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Interaction of Various Ecological Factors on Benthic Macroinvertebrate and River Health

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Abstract. River health is an aspect that goes beyond river cleanliness. This is because a clean river does not necessarily have life in it but a healthy river do. The ecological component is a factor that affects aquatic life which at the same time describes the level of river health. To answer this question, a study to identify the relationship between ecological factors and aquatic life with river health was conducted. This study was conducted in Sungai Mengkibol, Sungai Madek and Sungai Dengar in Johor. There were a total of five sampling sites, three for impact stations and two as reference stations, including one highland station. Total of seven elements namely ecological indices, physico-chemical water quality, river riparian, canopy cover, large woody debris (LWD), river discharge and substrate composition were measured and analyzed. Surber net measuring 500 micron mesh size combined with a rectangular quadrate of 30 cm x 30 cm (0.09 m^2) were used to sample the benthic macro-invertebrate. Chi-square test was performed to determine the association level between one variable with another, meanwhile Pearson's R value was analyzed to determine the correlation level either it is strong or weak. The results show that, all river ecological components have a significant correlation to the benthic macroinvertebrate ecological indices, however the association was varies. Based on the chi-square test, Pearson's value, p and Pearson's R value, the interplay (interaction) of various ecological factors on aquatic life forms and river health was produced with various p-value<0.05 and R-value is more than 0.5. It can be suggested that the ecological indices for benthic macroinvertebrates can be used as an indicator to assess river health.

1. Introduction

From the literature, it is evident that a river ecosystem is a fragile ecosystem where minimum changes made will cause a dramatic impact on the health of the river. Different land uses to produce different pollutants. Physico-chemical parameters are used to indicate whether the river water quality is good or bad [1]. [2] discovered the heavy metals component in Perak River Malaysia as one of the parameters to gauge Perak River's water quality status and expect the source to come from wastewater and industrial discharges. The finding is in line with what [3] found in their study, where they stated agricultural and forest-related activities as a cause of river pollution. Recently, researchers have been using the benthic macroinvertebrate as a bio-indicator to assess water quality and river health. [1] proposed that benthic macroinvertebrates could be utilised as a bio-indicator to assess recreational water quality. A few studies were conducted to determine the distributions of benthic macroinvertebrates in highland [4,5] and recreational rivers[6].

Recent studies conducted by researchers intend to look at the Physico-chemical quality and the health of the river by correlating between aquatic life, especially benthic macroinvertebrates, with Physico-chemical water quality [7,8] and other ecological attributes such as substrate compositions, canopy and riparian cover, channel morphology, large woody debris, etc. Several investigators have studied and analysed river bed grain size and benthic macroinvertebrate diversity indices [9,10]. Some of them studied the grain size distribution caused by land-use changes [11,12,13], which was the consequence to determine the composition of benthic macroinvertebrate assemblages. [14], through a survey carried out to identify the impacts on benthic macroinvertebrates from mining sites, have found that mine sites have higher conductivity, greater sediment deposition, and smaller substrate particle sizes resulting in decreased taxa diversity. A similar study was conducted by [13], but the impact was from the sedimentation basins discharge. The results have shown that there was no significant change in the number of macroinvertebrate individuals due to the sedimentation basin discharge. However, there was a considerable decrease in the number of taxa observed in the receiving stream directly below the basin outlet. This observed reduction in species richness was not significant 100 meters downstream from the basin discharge pipe. [15] found that instream conditions such as substrate composition, channel morphology, and woody debris were the factors influencing benthic macroinvertebrate community structure. [11] had found that species richness was affected by the amount of sand extraction and the amount of gravel settled at the sea or river bed, while the work by [9] showed that the increase in per cent composition by oligochaetes and Chironomidae occurred when median particle sizes were the smallest.

2. Materials and Methods

This study was conducted within the Sungai Endau watershed in the districts of Segamat, Kluang and Mersing in the state of Johor. The main tributary of these catchments is Sungai Sembrong which in turn is fed by several tributaries such as Sungai Madek, Sungai Mengkibol and Sungai Dengar. The river tributary selected for the study sites was in Order 2 to 3. There were five sampling sites, three for impact stations and two as reference stations (pristine), including highland stations (pristine-pristine). The reference stations were divided into two categories, namely, pristine and pristine-pristine stations. Two sampling stations per site and three sampling points per station were identified, except pristine-pristine station, which only had one station. The pristine station located at the foot of Gunung Berlumut was at an altitude of 75 m above mean sea level. In comparison, the pristine-pristine station is located on the peak of Gunung Berlumut at an altitude of about 300 m from mean sea level. The distance from the pristine station is approximately 2.5 km.

Surber Net was used to sample benthic macroinvertebrates, and Karr's Aquatic Insect Stream Sampling Protocol (1998) was followed with minor modifications to suit local conditions. Species Diversity and Richness software that was based on Shannon-Wiener Diversity Index (1963), Margalef Index (1958) and Simpson Index (1949) was used to analyse the data on benthic macroinvertebrates. The software was developed by Henderson from the University of Oxford, Department of Zoology and RMH Seaby PISCES Conservation Limited in 1994. The Excel Programme was used to calculate Evenness which was based on Hill Index (1973), while that for EPT Indices was based on [16]. On the other hand, Multi-parameter probe Model Yellow Springs Instrumentations (YSI) 6920 with 650 MDS Display/Logger and single parameter probe were used for in-situ determination of river water quality [17].

Meanwhile, water sampling for laboratory analysis was carried out based on the standard procedure provided by the [18]. The analysis was carried out according to procedures given by the Standard Methods for the Examination of Water and Wastewater [19]. At the same time, habitat characteristics were also assessed using a field survey form adopted from [20]. Canopy cover and riparian vegetation assessment was followed as given by "Field Methodology for the Christchurch River Environment Assessment Survey (CREAS)" and also from the study conducted by [21]. Valeport' Braystoke' Model 001 Flow Meter was used to gauge the river [22], and the Area Method was used to calculate river discharge [23]. According to the Pebble Count Procedure published by[24], Pebble Count was adopted to determine river substrate compositions. On the other hand, LWD, which measured the size, including diameter and length of the whole tree, logs or root wads, was carried out using measuring tape, ruler, and vernier calliper. The measurement was conducted within a 500-meter stretch between upper and lower stations. All measurements and observations of LWD were recorded in the field data sheet prepared.

A Chi-square test was performed to determine the association level between one variable with another [25]. Pearson Chi-Square Value or P-value was used to determine the level of association. A P-value smaller than 0.05 means some association between the components with a 95% confidence level [26]. On the other hand, when Pearson's R-value shows negative, the correlation is negative and vice versa. At the same time, the value itself represents the correlation level, whether it is strong or weak. Pearson's R-value greater than 0.5 means there is a strong correlation and the relation or correlation is stronger as the R-value increases. R-value below 0.5 is considered to have a weak correlation. As an output of the research, the interplay (interaction) of various ecological factors on benthic macroinvertebrates and river health was produced to give a clear picture of the correlation of each component.

3. Results and Discussion

All the results obtained were summarised in an interaction diagram showing the interaction of different components, as illustrated in Figure 1. This diagram illustrates the horizontal and vertical relationships and consists of three layers. The first layer is the relationship between water quality, riparian composition, canopy cover, channel deformation, LWD, substrate composition and river discharge (Table 1). It was found that LWD depends on riparian and canopy cover. The substrate compositions depend on LWD, riparian and canopy cover and river discharge. River discharge depends on the LWD, canopy and riparian cover. Channel deformation depends on the river discharge riparian and canopy cover. The physicochemical water quality depends on the LWD, canopy and riparian cover.

Table 1. Correlation between Physicochemical Water Quality and Physical Characteristics

Index	P - value	Pearson's R Value
River Discharge	0.572	0.199
Substrate Composition (D_{50})	0.545	0.354
	0.000	0.825
Canopy Cover	0.000	0.664
Riparian Composion	0.000	0.389

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The second layer is the relationship between benthic macroinvertebrates and the other components: water quality, riparian composition, canopy cover, channel deformation, LWD, substrate composition, and river discharge (Table 2-Table 6). Benthic macroinvertebrate is the dependent variable, and the other components are independent variables. Meaning that benthic macroinvertebrate was influenced by water quality, riparian composition, canopy cover, channel deformation, LWD, substrate composition and river discharge.

Table 2. Correlation between Canopy Cover and Biological Index

Index	P - value	Pearson's R Value
Diversity	0.004	0.595
Dominance	0.102	0.529
Richness	0.024	0.563
Evenness	0.043	0.288
EPT Composition	0.000	0.808

Table 3. Correlation between Substrate Composition (D_{50}) and Biological Index

Index	P - value	Pearson's R Value
Diversity	0.013	0.391
Dominance	1.000	0.366
Richness	0.271	0.300
Evenness	0.874	0.268
EPT Composition	0.002	0.594

Table 4. Correlation between LWD and Biological Index

Index	P - value	Pearson's R Value
Diversity	0.005	0.428
Dominance	0.004	0.597
Richness	0.005	0.533
Evenness	0.002	0.277
EPT Composition	0.000	0.611

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Table 5. Correlation between Riparian Composition and Biological Index

Index	P - value	Pearson's R Value
Diversity	0.020	0.019
Dominance	0.115	0.235
Richness	0.023	0.155
Evenness	0.088	0.036
EPT Composition	0.000	0.068

Table 6. Correlation between River Discharge and Biological Index

Index	P - value	Pearson's R Value
Diversity	0.405	0.350
Dominance	0.486	0.036
Richness	0.722	0.327
Evenness	0.156	0.207
EPT Composition	0.048	0.461

The third layer is the relationship between all the above components with river health. River health is the dependent variable, and other components are independent variables. It can be concluded that river health is influenced by benthic macroinvertebrates, physicochemical water quality, large woody debris (LWD), canopy and riparian cover, channel deformation, substrate compositions and river discharge.

A healthy river shown in a dark green circle is the centre of all other components and is the main component. The healthy river component is dependent on aquatic life (macroinvertebrates benthic), water quality, riparian composition, canopy cover, channel deformation, LWD, substrate composition and river discharge. Therefore, all the other components should have been assessed to assess the river's health. However, the correlation analysis found that benthic macroinvertebrate was dependent on water quality, riparian composition, canopy cover, channel deformation, LWD, substrate composition, and river discharge, which can be used as representative or indicators to assess river health. Thus, the benthic macroinvertebrate component is placed in an oval circle and coloured with bright green to indicate the hierarchy in the second layer and can be used as an indicator to represent the other components in the first layer. In addition, the relationship between benthic macroinvertebrate components and river health is also linked to arrows that are different from other components. It is associated with an arrow larger in size than other arrows and is coloured in bright green.

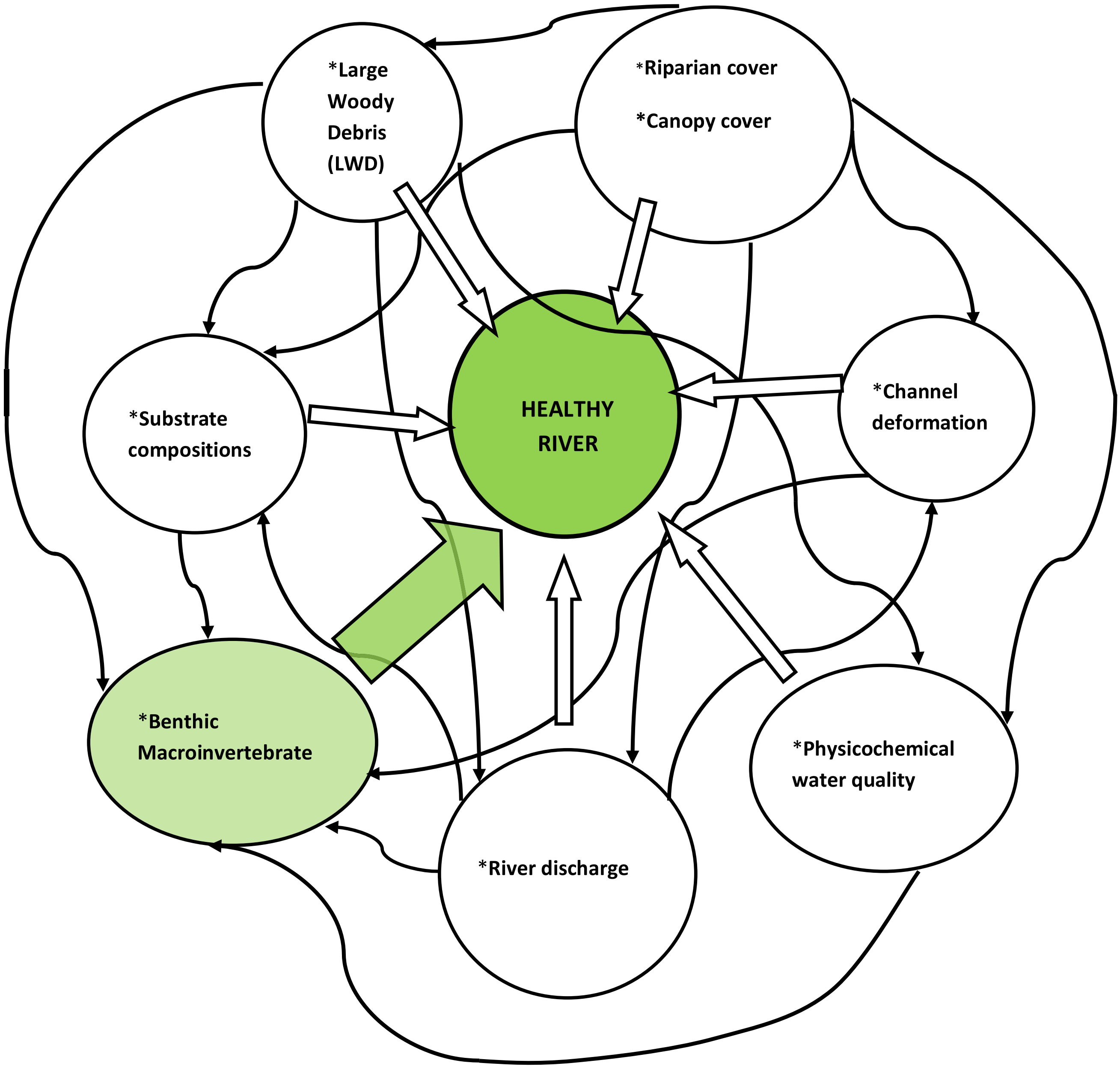

Figure 1. The interplay (interaction) of various ecological factors on aquatic life forms – an important determinant for a healthy river.

By looking at the benthic macroinvertebrates assemblage and composition, one can tell the river's health based on the recommendation made by the [27]. The report proposed that aquatic biota be used as a key indicator of river health assessment because damage to biota is often the end-point of environmental degradation. However, such data cannot be used exclusively as a basis for river rehabilitation. The reason is that there are many factors contributing to the benthic macroinvertebrates assemblage and composition in the river. Without a complete understanding of the condition of each factor, the rehabilitation process will not succeed. A simple analogy to this is like a physician prescribing medicine without first diagnosing a patient's illness, which will not help treat or alleviate the problem faced by the patient. Like any river rehabilitation work, all the related problems must be identified first and subsequently addressed towards remedying the river's health, as [28] discussed. The root of the problem changes depending on the land use. Changes in land use will contribute to pollution of the rivers (presence of suspended solids mainly) through runoff due to land clearance to remove natural vegetation and contribute towards irreparable damage to the habitat and the ecosystem within. Changes in the habitat have been known to affect the biotic community's characteristics in a river system [29]. All this will lead to changes in the benthic macroinvertebrates assemblage and composition of the river.

4. Conclusion

Based on the results obtained, it can be concluded that all river ecosystem attributes and aquatic life (benthic macroinvertebrates) interact and influence river health. However, benthic macroinvertebrates can be used as indicators to assess river health based on the correlation analysis. However, it cannot be used exclusively as a basis for river rehabilitation. The reason is that there are many factors contributing to the benthic macroinvertebrates assemblage and composition in the river. Without a good understanding of the condition of each factor, the rehabilitation process will not succeed.

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