characteristics (Sharma et al. 2008). Thus, physio-chemical water quality assessment are inadequate to determine the quality of water because they only tell the content of the water at the very precise and specific time of sample collection. It hardly or does not indicates what was the water content few hours ago, few days ago or months ago (Flotemersch et al. 2006). Nonetheless, the aquatic macroinvertebrates are at all time surrounded by water and any pollutant that may be in the water. If pollutants were in the water at any time between the past hours to even past months, the water quality will be reflected by the total number and diversity of macroinvertebrates present (Glastris et al. 2001). This is due to the fact that different taxa of aquatic macroinvertebrates have different requirements to live (Duran 2006). Different macroinvertebrates need different temperature, dissolved oxygen level or even certain habitat in order to survive (Glastris et al. 2001).

Monitoring the water quality in terms of water temperature, dissolved minerals and amount of bacteria present in the water is essential for healthy life. Beetle has been used as an indicator of water quality, but scarcely studied in Malaysia. One of the many ways to determine water quality is by using the diversity of the beetle taxa as a bioindicator (Benetti et al. 2012, Mabidi et al. 2017, Patang et al. 2018). Although several aquatic invertebrates such as Odonata and Coleoptera have been used as bioindicators for monitoring the quality of water bodies (Ojija & Laizer 2016, Azmi et al. 2018), this method has been scarcely used in Malaysia. Possibly, the lack of taxonomic keys and lack of information on habitat requirements and the ecological diversity of aquatic macroinvertebrates in this region must have made it less popular compared to the conventional methods (Salmiati et al. 2017). This study was undertaken to assess water quality by employing both physical-chemical and biological approaches in Fraser's Hill and Pangkor Island.

MATERIALS AND METHODS

Sampling Locations

This study was conducted in two locations in Peninsular Malaysia, specifically Fraser's Hill (3.7140° N, 101.7350° E) and Pangkor Island (4.1312° N, 100.331° E). Fraser's Hill is located in the Titiwangsa mountain range in Pahang, while Pangkor Island is off the coast of Perak (Figure 1). Fraser's Hill gained attention since the beginning of the 20th century by the British colonial and remains as one of the highland attractions in Malaysia. Highland tourism is known as one of the prospect that will accelerate the growth of Malaysian Tourism Industry (Azima et al. 2012). Fraser Hill's nature attractions are the bird watching, Maxwell, Rompin, Jeriau Waterfall, Allan Water and Paddock. Thus, these attractions have made Fraser Hill to be classified as an eco-tourism destination in Malaysia. Pangkor Island is a major tourism attraction in Malaysia thus it is being developed as a world class tourism center. Island tourism is also increasingly popular with tourists who travel to Malaysia. The sea bed is rich with exotic marine life and coral reefs while the forests are rich with flora and fauna. Pangkor Island is found ideal for sea activities such as swimming, scuba diving, fishing and also kayaking. Pangkor Island is also surrounded by nine small islands which serve as marine tourism activities attraction points (Mapjabil et al. 2015).

Water sampling

Water sample tests were carried out from January 2015 to December 2015 at Fraser's Hill and Pangkor Island, with samples being collected at four-month intervals. Water samples were collected from three localities in Fraser's Hill, namely Jeriau Waterfall (N03° 42.018', E101° 45.100'), Lasak Trail (N03° 42.712', E101° 46.259') and Raub Trail (N03° 42.780', E101° 46.236'). At each sampling location, seven sampling points were identified as replicates. Water samples for Pangkor Island were obtained from three localities, namely Pasir Bogak (N04° 13.894', E100° 33.160'), Teluk Nipah (N04° 14.906', E100° 33.065') and Teluk Cempedak (N04° 14.679', E100° 34.029'), and here too seven sampling points were identified as replicates.

Water quality recordings

Water quality assessment was carried out by measuring the factors listed by the Department of Environment of Malaysia (2007), such as water temperature, pH, dissolved oxygen (DO), total dissolved solids (TSS), salinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and ammoniacal nitrogen (NH_3-N) level (Table 1). Temperature readings were taken on site using a mercury-in-glass thermometer. All other readings were taken on site using Horiba U-500 series equipment. Table 1 shows the quality class of each parameter that contributes toward determining the overall quality of water. The range for each parameter is very important to calculate the WQI by following the best fit equations for the estimation of various sub index values as shown on Table 1.

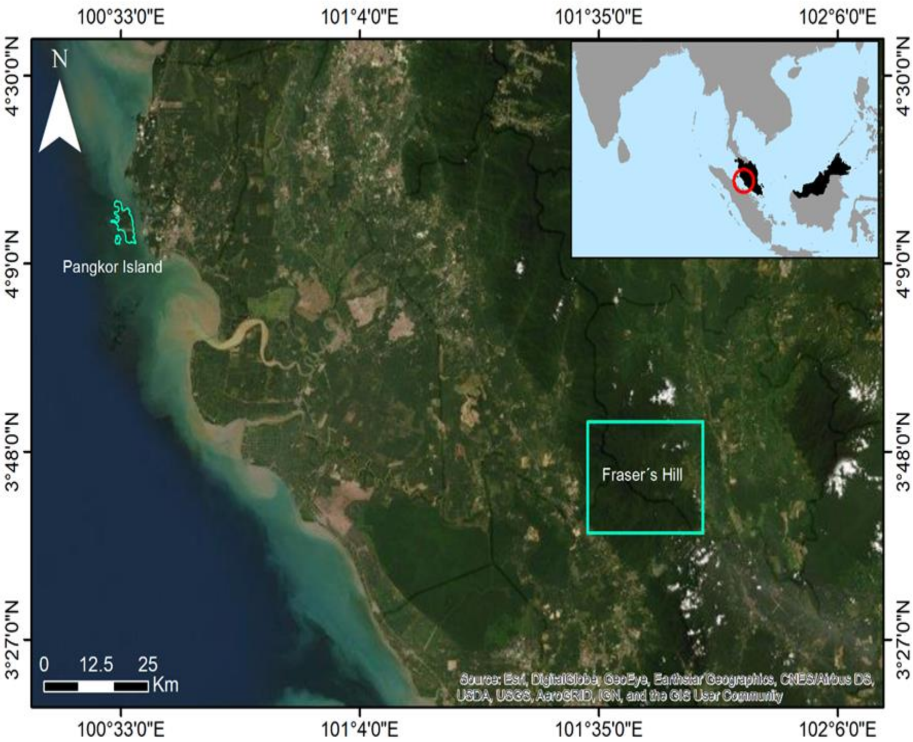

Figure 1. Sample collection locations.

Table 1. Parameters assessed, and water quality classification standard prescribed by the Department of Environment of Malaysia (2007).

Parameter	Unit	Classes				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/L	<0.1	0.1-0.3	0.3-0.9	0.9-0.27	>0.27
BOD	mg/L	<1	1-3	3-6	6-12	>12
COD	mg/L	<10	10-25	25-50	50-100	>100
DO	mg/L	>7	5-7	3-5	1-3	<1
pH	-	7	6-7	5-6	<5	<5
TSS	mg/L	<25	25-50	50-150	150-300	>300
WQI	-	<92.7	76.5-92.7	51.9-76.5	31.0-51.9	>31.0

Water beetle sampling from water bodies

Water beetles were collected using a sweep net during the day while light trapping was used to collect water beetles at night. Much of the collection was done during the daytime though. The aquatic net used had a long handle attached to a 30 cm by 30 cm square frame, to which was fitted a 1 mm mesh shaped as a basket. The net was swung from side to side in a 180-degree arc at every step as we casually walked along the middle of the shallow stream. The light trap consisted of a white mosquito net that measured 1.8m x 2.0m x 2.0m, illuminated by a 160-watt mercury vapor lamp powered by a portable generator. Lighting hours were set for six hours from 1730 to 2330 hours. The collected water beetles were preserved in 70% alcohol and later pinned on an insect box of size 229 x 330 x 64mm and dried at 40° C. The specimens were identified with the aid of a number of taxonomic keys (Triplehorn & Johnson 2005, Brancucci 2008, Merritt & Cummins 2008, Hájek et al. 2013).

Community structure analysis

The collected beetles were counted and the number of individuals (N) and and number of species (S) were recorded. The diversity of the beetle species found was analyzed using Simpson's Diversity index, where Simpson's index (D) was used to determine the rarity and diversity of the species present at the sites. Simpson's index is a measure of diversity that takes into account both species richness and abundance of the particular species present. It measures the probability that any two individuals randomly selected from an area will belong to the same species (Simpson, 1949).

Statistical analysis

The analysis between the class of water quality and the presence of beetles were made. All the water quality measurements were analyzed using the one-way analysis of variance (ANOVA, $p \leq 0.05$). The statistical analysis was performed with SPSS 16.0

statistical software. The Simpson's Diversity Index values were tested for significant differences between the two localities using ANOVA.

RESULTS AND DISCUSSION

Based on the water quality classification standard prescribed by the Department of Environment, water quality index (WQI) of the water bodies in Fraser's Hill and Pangkor Island can be classified as of Class I and Class II quality, respectively (Table 2). Statistical analysis revealed that there were significant differences in mean pH, dissolved oxygen and total suspended solids between both localities (Table 2). This study found that the mean water temperature in Fraser's Hill (20.75° C) was significantly lower than the mean water temperature at Pangkor Island (24.36° C). No significant differences were observed in BOD, COD and ammoniacal nitrogen content in the tested water bodies ($P<0.05$). The assessment was conducted by this study to correlate the physicochemical and biological methods. With the physicochemical parameters, the water quality was determined by measuring the presence of organic waste in the trails of waterfalls, and this was done by analyzing the pH, dissolved oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) (Bhateria & Jain, 2016). The biological parameters included the diversity and community composition of water beetles, as had been reported from other studies too (Tan & Beh 2015). Yosuff et al. (2019) reported the water quality of Pangkor Island water bodies as Class I and Class II.

Table 2: Water quality parameters for Fraser's Hill and Pangkor Island.

Parameter	Unit	Fraser's Hill	Pangkor Island
Temperature	°C	20.75±2.50	24.36±2.62
Dissolved Oxygen (DO)	(mg/l)	$9.4±3.84^{a}$	$6.22±0.88^{b}$
Biochemical Oxygen Demand (BOD)	(mg/l)	0.4±0.64	0.41±0.80
Chemical Oxygen Demand (COD)	(mg/l)	6.78±7.95	5.1±5.58
Total Suspended Solids (TSS)	(mg/l)	$0.01±0.01^{a}$	$1.35±1.56^{b}$
Ammoniacal Nitrogen (NH_3-N)	(mg/l)	0.05±0.05	0.04±0.07
pH		$6.23±0.65^{a}$	$6.43±0.53^{b}$
WQI		94.01	82.21
Class		I	II

($^{a, b}$ denote significant differences between the tested means)

Water quality index (WQI) is a widely used measure for assessing the overall quality of water, involving all the chemical, biological and physical parameters (Yogendra & Puttaiah 2008, Tan & Beh 2015). The temperature has an impact on the physical, chemical and biological characteristics of surface water, as it influences the dissolved oxygen content, among other things. The level of dissolved oxygen in the water is also affected by the photosynthesis of aquatic plants, metabolic rates of aquatic organisms and the sensitivity of these organisms to pollution, parasites and disease (Bhateria & Jain 2016). The temperature of stream water influences the amount of dissolved oxygen present; less oxygen dissolves in warm water than cold water. A high amount of Dissolved Oxygen was present in Fraser's water compared to water in Pangkor Island that had low dissolved oxygen (DO) level primarily because of the excessive algae growth caused by the presence of phosphorus, although we did not measure on this study. This indicates there is a significant difference between both study sites.

Dissolved oxygen (DO) is an important parameter required to determine the water quality in natural water resources. An optimal DO is required for the survival of many microorganisms and aquatic species like fishes. In addition, DO establishes an anaerobic environment, a condition in which oxidized forms of many constituents are found in abundance in the water. Fraser's Hill has more DO than Pangkor Island, suggesting that Fraser's Hill water is better for drinking as it has a lower level of organic pollutants. Appalasamy et al. (2018) reported lower levels of DO at Tioman Island compared to Fraser's Hill but of a higher value than Pangkor Island. This could be due to the increased influence of anthropogenic activities at Pangkor Island compared to Tioman Island. Yisa and Jimoh (2010) reported that low DO values in any water body directly relate to the presence of a high concentration of organic pollutants and nutrients. However, an adequate amount of DO is necessary for the growth of aquatic organisms and it should be in the range of 3 to 9 mg/L (Robinson et al. 2004).

In this study, Fraser's Hill (Class I) had a better overall quality of water than Pangkor Island (Class II); nevertheless, at both locations the water quality was in the acceptable range The pH, temperature, BOD, COD, TSS and NH_3-N are within the Class I range but some of the defining factors such as DO and WQI showed that the Fraser's Hill falls into Class I and Pangkor Island into Class II. Abdullah-Al-Mamun and Idris (2008) suggested for a revised water quality indices for Malaysia. Salih et al. (2013) noted that pH and temperature have a positive effect on BOD and COD in the shallow areas of Mengkuang reservoir in Malaysia, suggesting that the suspended particles absorb sunlight and increase the temperature of water. In the same study, they have reported that the high BOD and COD values would directly relate to the turbidity and presence of coliform organisms. Pauh River at Cameron Highlands, Malaysia also showed different classes of water quality (Tan & Beh 2015). Al-Badaii et al. (2013) studied the Semenyih River water quality based on the physicochemical and biological parameters and the suggestion was to use the river water for irrigation with precaution but extensive treatment needed before using for domestic purposes.

In another study in Sarawak, the river was also assessed for the fecal coliform count in relation to water quality (Sim & Thai 2018).

Tan and Beh (2015) reported that the total suspended solids (TSS) at Pauh River ranged from 0.02 to 0.20 mg/L, which is higher than Fraser's Hill but lower than Pangkor Island. The TSS showed significant differences compared to both study sites. According to the investigation, the waterfall area of the forest in Fraser Hills recorded a low average value of 0.01 mg/L compared to the average value of the coast in Pangkor Island, which was 1.35 mg/L. The results obtained in Pangkor Island showed higher concentrations of suspended solids, which lowered the water quality. Total suspended solids is directly related to the growth of bacteria in water bodies.

No significant differences were recorded in the content of ammoniacal nitrogen reported in this study. However, ammoniacal nitrogen (NH_3-N) is generally present in a range of concentrations in most water resources. Since it is a product of microbiological activity, the presence of ammonia in natural water is regarded as sanitary pollution. Ammonium (NH_4^+) present in the water gets oxidized by certain bacteria that occur in natural water into nitrites and nitrates. However, ammonia (NH_3), being a source of nitrogen also provides nutrients for algae and other plants, so it too contributes to overload the natural system, causing pollution. The pH of water is directly influenced by the presence of ammonium, which is alkaline, and so a high pH value indicates high levels of NH_3 in a water system (Camargo & Alonso 2006, Majumder et al. 2006). Li and Bishop (2004) suggested that low levels of NH_3-N can enhance the nitrification and denitrification process in rivers and water bodies, which can assist self-purification.

A total of 112 specimens from three beetle families were collected from Fraser's Hill, while 41 specimens representing two families were sampled from Pangkor Island (Table 3). A total of seven species of water beetles from three families were identified in the samples of this study. The total number of individual beetles of the family Gyrinidae from both localities was 27. The highest catch from both localities represented the family Hydrophilidae (n=76), whereas specimens of the family Dytiscidae were collected from Fraser's Hill only (Table 3). *Hydrophilus triangularis* was the highest catch (n=23) from Fraser's Hill, closely followed by *Lacconectus krikkeni*.

Water beetle species were more diverse in Fraser's Hill (0.93) compared to Pangkor Island (0.66) as shown in Figure 2. The ANOVA analysis revealed that there was a significant difference ($p<0.05$) between the diversity values of water beetles at Fraser's Hill and Pangkor Island (Figure 2). These results show that the higher selected beetle taxa presence correlated with the higher quality of water, which has been discussed by Benetti and Garrido (2010) as well. This is mainly the addition of contaminations to the river water.

Table 3. Abundance of family and species of water beetles collected from Fraser's Hill and Pangkor Island.

Family	Name of species	No. of Specimens	
		Fraser's Hill	Pangkor Island
Dytiscidae	*Cybister sugillatus*	15	0
	Lacconectus corayi	14	0
	Lacconectus krikkeni	21	0
Gyrinidae	*Porrhorrhycus marginatus*	9	18
Hydrophilidae	*Hydratus* sp.	10	0
	Hydrophilus triangularis	23	10
	Sternolophus rufipes	20	13
Total		112	41

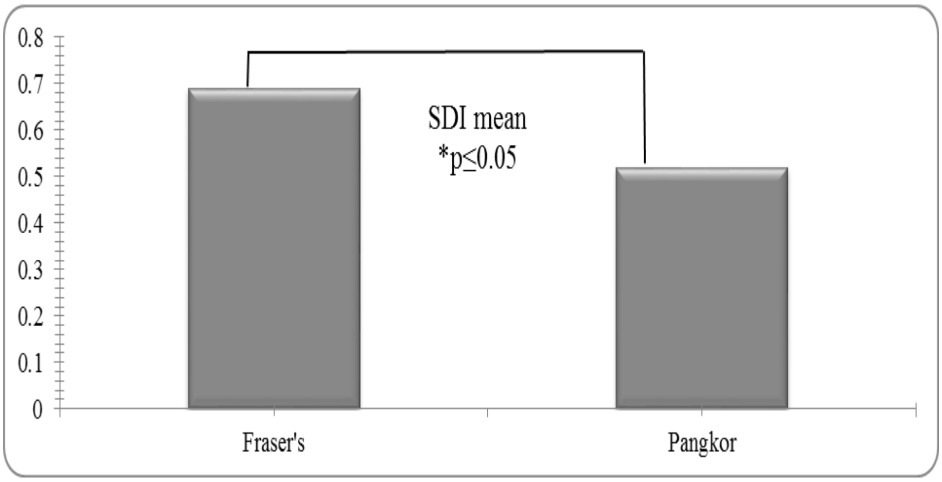

Figure 2. Simpson's diversity index indicated that there was a significant difference between the two study sites.

The biological parameters of water bodies can be assessed by the presence of aquatic insects and microorganisms. Aquatic insects behave as model organisms in analyzing the structure and function of freshwater systems. These invasive insects aid in nutrient recycling, translocation of materials, and decomposition. The decomposed particles and nutrients released by the aquatic insects are further degraded by bacteria and fungi in the water body's ecosystem (Solanki & Shukla 2015). Ground-dwelling predatory beetles are commonly occurring macro-organisms that are found in

Malaysian waterfalls and Islands. These ground beetles (Coleoptera: Carabidae) are a diverse and abundant group of species that can survive under low oxygen conditions in low pH water bodies. The larvae of Coleoptera are more sensitive and vulnerable than adults and their survival requires a suitable environment with low pH, low temperature and low values of COD and BOD. Moreover, temperature is important biologically and plays an important role in the metabolic activities of organisms (Sirajudeen & Mubashir 2013). The presence of DO in water plays a vital role in the lifecycle of aquatic organisms. Hoback and Stanley (2001) reported that the larvae and pupae of aquatic insects need more oxygen than the mature ones and as they are highly susceptible to hypoxia, cannot survive in a low oxygen environment. In the current study, DO was higher in Fraser's Hill and therefore, the survival rate of larvae and pupae of beetles would be high, and this would also promote their growth. However, adult beetles can survive in water bodies with low DO, high temperature, and rich in nutrients. Temperature was positively correlated with salinity, DO, turbidity, TDS and TSS (Harun et al. 2017). Recently, Hydrophilidae and Helophoridae species of Coleoptera were found in the water bodies of Turkey, suggesting that the temperature and salinity of their waters were favourable to the survival of these species (Akunal & Aslan 2017).

Aquatic coleopterans have highly diverse forms and are the common prey of many species of fish and macro-vertebrates. These aquatic beetles serve as biological indicators due to their richness, diversity, ecological faithfulness, and naturalness. The increase in pollution, agricultural intensification and runoff, and draining of wetlands has had a negative impact on the fragile water bodies (Eyre & Foster 2009, Sanchez-Fernandez et al. 2004). Water quality can be assessed based on the presence of certain aquatic insects such as Coleoptera, Trichoptera, Ephemeroptera and Plecoptera, which can act as biological indicators (Merritt & Cummins 2008, Tan & Beh 2015, Appalasamy et al. 2018). This study found a total of 155 beetles in the Fraser's Hill and Pangkor Island waters, belonging to three different families, including Dytiscidae, Gyrinidae and Hydrophidea. However, water beetles of the Dytiscidae family have been reported as the most common species in the world (Jäch & Blake 2008) as they are found in almost every running and standing water body across the world. However, no Dytiscidae was found in Pulau Pangkor, which is indicative of a badly disturbed aquatic environment. Interestingly, Dytiscidae have been reported as aggressive predators of mosquito larvae (Schafer et al. 2006).

Fraser's Hill (Class I) had better overall water quality than Pangkor Island (Class II); nevertheless, at both locations the water quality was in the acceptable range. The presence of high levels of ammoniacal nitrogen in the water makes it difficult for aquatic organisms to survive. High Biochemical Oxygen Demand (BOD) indicates a high content of easily degradable substances in the water while low BOD indicates a low amount of organic materials. Chemical oxygen demand (COD) does not differentiate between biologically active organisms and inert organic matter, as it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. The shape of the COD bar chart shows there is no significant difference between the two study sites.

CONCLUSION

Water quality classes are useful for summarizing information in order to obtain regional and national perspective. Consequently, the water quality was affected by total suspended solid and dissolved oxygen and presence of biological organisms. The Fraser Hill’s waterfall is in the forest region so it is relatively clean and categorized as Class 1, whereas the Pangkor Island River is in the offshore of the sea is categorised under Class II. The pollution may be due to interference of human beings. It is concluded that sustainable tourism development is possible if government can just shift a little attention to its development. In addition, beetle is a useful tool in the detection of such environmental changes as the introduction of pollutants that affect their community diversity. The use of beetles as a water quality indicator is recommended since they integrate information over longer periods of time and signify the responses of aquatic habitats, making biotic monitoring indices good tools for the sustainable management with a much more reliable result.

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