SCATTERING OF MACROINVERTEBRATES AS AN INDICATOR OF WATER QUALITY BY USING BIOLOGICAL MONITORING WORKING PARTY - AVERAGE SCORE PER TAXON METHOD

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I hereby declare that the work in this project report is my own except for quotations and summaries which I have duly acknowledged.

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ABSTRACT

Sources of water must be monitored regularly to determine the status of water quality. Poor water conditions are not only an indicator of environmental degradation but also a threat to the ecosystem. Little evidences have been made on the streamflow of Gunung Belumut waterfall to obtain an overview of the diversity of macroinvertebrates and its interaction with water quality. This research intends to delve into the taxonomy richness of macroinvertebrates in water quality monitoring by using Biological Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT) method and were referred to a set of references by BMWP-England and BMWP-Costa Rica and the BMWP-ASPT used in Malaysia. Next, the research intends to determine the interaction of physicochemical parameters and Principal Component Analysis (PCA) correlation between macroinvertebrates and water quality. The development of simple guidelines for macroinvertebrate sampling techniques were established with application of BMWP-ASPT method. The water quality recorded that the water quality upstream ranged between 6.27–8. Meanwhile, the water quality of the middle stream ranged from 4.9–5.7. Finally, the downstream recorded a status of almost clean to clean with score value of 6.5. The Simpson's diversity index (D) resulted in values of 0.806, 0.886 and 0.889 for upstream, middle stream and downstream, respectively. Meanwhile, the Shannon – Wiener index (H') values were 0.605, 0.895 and -0.024 for upstream, middle stream and downstream respectively. The PCA results show that macroinvertebrate abundance such as *Leptophlebiidae, Capnidae, Hydropsychidae, Gyrinidae, Heptageniidae, Coenagrionidae,* and *Potamidae* was mostly influenced by the environmental variables of temperature (25.16 °C–26.16 °C), pH value (6.3–6.8) and dissolved oxygen (6.58 mg/L–7.42 mg/L). Semi-quantitative and quantitative sampling techniques also quantified the outcomes of the macroinvertebrate samples. To conclude, the interaction between aquatic organisms and water quality parameters is important for maintaining the ecosystem of freshwater resources and the monitoring of water quality in Malaysia.

ABSTRAK

Sumber air yang terhad perlu dipantau secara berkala untuk menentukan status kualiti air. Kualiti air yang rendah bukan sahaja merupakan indikasi kemerosotan persekitaran, ia juga merupakan ancaman kepada ekosistem. Kurang informasi mengenai aliran air terjun Gunung Belumut untuk menilai gambaran keseluruhan kepelbagaian makroinvertebrata dan interaksinya dengan kualiti air. Penyelidikan ini bertujuan untuk mengkaji kualiti air untuk menilai kekayaan taksonomi makroinvertebrata dalam pemantauan kualiti air dengan menggunakan prestasi Kumpulan Kerja Pemantaunan Biologi-Purata Markah Per Tipon (BMWP-ASPT) dan dirujuk pada BMWP-England dan BMWP-Costa Rica dan BMWP-ASPT yang digunakan di Malaysia. Seterusnya, penyelidikan bertujuan untuk menentukan interaksi parameter fizikokimia dan korelasi Analis Komponen Utama (PCA) antara makroinvertebrata dan kualiti air. Pembangunan garis panduan ringkas kepada teknik persampelan makroinvertebrata telah diwujudkan dengan menggunakan kaedah BMWP-ASPT. Kualiti air yang diperhatikan menunjukkan kualiti air di hulu berjulat antara 6.27 – 8. Manakala, kualiti air sungai aliran tengah berjulat antara 4.9 – 5.7.Akhir sekali, hilir mencatatkan status hampir bersih hingga bersih dengan nilai skor 6.5. Indeks kepelbagaian (D) menunjukkan nilai 0.806, 0.886 dan 0.889 masing-masing untuk hulu, aliran tengah dan hiliran. Sementara itu, nilai indeks Shannon - Wiener (H ’) masing-masing adalah 0.605, 0.895 dan -0.024 untuk aliran hulu, tengah dan hiliran. Keputusan PCA menunjukkan bahawa kelimpahan makroinvertebrata seperti *Leptophlebiidae, Capnidae, Hydropsychidae, Gyrinidae, Heptageniidae, Coenagrionidae*, dan *Potamidae* kebanyakannya dipengaruhi oleh pembolehubah persekitaran suhu (25.16 °C – 26.16 °C), nilai pH (6.3 – 6.8) dan oksigen terlarut (6.58 mg/L– 7.42 mg/L). Teknik persampelan separa kuantitatif dan kuantitatif juga mengukur hasil sampel makroinvertebrata. Kesimpulannya, interaksi antara organisma akuatik dan parameter kualiti air adalah penting utuk mengekalkan ekosistem sumber air tawar dan pemantauan kualiti air di Malaysia.

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LIST OF ABBREVIATIONS

APHA	-	American Public Health Association
ASPT	-	Average Score Per Taxon
ANOVA		Analysis of Variance
BBI	-	Belgian Biotic Index
BOD	-	Biological Oxygen Demand
BMWP	-	Biological Monitoring Working Party
BMWP-CR	-	Biological Monitoring Working Party-Costa Rica
BMWP-E	-	Biological Monitoring Working Party-England
BMWP-PL	-	Biological Monitoring Working Party -Poland
BMWP-MY	-	Biological Monitoring Working Party -Malaysia
CCA	-	Canonical Correspondence Analysis
D	-	Simpson's Diversity Index
DO	-	Dissolved oxygen
EA	-	Environment Agency of England
EC	-	Electrical Conductivity
EPT	-	Ephemeroptera, Plechoptera, and Trichoptera
FBI	-	Family Biotic Index
GPS	-	Global Positioning System
H		Shannon-Wiener Index
HBI	-	Hilsenhoff Biological Index
IS	-	Indicator Species
MCO	-	Movement Control Order
MOEFCC	-	Ministry of Environment, Forest and Climate Change
PCA	-	Principal Component Analysis
RIVPACS	-	River Invertebrate Prediction and Classification System
TDS	-	Total Dissolved Solids
TKN	-	Total Kjeldahl Nitrogen
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Research background

Water plays a unique role in environmental balance. It is possibly the most valuable natural resource after air. Thereby, this resource must be carefully maintained and conserved. Sources of water must be checked on a regular basis to determine the quality of water. The terrible state of water quality is more than a sign of environmental degradation; it poses a threat to the environment. Thus, water quality is critical in both environmental and economic terms.

Since water quality is a critical problem that needs to be seriously tackled Shamshirband *et al*., (2019), bioassessment is a generally recognised way of measuring the water quality of any ecosystem. This set of tools help monitor and track the trend and status of water quality. Therefore, to take part in water quality monitoring using bioassessment of macroinvertebrate diversity in stream flow, a study was conducted at Gunung Belumut waterfall, Ulu Dengar river and a stream intersection of Kahang river for ten months.

Benthic macroinvertebrates are the broad community of species consisting of several *Planarians, Annelids, Molluscs, Crustaceans, Arachnids* and *Arthropods* (Kumari & Maiti, 2020). The sampling of macroinvertebrates and water samples was conducted for ten months at specified locations. The macroinvertebrates were sampled and analysed in-situ for a period of time for different water samples collected at the same time as macroinvertebrate sampling. It is done to detect changes in the properties of macroinvertebrates and preferences based on physical water properties. These sedimentary and bottom-dwelling species are continually subjected to environmental

variability and through their diversity, abundance, metabolism, anatomy, behaviour and their susceptibility to varying degrees of stress and at various time scales is revealed (Karaouzas *et al*., 2019).

On the other hand, there are various biotic and diversity indexes used in water quality assessment. However, the result of diversity index assessment needs to be supported by another water quality assessment as the monitoring process because the indices only reflect the approximate estimation of the group structure (Cao *et al*., 1996). Biotic indices such as the Biological Monitoring Working Party (BMWP) and the Average Score Per Taxon (ASPT) method can be used for better evaluation. Qualitative data on species diversity and quantitative information on the vulnerability of individual taxa can be evaluated by applying this approach in a research study (Varnosfaderany *et al*., 2010). Previously, a study on diversity of aquatic insects at Hutan Lipur Bukit Soga Perdana, Batu Pahat, Johor, was conducted by Zakaria *et al*., (2018) using three biotic indices such as BMWP, Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa richness and Hilsenhoff Biotic Index (HBI) to classify the ranking of water quality. In addition, a study by Al-shami et al., (2011) demonstrated that the BMWP and ASPT indices produce values similar to the WQI scores for communities of lower altitude macroinvertebrates compared to other indices such as Hilsenhoff's Family Biotic Index (FBI).

Previously, Sembrong River located in Kluang, Johor, was hit by chemical pollution suspected to occur due to a palm oil factory releasing effluent illegally. As reported by Berita Harian on 5 Oct 2020, the pollution had caused thousands of fishes and prawns to float on the water surface. This consequently impacted the source of food supply for village communities of indigenous people living at Kampung Sedohok, Kluang, Johor. This shows that the invertebrates are impacted by polluted river water. As a result of this research, a set of guidelines for macroinvertebrate sampling and monitoring based on the scattering of macroinvertebrates and its sensitivity was produced.

The changes of macroinvertebrate assemblage in rivers can be used as early-warning signals of pollution at selected locations. This experimental study is conducted to connect the ecosystem of water with diverse types of living aquatic species, primarily macroinvertebrates, in rivers. This is because the quality and health of rivers are also reflected by its biological aspects. This research also focuses on the impact of physical characteristics of rivers or morphological traits of streams on the

diversity of macroinvertebrates. From the analysis and further observation of the trends of macroinvertebrates, a set of simple guidelines for a wide range of practices in Malaysia was produced based on the morphological traits of selected study locations.

1.2 Problem statement

The study of water quality monitoring status via multivariate ecological indicators has been used widely in managing water ecosystems. The living status of underwater organisms eventually reflects the ecological trends of stream flow. The assemblage of macroinvertebrates is often considered as good indicators of long-term changes in environments due to their confinement to the bottom, long life cycles and limited abilities of movement (Masikini *et al.*, 2018). Besides, the macroinvertebrates scoring data based on pollution tolerance has been widely implemented in the study compared to other biota. One of the methods used for describing the level of water quality by using the macroinvertebrate scoring system is known as Biological Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT). This method is widely used in monitoring water quality in various regions and countries despite concerns about seasonal changes (Bo *et al*., 2017). Certain countries such as England and Costa Rica have their own set of references of diversity and richness of macroinvertebrates (Ochieng *et al*., 2020). As this method focuses on the sensitivity and tolerance of macroinvertebrates in adapting to water quality, it is a suitable standard and reference for evaluating water quality.

Besides, the breeding of a fish species has been conducted intensively at Hutan Lipur Gunung Belumut waterfall under the Johor State Fisheries Department. However, the diversity of macroinvertebrates existing within the flow stream of the waterfall from upstream to middle stream and downstream of Hutan Lipur Gunung Belumut has not been analysed yet. The selected sampling locations in this study might impacted from anthropogenic impact such as pesticides, domestic waste discharge from houses which will influence the water quality in stream. In Malaysia, the standard for evaluating macroinvertebrates varies due to different access to stream locations and suitability of the application. A research study by Ochieng *et al*., (2020) from Eastern Uganda analysed the diversity of macroinvertebrates using the comparison of BMWP from England (BMWP-E) and BMWP from Costa Rica (BMWP-CR). Both BMWP

methods are applied in different seasons for temperate regions and tropical regions, respectively. As Malaysia is located in the equatorial region and has a tropical rainforest climate of being hot and humid throughout the year, the implementation of study method reference for evaluating macroinvertebrates needs to be tested and analysed. As mentioned by Zakaria *et al.,* (2018), the study located at Hutan Lipur Bukit Soga used three different biological methods to classify water quality ranking without the implementation of the ASPT method. Hence, the premier testing using BMWP-ASPT method was conducted in the river located in Johor, mainly in the flow stream of Hutan Lipur Gunung Belumut waterfall. BMWP-ASPT characterises macroinvertebrates at the lowest species category to evaluate the score value of tolerance to pollution.

Moreover, benthic macroinvertebrates were used in this biomonitoring study because of their wide spectrum of sensitivity to changes in water physicochemical characteristics (Ochieng *et al*., 2020). Macroinvertebrates are sensitive to their surroundings and are affected by the changes in environmental characteristic. Insensitive and sensitive macroinvertebrates have their own score of tolerance to evaluate water quality. Various factors contributing to the score of tolerance include how macroinvertebrates respond to different climatic conditions or weather variables (Li *et al.,* 2012).

In biological monitoring, a macroinvertebrate's sensitivity to certain water quality parameters is of concern. With regards to a research study conducted primarily in Johor, Malaysia, the development of suitable and simple guidelines for macroinvertebrate sampling and the implementation of the BMWP-ASPT method has not been adapted for different uses. A flexible guideline for suitable sampling techniques pertaining to stream flow conditions can be referred to by multi-level community structures such as school syllabi, governmental organisations or tertiary education.

Therefore, in this study, the justification of the richness and diversity index of macroinvertebrate assemblages does not only depend on the biotic index. It integrates the Simpson's diversity index and the Shannon-Wiener index which emphasise the correlation between biotic index and richness of species.

1.3 Research hypothesis

The following hypotheses have been made for this research study:

1. The macroinvertebrates found in the upstream are expected to be higher in diversity and may differ in species compared to those found in the middle stream and downstream.
2. The physical characteristics' trends in water quality are expected to influence the variability of macroinvertebrate assemblages in the stream.
3. The correlation analysis between macroinvertebrate diversity and water quality is expected to be positive.
4. Simple guidelines for biological monitoring with the approach of sampling techniques primarily for Johor, Malaysia is expected to clarify the use of fast and cost-effective water quality assessment.

1.4 Research aims and objectives

The objectives of this study are:

1. To investigate the performance of macroinvertebrate taxonomy richness in water quality monitoring by using the performance of BMWP-ASPT implemented in Malaysia with reference to BMWP-E and BMWP-CR.
2. To determine the physicochemical parameters and the principal component analysis correlation between macroinvertebrates and water quality parameters.
3. To develop a simple guideline on macroinvertebrate sampling techniques and the application of the BMWP-ASPT method to be implemented in Malaysia.

1.5 Research scope

This research study focuses on the evaluation of water quality based on the diversity of benthic macroinvertebrates in river flow. Benthic macroinvertebrates have different assemblages underwater according to the water quality status compared to other biological indices which require more assistance and are time consuming. The analysis of the diversity of macroinvertebrates and scale of tolerance to pollution were applied using the method implemented in most countries which is Biological Monitoring

Working Party-Average Score Per Taxon (BMWP-ASPT). This research study hereby focuses on the implementation of a premier test located at three stream flows in Kluang district, Johor. The applied method for the monitoring process was the set of references for BMWP-ASPT. Then, scattered data of macroinvertebrates existing in the stream flow were compared to the performance of macroinvertebrate taxonomy richness with BMWP-E and BMWP-CR. The goal of this study was to justify which set of BMWP-ASPT is the most appropriate and similar to those used in Malaysia, which is located in an equatorial area and includes a tropical rainforest. Secondly, the evaluation of physical parameters is part of this research to provide an overview of the relationship between water quality parameters and sensitivity of macroinvertebrates towards river ecosystems. The physical parameters recorded in this study were temperature, pH, dissolved oxygen (DO), electrical conductivity (EC) and total dissolved solids (TDS). The values of physical parameters and abundance of benthic macroinvertebrates recorded were evaluated in the Principal Component Analysis (PCA) in XLSTAT to predict the statistics of scattered macroinvertebrates and water quality. Simpson's diversity index and Shannon-Wiener index were used to evaluate the diversity and richness of the species to monitor the correlation between the scattering of macroinvertebrate and water quality. The sampling locations for this study were mainly focused on the stream flow of Gunung Belumut Kluang waterfall as the upstream, the Ulu Dengar river and intersection of Kahang river as the middle stream and downstream location, respectively. Sampling and analysis were conducted for ten months between May 2021 until February 2022 under limitations due to the Movement Control Order (MCO) to predict the trends and status of water quality based on macroinvertebrate indicators and water samples. Later, a simple guideline for macroinvertebrate sampling techniques specifically for each morphological condition of the study location was established.

1.6 Significance of research

The taxonomy richness of macroinvertebrate diversity in the stream flow from the upstream of Gunung Belumut waterfall to the downstream of the Kahang river intersection is expected to have slightly different and uncommon taxa compared to the diversity of BMWP-E and BMWP-CR. The outcomes from the study were used for further references in the biological monitoring of water quality status. The analysis and implementation of reference using BMWP-E and BMWP-CR along with the ASPT method were given a certain reference for species and family abundance based on the reference country. Moreover, the result of physical parameters extracted from the water quality testing was crucial to indicate and measure the trends of water quality patterns of the study locations with regards to the scattered data of macroinvertebrates. Hence, the results and analysis of the study were well situated to enhance and help develop simple guidelines for macroinvertebrate sampling for public referral and future studies due to the different morphological traits of streams. Finally, the conclusion from this study could also serve as a tool for community-based educational sharing and spreading awareness on the importance of conserving the diversity of macroinvertebrates as an indicator of water quality assessment in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous studies related to freshwater resources, biomonitoring by macroinvertebrates, water quality analysis method and water quality-macroinvertebrate interactions. This includes theories, fundamentals and background knowledge of macroinvertebrates and water quality interactions. Besides, this chapter elucidates numerous case studies which clarify the importance of using bioindicators in assessing stream water quality. Moreover, recent studies in assessing stream water quality according to the relationship between richness of macroinvertebrates and physicochemical parameters comply with the need to identify trends of water quality in freshwater resources.

2.2 Freshwater Ecosystem

Two types of water are known as seawater and freshwater. Seawater accounts for 97% of the total water in the ocean and seas while freshwater accounts for 3% of the total water on earth. The terrestrial phases of the global hydrological cycle, including rain, rivers, streams, reservoirs, dams, wetlands and groundwater are represented by natural freshwater habitats. Freshwater habitats encourage the provision of certain ecological resources that are jeopardised by the plethora of anthropogenic stressors such as climate change, invasive species and many other stressors.

Fortunately, many options for freshwater ecosystem conservation exist and must be acted upon immediately (Andrea *et al.,* 2020). Li *et al.,* (2012) found that the

ecological effects of climate change on terrestrial and marine ecosystems are increasingly apparent but evidence from freshwater is scarce, particularly in Asia. Meanwhile, river flow regimes have been transformed by groundwater and surface water management operations globally, prompting widespread ecological responses (White *et al.*, 2021).

Besides, freshwater ecosystems are crucial to aquatic life and the human population. It is in high demand worldwide although its conditions are also gradually deteriorating. Unfortunately, freshwater resources are scarce and threatened by extensive changes of ecosystems which includes changes in morphology of the river, hydrology, loss of native species, aquatic invasive species and many more (Carpenter *et al.*, 2011). Inland freshwater resources such as waterfalls have attracted little concern from researchers worldwide (Hussen *et al.*, 2018). However, biotic indices focused on macroinvertebrates and diatoms are routinely used for evaluation of the ecological state of freshwaters, indicating varying responses to anthropogenic pressures (Karaouzas *et al.*, 2019).

In addition, inland freshwater such as waterfalls also consists of the flora and fauna living around the water body and inside water regimes. Each component in freshwater relates and depends on each other to survive. The food web cycle plays a critical factor in balancing the ecosystem. However, Obeten & Ujung (2012) informed that the knowledge of waterfall systems is limited to hydrology and geological features thus it is recognised as natural monuments for revenue generation. Besides, waterfall systems have the potential to become ecotourism sources in developing countries. In fact, waterfalls commonly form a rich biome for native and exotic species which are washed upstream over the waterfalls to settle downstream in a more volatile stagnant environment.

2.2.1 Biodiversity stressors in waterfalls

The waterfall is considered as one of the intrinsic values among nature monuments in the world. The ecosystem and species possess a wide scope of instrumental values in life such as recreational values, natural resources values and ecosystem service values. Waterfalls are magnificent entities in which stream water takes place on unique relief (Haghe, 2011). It is viewed as a natural resource and a source of risk, pleasure and

constraints. In a waterfall ecosystem, various entities render specific uses and advantageous attributes in water quality monitoring. For instance, macroinvertebrates in tropical and temperate regions differ in species richness and are therefore suited for biological monitoring. Many researchers concentrated on the anthropocentric values of waterfalls in the water ecosystem (Berque, 2000).

Moreover, the heterogeneity of environmental stressors in waterfall streams affects the assemblages of benthic macroinvertebrates. Biodiversity stressors affect all organisms in the context of their population and survival growth among biotic organisms in the food chain cycle. Environmental stressors may be natural or anthropogenic stressors which include climate change or inadequate and excessive nutrients, habitat disturbances, storms and many more. The anthropogenic stressors caused by humans are the most critical events that impact the ecosystem in various forms (Freedman, 2018).

Besides, there are a significant number of native species in freshwater habitats, in which some of the species are endangered (Desjonquères *et al*., 2020). The impact of a tremendous threat to freshwater ecosystems needs to be monitored and evaluated within the time frame. As reported by World Wide Fund (WWF) (2018), a high rate of pollution has reduced the number of species in the freshwater system by 83% from 1970 until 2014. Hence, freshwater monitoring is interpolated with the characterisation of macroinvertebrates and aquatic communities (Bailey *et al*., 2014).

Furthermore, the degradation of water quality is also affected due to the sensitivity of biotic indices to eutrophication. The water quality along the stream from upstream to downstream might have a variety of water compositions reflected by the bio-stressors present at the sampling location. The macroinvertebrate assemblages in waterfall ecosystems are also influenced by different factors based on geologic structures, soil conditions as well as the physicochemical composition of water.

Besides, the status and trends of macroinvertebrate sensitivity are important in the development and management of conservation measures. The diversity of macroinvertebrate assemblages along the stream could yield records of undiscovered and undescribed species through time. The interaction between aquatic ecosystems and macroinvertebrate abundance is one of the fundamental attributes in freshwater. Unfortunately, there is a scarcity of studies on the potential of fisheries and aquaculture, biodiversity conservation and aquatic ecology of waterfalls. (Obeten & Ujung, 2012).

2.2.2 Stream Morphology and Habitat Preference

The identification of relationships between macroinvertebrates, stream physical habitat and land-use patterns need to be emphasised. Substrate characteristics and the existence of coarse woody debris were found to have the strongest correlations affecting the richness and structure of macroinvertebrate assemblages (Richards & Host, 1994). Several influences acting at a watershed scale, such as land use patterns and riparian environments, change stream characteristics primarily consisting of river morphology, substrate concentrations and the presence of woody debris.

Previously, a nested ANOVA analytical approach tested by Jerin (2021), showed that there was a relative importance of three nested spatial scales which are broader-scale upstream to downstream variation and local variation at the hydraulic unit scale in a bedrock-controlled stream to explain variations in channel morphology and riparian trees. The study revealed that channel morphology is largely influenced by local-scale variation, explaining about 92% of slope, 46% of bank width, 99% of average depth, 54% of width-depth ratio, 86% of cross-sectional channel area and 100% of hydraulic channel radius. Moreover, local-scale controls explain 60% of variations in species richness. Therefore, at a local stage, morphological variation of rivers is largely due to geological controls such as faults, bedding planes, joints and fractures.

Stream morphology is related to the size and shape of streams. It depends upon a series of complex processes along with the phase. Consequently, stream morphology is the main metric that can be used to assess the sustainability of the stream channel. As stated by a previous study by Jerin (2021), stream channels have certain observable characteristics as these functions depend on the quantity and frequency of flood events in a stream. Inadequate flowing water hardly shapes a stream. However, a large number of flood events will alter the shape and features of a stream. For a site study at waterfalls and streams, the substrate element at the bottom of a stream is important as macroinvertebrates have differing preferences. This research was conducted in Johor, Malaysia, to assess site study conditions and to link the morphology of the stream to the preferred habitat of macroinvertebrates. An optimal geomorphic classification would be process-based, applicable over several spatial and temporal scales, able to accommodate variability both within and across physical environments and capable of

predicting channel reaction to disruption (Frissell *et al.*, 1986; Naiman *et al*., 1992; Montgomery and Buffington, 1997). Since stream channels are complex and generally in a state of adaptation, their current conditions conversely indicate the past, long-term or future conditions of a stream (Kondolf & Micheli, 1995).

The state conditions of stream morphology are affected by a variety of anthropogenic pressures. It is important to study the resilience of streams in maintaining the ecosystem of water to create a reliable living habitat for macroinvertebrates as macroinvertebrates are attracted to the hydrological status of each stream flow ecosystem. Stream communities have a number of adaptations to natural hydrologic disturbances, including the combined effects of changes in land use and climate, as well as the timing, intensity and incidences of weather events such as erosive rainfall, soil erosion and drying that become unpredictable over time (Resh *et. al.,* 1988) and the distribution of biological communities in water flow (Grimm & Fisher, 1989).

2.2.3 Factor Influencing Macroinvertebrates Assemblages

In general, lasting drought or flood events affect the hydrological status of streams. The disturbance effect of morphological traits of streams impacts the habitat of macroinvertebrate assemblages. The lower flow of stream water impairs flow velocity, habitat size, temperature and level of oxygen (Bae *et. al.,* 2012). Reported by Asmamaw *et al.,* (2021), macroinvertebrate abundance may increase or decrease in response to low-flow conditions, depending on the duration and the intensity of the drought. In the timeline of the site study in streamflow starting from the upstream of Hutan Lipur Gunung Belumut to the downstream, the flow of water fluctuated between high velocity to low velocity due to seasonal change during the sampling period. This may lead to the comparable abundance of species found during the sampling process.

The change in morphological traits of streamflow and hydrological status gradually develops a surviving period for macroinvertebrates to adapt and enhance a scale of tolerance to its surroundings. A study by Hussain & Pandit (2012), showed that several species, including flatworms, *Oligochaetes* and *Chironomidae* larvae had to penetrate into the soil of bed sediment to locate enough moisture and survive prolonged drying. The result of macroinvertebrate abundance due to the effect of

reduction in flow velocity in streams may be viewed by computing the analysis using a paired t-test (Asmamaw *et al.*, 2021). From the report, species abundance was twice as high during a normal flow compared to the low-flow periods. The taxonomic richness based on family level also reached the highest point during the normal-flow period. The previous study was carried out at a tropical mountain stream, thus the early dry season (winter) might have shown a stable and suitable condition to meet environmental requirements to support greater species abundance.

2.3 Assessing water quality through bio-indicator

Macroinvertebrates have been widely known over the world as a bio-indicator agent in assessing the impact of human activity towards freshwater ecosystems, hence resulting in 27% of the 297 European methods using macroinvertebrates listed in the previous study (Birk *et al*., 2012). For instance, benthic macroinvertebrates have been found to live in streams and at the bottom part of it (Sharifah *et al*., 2015) to regulate their living cycle and balance the ecosystem.

Thereby, aquatic invertebrates are commonly used to monitor water quality as it is visible to the naked eye and require minimal equipment for on-the-spot analysis. In general, using aquatic invertebrates to assess water quality depends on the characteristics of macroinvertebrates in tolerating the state of the environment. Apart from that, macroinvertebrates are also numerous in most streams, are readily collected and identified, possess very limited mobility and have a long life cycle over the year (Hilsenhoff, 1988). Besides, a variety of indices were developed recently according to species and distribution of aquatic invertebrates in streams (Tasneem & Abbasi, 2012).

When examining water quality status, many researchers found that the diversity of aquatic life reflects the physicochemical properties of water and the physical habitat characteristics of watershed preferences and their feeding habits (Merrit & Cummins, 1996). Hence, their different tolerance levels and survival in water bodies and changes in habitat are some of the criteria that make macroinvertebrates appropriate as bioindicators.

Besides, because of their restricted mobility, they are also one of the biotic components that are most vulnerable to change since they spend most of their lives in the lower part of a water body (USEPA, 1999). As recreational areas are usually used

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PUBLICATIONS

PUBLICATION (Scopus)

1. Study of Water Quality Based on Diversity of Macroinvertebrates Using Average Score Per Taxon Method in Corporate Social Responsibility Program Approach at Gunung Belumut and Gunung Lambak Waterfall
   Publication in International Conference IConCESS 2021.

UPCOMING PUBLICATION (Scopus)

1. The Interest of Using the Biological Monitoring Working Party Method in Assessing the Water Quality.
   Publication to Scopus Index: Journal of Engineering Design (Toronto)

COMPETITION

1. The International Research and Innovation Symposium and Exposition 2021 (RISE).
   Innovation Title: Cage Sampler for Macroinvertebrates Sampling
   Award: Bronze medal

2. Malaysia International Water Convention (Poster Competition)
   Innovation Title: Cage Sampler for Macroinvertebrates Sampling
   Award: 5th place