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Evaluation of Water Quality of Coban Rondo Waterfall based on Benthic Macroinvertebrates as Bioindicator

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Abstract Human activities in water-based tourism areas may contribute to the degradation of the water quality. This research aimed to evaluate the surface water quality by using accurate biotic index of benthic macroinvertebrates as a bioindicator in Coban Rondo water river in Pujon, Malang Indonesia. Three locations including upstream, waterfall, and downstream were the sources of the macroinvertebrate samples taken in two different periods during the dry season in 2017 and the rainy season in 2018. The research was conducted from August 2017 to October 2018. Benthic macro-invertebrate sampling was conducted in each site. Results indicated that the pH of the water in Coban Rondo ranges from 6.5 to 7.5. The electrical conductivity is found higher during rainy season than dry season. Similarly, the (Biochemical Oxygen Demand) BOD level is also significantly higher in the rainy season. Meanwhile, the level of (Chemical Oxygen Demand) COD and (Dissolved Oxygen) DO are varied with the COD level found higher in the waterfall during rainy season but downstream in the dry season. The DO level is still acceptable based on the (Food and Agriculture Organization) FAO level of agricultural and drinking water. Moreover, the bioindicator results show that there are 32 species of macroinvertebrates, with average total abundance of 1662 organisms/m^2. Majority of the macroinvertebrates are Uenoidae, Hydropsychidae, and Baetidae which belong to taxa tolerance 1 – 4. Additionally, only waterfall station which is dominated by Caenidae with the tolerance of 7. Therefore, the water quality in Coban Rondo waterfall ranges from significantly polluted in the waterfall station to very good and excellent quality in general condition. There are a total of 140 taxa recorded in this study, including 80 taxa during the rain season and 60 taxa in the dry season and a difference in the total macroinvertebrate abundance in two seasons with a sharp fluctuation found during dry season. The Shannon Wiener diversity shows an average index of above 2 which indicates that the water has good quality and not polluted.

Keywords Coban Rondo, Macroinvertebrate, Bioindicator, Water quality, Waterfall

1. Introduction

Tourism is the world's largest industry. Tourism also brings both benefits and negative impacts to the area where the tourism takes place [1]. It is especially important to consider the impact of human in waterfall ecosystem. Some human activities in the ecosystem can alter and reduce environ-mental services of natural resources [2]. These can cause a decline of interest for waterfall tourism. Many nature-based tourism destinations have been reported under tourism activity pressure, including habitat degradation, pollution, wildlife reduction and extinction, exotic species introduction and invasion. In the situation where interest to visit nature is growing rapidly, managing waterfall is important [3]. It often puts a strain on water resources and can threaten the health of humans and animals [4]. In aquatic ecosystems interaction between environment and population processes affects the distribution and abundance patterns of species [5].

Therefore, the condition of aquatic animals is one of the indicators of water quality. It can monitor the object changes (biochemical or physiological or behavioral) that may indicate a problem in the ecosystem. The biological indicators tell us about the cumulative effects of various pollutants in the ecosystem and the extent of the problem that may be present, which cannot by examined from physical or chemical testing [6]. Thus, water quality and ecosystem health can be assessed through the existing diversity of benthic macroinvertebrates which can be evaluated by considering taxonomic composition, the existing functional trophic groups, and the types of predominant communities [7]. For livelihood water supplies, micro-organism content (total viable bacterial count (TVBC)), coli-form group, mold

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and yeast count, Enterococcus and sulfur-oxidizing bacteria) are common items used to evaluate water quality. Including the micro-organisms, the assemblage of macrophytes, microalgae, invertebrates and fish has been used to monitor water quality in different aquatic ecosystems for different purposes in recent years. Aquatic insects are used to assess the "health" of a river [8]. A more favorable water quality index would be characterized by finding sensitive as well as tolerant organisms [9]. The species of macrozoobenthic has different tolerant degree to environmental changes and therefore is able to be used in water quality assessment. There are some indices available to uses complementarily with macrozoobenthic analysis to examine level of organic pollution in water environment, including FBI (Family Biotic Index) and HBI (Hilsenhoff Biotic Index) while ASPT index (Average Score Per Taxa) was used to identify level of toxic material pollution [10]. Any changes in the physical and chemical variables can affect aquatic biota in a variety of ways [11]. The deterioration of water quality has led to the annihilation of ecosystem balance, and contamination and pollution of ground and surface water resources.

Several studies have been conducted to analyze the quality of river water from the bioindicator level. A study [12] monitored water quality using biotic indices of benthic macroinvertebrates along surface water ecosystems in tourism areas in East Java. The study found that the upstream and middle streams of two sites were good to excellent based on NSF-WQI (National Sanitation Foundation-Water Quality Index) water quality and biotic indices and the water was qualified as drinking water and recreational purposes. The result showed that high NSF-WQI index indicated good water quality. In addition, a study [13] analyzed the water quality of tertiary irrigation in several subdistricts in Malang and found that 27 taxa of benthic macroinvertebrates belonging to 10 classes were found in the three subdistricts. Based on benthic macroinvertebrate communities which was used to determine the HBI, the water quality in the irrigation channels were categorized into the fair category (fairly significant organic pollution) to fairly poor (significant organic pollution), while based on the value of ASPT, the water were categorized into probable moderate pollution to probable severe pollution. Another study [14] analyzed the community structure of benthic macroinvertebrates for evaluation the water quality in Nyolo springs and its drains located at Ngenep village, Karangploso Malang. The analyzed profile of biodiversity included taxa richness, Importance Value Index, and index of diversity (H'). The results showed that the taxa richness of benthic macroinvertebrate were 28 taxa and there was variation among stations. Baetidae, Caenidae, *Melanoides tuberculata*, Odonata from Euphaeidae family, Planaria and Hydropsychidae from species *Cheumatopsyche* sp. were found in the all of station. The level of organic pollution in the drains was lower based on the dominance of benthic macroinvertebrates taxa, in the contrary the toxic pollution level was higher based on the value of Shannon Wiener diversity index of benthic maroinvertebrates. Moreover, a study [15] analyzed the changes of benthic macroinvertebrate community structure and water quality along the stream of Sumber Awan wellspring based on macroinvertebrate biotic index such as HBI and ASPT value. The result showed that the community structure of benthic macroinvertebrate at second until fifth station was dominated by Hydropsychidae and Lepidostomatidae as an intolerant taxa to the pollution, the first and sixth station dominated by Thiaridae as a facultative taxa, and the seventh station dominated by Oligochaeta and Chironomidae as a tolerant taxa to the pollution. Based on FBI and H value, the first until sixth station was categorized in fair water quality (FBI value 5.16-5.57 and H 2.05-2.77), whereas the seventh station has very poor water quality. The result indicated that the water quality along the stream until ±800 m from Sumber Awan wellspring decreased because of organic pollution from human activity around the stream, include public bathing, washing and latrine, also agricultural and animal husbandry wastes. Additionally, the profile of benthic macroinvertebrates community and pysicho-chemical irrigation water quality in organic and conventional farming at Lawang district especially Sumber Ngepoh village had been investigated [16]. Results of this research showed that benthic macroinvertebrates community at irrigation water of organic farming was more diverse than conventional farming. Taxa that dominated at irrigation water of organic farming were *Melanoides tuberculata* (Thiaridae), *Parathelpusa* sp. (Decapoda), *Acentrella* sp. (Baetidae), *Caenis* sp. (Caenidae) and *Cheumatopsyche* sp. (Hydropsychidae). However, taxa that dominates at irrigation water of conventional farming were *Melanoides tuberculata* (Thiaridae), *Tarebia granifera* (Thiaridae), *Parathelpusa* sp. (Decapoda) and *Corbicula javaniva* (Corbiculidae). Based on Hi and FBI values from benthic macroinvertebrates, water pollution of organic matter at irrigation water conventional farming higher than organic farming. Conclusion from this research is that irrigation water quality of organic farming is better than irrigation water of conventional farming.

Nevertheless, there has not been any study examining the bioindicators to analyze the quality of water of the waterfall tourism objects. All the previous studies were conducted to analyse the spring water, conventional and organic farming water, and surface or river water. This study is different in a way that this study focused on the water quality of waterfall tourism attraction. As one example of the waterfalls used as ecotourism is Coban Rondo, this waterfall is of an excellent object to study. Coban Rondo ecotourism is a part of natural conservation region which possesses plant, animal, and ecosystem potentials. It also has natural uniqueness which can be optimized as the tourism attraction [17]. As a long record and popular tourist destination, Coban Rondo waterfall has a potential to lose its natural ecosystem and biodiversity [18]. However, among the previously conducted research, there has not been any analysis on the quality of water in Coban Rondo in relation with the benthic macroorganism. Therefore, the purpose of this study was to analyze the macroivertebrates as bioindicators of water quality of Coban Rondo waterfall.

2. Materials and Methods

2.1. Study Area

Coban Rondo waterfall is located in Pandesari, Pujon district, Malang regency, East Java. Coban Rondo is situated on 1135 meters above sea level and it is 84 meter high (see Figure 1). The water discharge is between 150 liter/second in the rainy season and 90 liter/second in the dry season. This waterfall is also used as drinking water management for the people in Pujon area. Coban Rondo waterfall is home of different vegetation and aquatic organisms. Coban Rondo ecotourism is a part of natural conservation region which possesses plant, animal, and ecosystem potential. The vegetation near the waterfall is dominated by big trees and fern which are heterogeneous. Geographically, the sampling areas are located in upper stream at 7°53'14.2"S 112°28'35.3"E, in waterfall or downstream at 7°53'04.4"S 112°28'36.8"E, and in the river area at 7°52'58.9"S 112°28'33.6"E. The upper stream is located as far as 500 meters from the waterfall. On the sides of the upper steam are conifers and similar to the upper mountain forest. Moreover, the downstream where the waterfall is located is rich of ferns dominated by Athyriumprocumbens [19] and bryophyte.

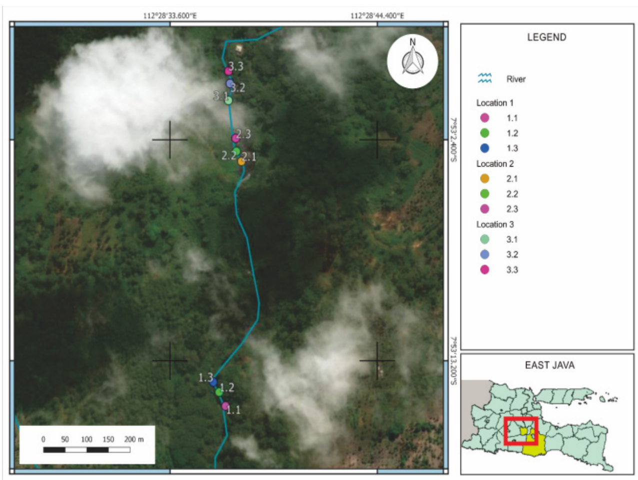

Figure 1. The distribution of sampling sites in Coban Rondo waterfall area

2.2. Methods

The sample in this study is benthic macroinvertebrates which were taken from 3 main locations in upper stream, downstream, and river nearby in Coban Rondo waterfall. There were 54 samples consisting of 27 samples in rainy season and 27 samples in the dry season. The tools used in this study include Surber nets, large plastic bowls, plates, pipets, and small and medium size bottles. Alcohol was used to preserve the samples.

Observations and water sampling were conducted to collect data from the specific area where research is being conducted. Samples were taken from 3 main locations including upper stream, downstream, and river nearby with 3 samples in each location. The water samples were taken during the rainy seasons from the research area.The samples of water were taken using water sampler and filtered to remove the insoluble materials. The water samples were collected in eighteen plastic bottles and nine intransparant glass bottles of 400 ml in size.

The measurement of pH and water conductivity was conducted in the field. On the other hand, the analysis of BOD and DO was done in the laboratory of Ecology, Brawijaya University and COD level was analyzed in the laboratory of Jasa Tirta company, Malang. The samples of water were analyzed in the laboratory to determine the physical components of the water and the chemical pollutants absorbed in the water in order to determine the water quality in Coban Rondo waterfall. The water quality parameters and the methods are presented in Table 1.

Table 1. Parameters and Methods

Parameters	Unit	Methods
pH		pH meter
Conductivity	µS/cm	Conductivitymeter
Dissolved Oxygen (DO)	mg/L	Digital Oxygenmeter
Chemical Oxygen Demand (COD)	mg/L	Spectrophotometer
Biochemical Oxygen Demand (BOD)	mg/L	
Macroinvertebrate	individu/meter	Taxa richness

Using membrane filtering, macro-invertebrates in the head stream, waterfall, and downstream locations were collected and placed in the plastic bowls. Surber nets were used to collect the macroinvertebrates living on the rocks and coarse sand in shallow waters. Each sampling site consisted on 3 subsample locations from which macroinvertebrate samples were collected twice each season. Each subsample covered 100 cm^2. The living macroinvertebrates were collected and preserved in small bottles containing 70% alcohol. All the raw materials sampled in the wild were stored in the bottles and preserved under low temperature onsite. Samples collected in the wild were transferred to laboratory. The second analysis was done to analyze the biodiversity level of macro-invertebrates of Coban Rondo waterfall conducted in the Ecology Laboratory of Brawijaya University. The organisms were thawed at room temperature, spread in petri dish and sorted under a stereo-microscope. The specimens were identified to the lowest taxonomic category, at least to the family level using benthic macroinvertebrate detector guide. The density of benthic organisms were standardized by the cover area of the sampling tools. The macroinvertebrates were analyzed to find the potential of living organism which can live in the upper stream, downstream, and nearby river. Using macro-invertebrate index, the species determination of the macro-invertebrate samples was generated.

2.3. Data Analysis

The data from the field measurements and laboratory analyses were used as bioindicators to determine the water quality levels. Using Analysis of Variance (ANOVA) followed by Tukey HSD (Honest Significant Difference) test and cluster analyses and Biplot, the difference in the water quality among the three locations were determined at the significance of 0.05 with SPSS for Windows Release 16.

3. Results and Discussion

3.1. pH Level in Coban Rondo River Water

The water quality parameters used in this study consisted of pH, conductivity, BOD, COD, and DO levels. Based on the analysis, pH level in Coban Rondo waterfall ranged above 6 and below 8. It was higher in the dry season compared to that in rainy season. However, among the sites, the dominance pH was different throughout the year. While the pH level was found highest in the downstream during rainy season at 6.96, quite the opposite the waterfall area showed the highest pH level at 7.47 during the dry season. The highest pH level was found during the dry season. During the dry season, the pH level rose up to 0.5 difference, but it dropped during rainy season. This result is similar to the finding of Mihu-Pintilie [20] which shows that at the surface, the pH reaches a maximum of 8.6 during the spring and drops to a minimum of 6.7 during the autumn. The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increased carbon dioxide concentration will therefore lower pH, whereas a decrease will cause it to rise.

3.2. Electrical Conductivity in Coban Rondo River Water

Table 2 shows that the water conductivity during rainy season was higher at above 125 µS/cm, especially in the second sampling in January 2018. The highest conductivity was at 132.60 µS/cm, which was found in the downstream. However, the conductivity in the dry season varied considerably from 68.65 µS/cm in the upper steam to 104.90 µS/cm and 121.05 µS/cm in the downstream and waterfall. This result can be caused by the height of the waterfall and the volume of waterfalls from the upper stream. The waterfall is 84 meters high with discharge speed at 150 L/second [18]. This is potential to have high conductivity value. The level of conductivity can be used to analyze the salinity level in the water leading to the analysis of water availability for crops. The level of conductivity can be the indication of salinity problems or levels of dissolved salts conditions that influences agricultural crops [21]. This is still in the range of water conductivity standard of FAO. Conductivity values less than 0.7 dS/m indicating no problems of salinity in irrigation water so that it can be used for all agricultural crops without restrictions. During the raining season in Indonesia, the temperature tends to increase, thus, it also increases the conductivity. Electrical conductivity increases with the temperature because it increases the ionic mobility. However, as during dry season especially between June and August the temperature in Indonesia, especially Pujon area, drops significantly, the conductivity also decreases. This happens due to the influence of the monsoon season which blows the freezing winter wind from Australia to the south part of Indonesia.

3.3. BOD, COD, and DO in Coban Rondo River Water

The presence of organic matter in the waters can be analyzed from the BOD and COD parameter values. BOD and COD are the levels of oxygen needed to degrade organic materials biologically (BOD) and chemically (COD).

According to the result, it is seen that the BOD level in the area of Coban Rondo ranged from 6.43 mg/L to over 8 mg/L during the rainy season and 3.60 mg/L to 10 mg/L in the dry season. The highest BOD level was indicated in the upper stream during the dry season by as much as 10 mg/L. This can be caused by the abundance of plants in the area of upper stream of the waterfall, thus, there are many dead plants. However, there was a decrease in the level of BOD in the waterfall area from 8.13 mg/L in the rainy season to only 3.60 mg/L in the dry season. In the rainy season the water tended to contain a higher BOD level than in the dry season. The reduction in the water volume causes the flow of the dead plants from the uppersteam decreasing, thereby dropping the level of BOD in the water. According to Gardiner [22] acid rain destroys streams and kill trees and destroy the leaves of plants and ozone in the lower atmosphere can prevent plant respiration by blocking stomata (openings in leaves) and negatively affect plants' photosynthesis rates which will stunt plant growth. Moreover, more sodium chloride (ordinary salt) in water may kill plants and plants may be killed by herbicides in water [23]. As the average BOD remained high in the rainy season, it can be concluded that the water of the waterfall during rainy season is still acceptable for agriculture, but it is less likely to be suitable for agriculture during dry season due to the low BOD content. The maximum limits of BOD based on Indonesia government standard Class III for agriculture is 6.0 mg/L.

Moreover, the result of the analysis also shows that the COD levels in the upper stream, waterfall, and downstream accounted for 18.60 mg/L, 20.88mg/L, and 14.49 mg/L respectively during the rainy season. A different condition was found during dry season, when the COD level dropped significantly to 13.25 mg/L in the upper stream and slightly in the waterfall to 19.22 mg/L. On the other hand, there was an increase in the COD level in the downstream during the dry season. This indicates that the water is not suitable for drinking water due to high COD content (above 10 mg/L of drinking water), however, it is still under category of recreation, fishery, animal husbandry, and irrigational water (25-100 mg/L). This condition happened because during the sampling in the rainy season, there was pipe fixing with the human interruption on the water flow in the upper stream which influenced the water in the waterfall and downstream. Besides, the activities of visitors in the waterfall area also added the cause of the high COD content. Moreover, the high level of COD in the downstream during the dry season could be caused by the decreasing volume of water and the accumulation of trash in the downstream as COD indicated the amount of organic pollutants in the surface water.

In contrast, the values of DO both in the rainy and dry seasons remained stable, ranging from 6.30 mg/L to 7.83 mg/L. The level of DO was at the average of 7.08 mg/L in the rainy season and 7.23 mg/L in the dry season. DO and pH have the same annual cycle. The highest DO level was reported in the upperstream during the dry season. The higher average of oxygen concentration (7.2 mg/L) recorded during the dry season is due to an enhanced photosynthetic activities and reduced turbidity during the dry season. These values are above the minimum of DO in water quality standard according to the provision of Indonesia government regulation No. 82 of 2001 in which Class I is at 6 mg/L for drinking water, Class II with minimum 4 mg/L, Class III at 3mg/L and Class IV is 0 mg/L. This indicates that the water is still suitable for drinking water.

The results of the water quality parameters are described in the Table 2.

3.4. Bioindicator of Water Quality

The results of the laboratory analysis of the microinvertebrates as the bioindicator of water quality are shown in the following Figure. According to Figure 1, there were 32 species of macroinvertebrates, with average total abundance of 1662 macroinvertebrates per meter square of the area. These 32 species included Uenoidae, Baetidae, Planaria, Chironomidae, Parathepusa convexa, Taeniopterygidae, Gammaridae, Hydropsychidae, Heptagenidae, Muscidae, Hydropilidae, Blephariceridae, Psychodidae, Tipulidae, Sericostomatidae, Dicosmocus, Caenidae, Lepidostomaiidae, Macromiidae, Leuctridae, Elmidae, Perlidae, Hirudinea, Polycentropodidae, Umnephilidae, Dryopidae, Brachycentridae, Dolichopodidae, Ptilodactylidae, Simuliidae, Corixidae, and Perlodidae. These variations are illustrated in the Figure 2 as follows.

Table 2. Water Quality of Coban Rondo Waterfall

Season	Rainy season			Dry season		
Parameter	Upstream	Waterfall	Downstream	Upstream	Waterfall	Downstream
pH	6,82	6,85	6,96	7,11	7,47	7,32
Conductivity (μS/cm)	126,30	130,47	132,60	68,65	121,05	104,90
BOD (mg/L)	8,53	8,13	6,43	10,00	3,60	3,73
COD (mg/L)	18,60	20,88	14,49	13,25	19,22	23,69
DO (mg/L)	6,30	7,72	7,22	7,83	7,23	6,63

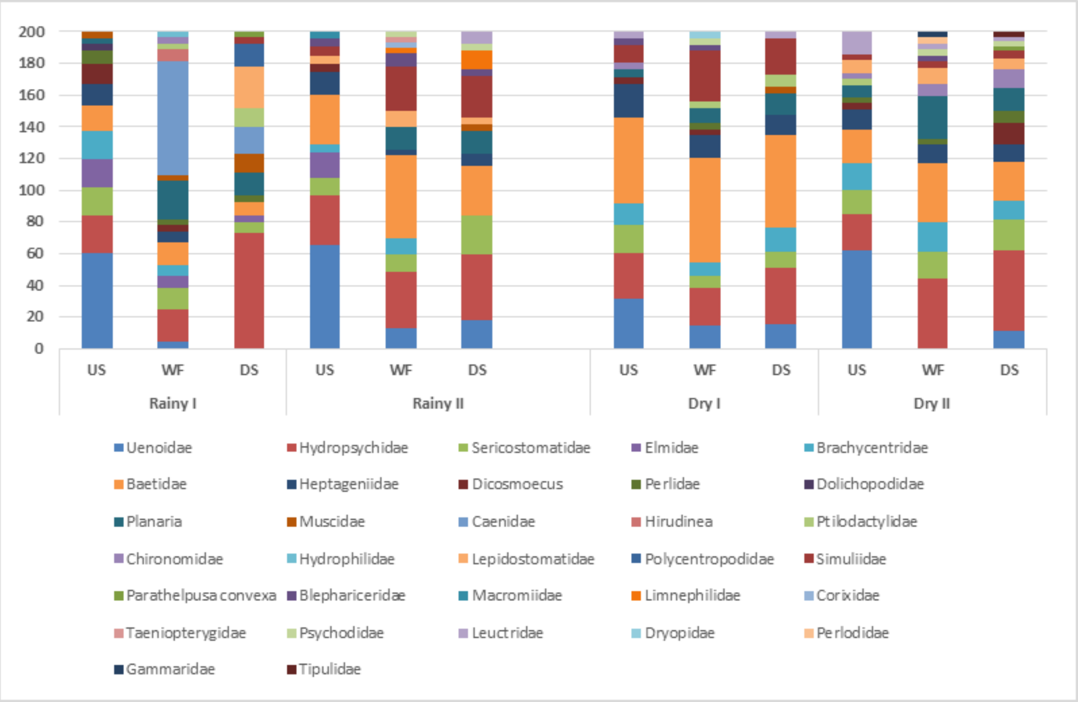

Figure 2. Macroinvertebrate Species in Coban Rondo Waterfall

According to the laboratory result, in the first sampling of the rainy season in December, the upperstream was dominated by Uenoidae, from the family of Trichoptera. According to Bode [24], Hauver and Lamberti [25], Hilsenhoff [26], and Plafkin [27], Uenoidae as scrapper feeding habit has a tolerant value of 3 indicating very intolerance to water pollution, which shows that the water has excellent quality with unlikely organic pollution based on the FBI index. Meanwhile, the waterfall was dominated by Caenidae of the family of Ephemeroptera. According to the tolerance value, Caenidae has a tolerance of 7 which shows tolerance to water pollution. This indicates that the water quality in the waterfall station is fairly poor according to FBI [26]. There is a significant degree of organic pollution in the water. This can be caused by the pollution from human activities. According to the visitors like to the observation, visitors entered the waterfall location, for drenching under the waterfall and taking pictures. This can be the cause of the degradation of water quality in the waterfall site. In contrast, Hydropsychidae was found abundant in the downstream, followed by slight number of Caenidae. According to taxa tolerance, Hydropsychidae has a tolerant value of 4, belonging to Trichoptera family. This level shows intolerance, indicating that the water is very good. This is because not many human activities were conducted in the downstream location. This pattern remained the same during the second sampling of the rainy season with Hydropsychidae and Baetidae in the second largest community. However, the waterfall station was dominated by Baetidae species. According to taxa tolerance, Baetidae belongs to a family of Ephemeroptera and has tolerant value 4. This level shows intolerance, indicating that the water is very good. This means that there was an increase in the water quality compared to the first sampling. This can be caused by the restriction to come closer to the waterfall, which was applied by the Coban Rondo management due to the sliding land from the upperstream and often flooding waterfall.

A similar finding was found during the dry season. The dominant benthic macroinvertebrate during the first sampling in the dry season was Baetidae in every location. Interestingly, the waterfall location also showed abundance of Simuliidae. Simuliidae has a tolerance of 6 which indicates that the water with Simuliidae has fair quality. This means that there is fairly significant degree of organic pollution in the water. However, in the second sampling result, the upperstream was dominated by Uenoidae, while the waterfall and downstream areas were abundant of Hydropsychidae and Baetidae with small number of Planaria in the waterfall and Brachycentridae in the downstream. Planaria is from the family of Playhelmynthes and has a tolerant value of 4 indicating very good quality of water, while Brachycentridae is from Trichoptera family and has a value of 1 which shows excellent water quality. Thus, according to the variation of macroinvertebrates found in the rainy and dry seasons, the water quality in Coban Rondo waterfall ranges from significantly polluted in the waterfall station to very good and excellent quality in general condition.

3.5. Taxa Richness of Macroinvertebrates

A high diversity of benthic macroinvertebrates with a total of 140 taxa was recorded in this study, including 80 taxa during the rain season and 60 taxa in the dry season. According to Figure 2, there are micro-invertebrate 41 taxa found in the waterfall from the first sample in the rainy season. It is shown that during the rainy season the lowest taxa index in found in the upper stream at value of 12. The second value is 13 found in the downstream, while the highest taxa richness is in the waterfall location at 16 in the rainy season. However, the level of taxa richness in the waterfall reduces slightly during the second sampling to 14, while those in the upperstream and downstream remain the same. The highest taxa number of the organisms in the waterfall can be caused by the high organic mater and the high DO level resulted from the natural process, including debris of organic mater from dead trees from the upperstream [28]. The headwater system is an important source of nutrients and organic matter such as dissolved organic carbon for the downstream ecosystem [29]. On the other hand, there was a decrease in the taxa index during the dry season. There were only 26 taxa of macroinvertebrates in the first sample. Additionally, the second sampling analysis resulted in only 34 taxa. Those numbers are fewer compared to those in the rainy season. Similarly, the highest taxa was also found in the waterfall station.

Moreover, the individual abundance during the rainy and dry season is different. During the dry season there were more microinvertebrates and the numbers fluctuated compared to that in the rainy season. The total abundance of individu per m^2 ranges from 694 to 2253 organisms/m^2 in the rainy season with the largest abundance of macroinvestebrates found in the waterfall station. The number of macroinvertebrates in the rainy season remained stable among the three locations: upper stream, waterfall, and downstream. However, there was an increase in the macroinvertebrate abundance in the waterfall during the second sampling. Additionally, the highest abundance of macroinvertebrates was indicated in the site 2, waterfall location taken during the second sampling. In contrast, there was a decrease in the number of macroinvertebrate individuals during the dry season. In the first sampling, the total individual of macroinvertebrates was 1000 individuals/m^2 in the upper stream, 3980 individuals/m^2 in the waterfall, and 1397 individuals/m^2 in the downstream. Nonetheless, the analysis result of the second sampling shows that the number of organisms reduced to 2020 organisms/m^2 in the upper stream, 201 individuals/m^2 in the waterfall, and 1061 individuals/m^2 in the downstream. Interestingly, there was a substantial decline in the number of benthos in the waterfall site during the dry season even though the highest organism abundance level was found in the waterfall location during the first sampling. This decline can be cause by environmental change. During the second sampling there was a land slide occuring in the upperstream which influenced the water content in the waterfall. As the waster contained small peebles and broken twigs and the water conductivity was high in the waterfall, these falling materials damage the living organisms in the waterfall, thereby causing the reduction in the number of macroinvertebrates in the station. The different numbers of organisms found between rainy and dry seasons can be caused by the temperature change. Benthic macroinvertebrates are sensitive to changes in temperature, precipitation, and the associated flow regimes [30, 31]. Moreover, the abundance of stream invertebrates is known to be influenced by environmental conditions such as: hydraulic stress, temperature and water chemistry [32, 33]. The dry and rainy season variation is important to determine ecological changes in the tropics [34]. Rainfall distribution patterns have great impact on both the chemistry of water as well as the population dynamics of the fauna [35].

The results of the analysis show that there is a difference in the total macroinvertebrate abundance between the rainy season and dry season with a sharp fluctuation found during dry season. The results of taxa richness and total abundance are described in the Figure 3.

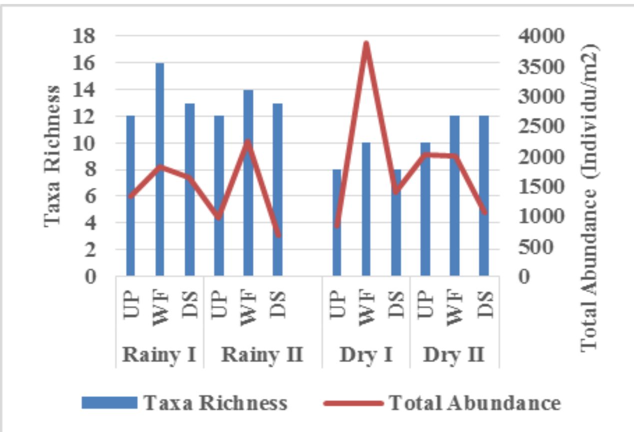

Figure 3. Taxa Richness

3.6. Diversity Index of Macroinvertebrates

Shannon Wiener diversity index is one of the accurate indexes to examine the level of pollution in water ecosystem caused by toxic materials. According to the Shannon Wiener Diversiy Index in Figure 3, the diversity index of macroinvertebrates found in all observed stations ranged from 1.94 to 2.65 in the rainy season and 1.87 to 2.80 during dry season. This indicates that the index result shows higher values during the dry season compared to the rainy season and the majority ranged above 2. It is interesting to note that there was an inverse pattern between the samples taken in the first sampling and second sampling times during the rainy season. In the first sampling results, the index shows regularly decreasing numbers as the water flows to the lower sites. However, an exact opposite change was found in the result of second sampling where the index was higher in the downstream rather than upperstream with the highest index indicated in the downstream.

According to the results, majority of the index values do not show a number of below 2 in the Shannon Wiener index. The Shannon Wiener Diversity Index indicates that the value of above 2 refers to the not polluted water condition. Thus, this indicates that the water is not polluted. Based on the index value, it is shown that the water in the upperstream and downstream is not polluted, as shown by H > 2 (Figure 4). In contrast, the results also show that the lowest diversity index was found in the waterfall during the dry season. The Shannon Wiener index indicates that during the first sampling However, during the dry season the water of the waterfall location was slightly polluted. It was indicated by the diversity index of below 2. This can be caused by the high human activity in the river, including recreation, bathing and washing. There is also an impact of agricultural activities with the use of chemical fertilizers and pesticides surrounding the upperstream stations.

The results of the analysis shows that there was a higher diversity index in the area of Coban Rondo during the dry season. Moreover, majorityof the stations show a value of above 2 in the diversity index. Therefore, it can be concluded that the water of Coban Rondo waterfall is not polluted. The results of Shannon wiener diversity index is described in the Figure 4.

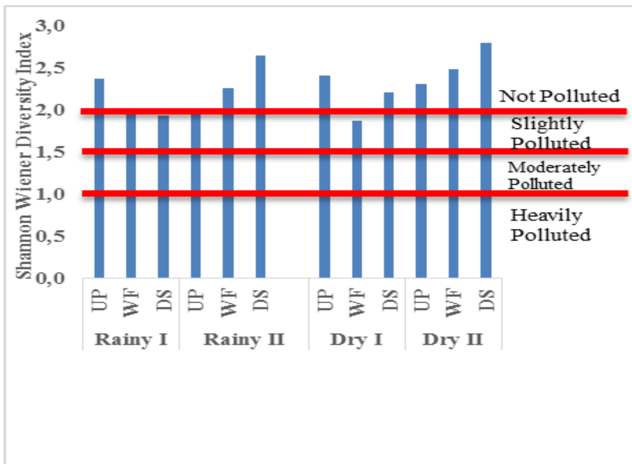

Figure 4. Shannon Wiener Diversity Index

3.7. ASPT Value

The Average Score Per Taxon (ASPT) represents the average tolerance score of all taxa within the community, and was calculated by dividing the BMWP by the number of families represented in the sample (Friedrich *et al*., 1996). This analysis is used to show the quality of water. According to the analysis, the ASPT value of Coban Rondo waterfall ranged form 4.92 to 7.12. The result shows that the ASPT values during dry season are higher than the values in the rainy season. The findings also indicate that the lowest value was found in the waterfall location during the first sampling in the rainy season at just below 5 and an increase of the value in all stations during the second sampling of rainy season to approximately 7. However, in the dry season the ASPT value tended to be stable at just above 6, except for the upperstream which always had the lowest value in the dry season. ASPT values of above 5 indicate good water quality. This finding is in correlation with the diversity index which shows that during the dry season the water quality is more than that in the rainy season. The ranges of the ASPT values can be seen in Figure 5.

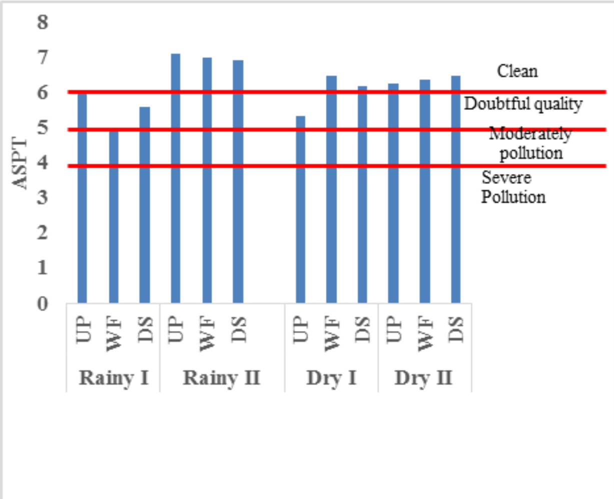

Figure 5. ASPT Value

According to the finding, the water quality of Coban Rondo waterfall is generally not polluted during the raisy season, but slighly polluted during the dry season. The water quality in Coban Rondo waterfall ranges from significantly polluted in the waterfall station to very good and excellent quality in general condition. However, the previous studies mosly revealed that the water quality in the irrigation water was from the fair category (fairly significant organic pollution) to fairly poor (significant organic pollution) and the conventional farming water was more polluted than the organic farming water. Nonetheless, the result of the previous research on the tourism water showed similar result of good quality of tourism water.

4. Conclusions

To sum up, the pH, conductivity, BOD, DO, and levels COD still meet the standard of irrigation water. Moreover, the DO levels indicates the suitability of the water of some stations for drinking. There is a dynamic community of macroinvertebrates in three stations, upperstream, waterfall, and downstream of Coban Rondo waterfall. High taxa richness is recorded, indicating that the rivers appear very rich. The potentially important factors that influence some differences in community structure in each station can be the environmental factors such as the seasons, the activities in basins watershed and the physicochemical variables which result in the distribution pattern of benthic macroinvertebrates in Coban Rondo waterfall. In further study, it is allowed, from this present work to address on the one hand the nutritional role of each available habitats and physicochemical factors on the aquatic communities and the role of the aquatic macroinvertebrates as biological indicators of deteriorated habitats.

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