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Effect of Water Parameters on Ephemeroptera Abundance in Telipok River, Sabah Malaysia

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Abstract:- This research was conducted to investigate the relationship between Ephemeroptera with water parameter such as pH, conductivity, turbidity, dissolved oxygen and total suspended solid in Telipok River, Sabah (Malaysia) using multiple linear regression. There were 32 possible models were considered in this work derived from the four significant correlation coefficients (between the dependents and independents variables). Eight selection criteria (8SC) were used in selecting a best model which signified the abundance of Ephemeroptera in the river. In order to understand the effect of the water parameters on Ephemeroptera numerical illustrations given in this work.

Key-Words: - multiple regression, eight selection criteria, interaction, best model, ephemeroptera, water parameter

1 Introduction

Pollution either anthropogenic or naturally can adversely affect any ecosystem. It create imbalance between the living organism and its surrounding by altering the habitat quality of the environment. Streams and river are an example of an important habitat and source of water for all living organism and human being. River or stream pollution will not just increase water shortage for daily use but also affect the aquatic species richness and diversity. The quality of the water will be reflected by the types of the creatures that can survive such as aquatic macroinvertebrate.

Aquatic macroinvertebrate also known as aquatic insect is often used in indication of river water quality because they can be affected by physical, chemical and biological conditions of a stream. They are good ndicators of watershed health because they live in the water most of their lifecyle, easy to collect and identify, shows differ in tolerance to amount and types of pollution, have limited mobility and an integrator of environmental condition. There are several order of aquatic insects. Some of it are, Ephemeroptera (E), Plecoptera (P) Tricoptera (T), Odonata (O) and, Diptera (D).The insect order EPT are often found in clean pollution free streams, because majority of these taxa are very sensitive to poor water quality. They are largely found in streams or river that unpolluted by organic waste and waters with high concentration of oxygen.

Unfortunely, dissolved oxygen (DO) is not the only factor that affecting the aquatic insects. Other parameter such as total suspended solid (TSS), turbidity (T), conductivity (C) and pH are some of the crucial indicator for water quality which also can play an important role to the inhabitance of these insects [13]. Moreover, when discussing an environmental dynamic it is advisable to look at all the factors as contribute together rather than as a single factor [3].Hence the impacts of each of this water quality on the aquatic insects are needed to be studied.

2 Problem Formulation

2.1 Sampling and measurement

Telipok river is situated 25km from Kota Kinabalu, Sabah Malaysia. The river has low gradient bank with shallow run. There are riffles and riparian vegetation along the river. The river was divided into 9 sampling locations and each were 50 meter long with 5 sub-sampling site.

Water parameter such as dissolved oxygen, conductivity, pH and turbidity were measured in the field using the Vernier Logger Pro meter. Gravimetric method [2] was used to analysed the water sample for total suspended solid. All samples for water parameter were collected before proceed with insect collecting activities. Kicking and dipping method [3, 12] were used to collect the insects, sorted and preserved with 80% ethanol in the field. Then, they were identified to order level in using taxonomy keys [6, 9].

2.2 Statistical analysis

Pearson correlation analysis was used to investigate the relationship between the water parameter and Ephemeroptera. The specific relationship between Ephemeroptera and water parameter was determined by using the best selection multiple linear regression. The dependent variable was Y: the number of ephemeroptera and the five independent variables were X_1: pH, X_2: conductivity (C), X_3: turbidity (T), X_4: dissolved oxygen (DO), and X_5: total suspended solid (TSS). The relationships between variables can be defined as follows [14] ;-

$$Y = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_k X_{ik} + \varepsilon_i \qquad (1)$$

where; $i = 1, 2, \cdots, n$

$\varepsilon = error\ term$

Since Y is in discrete form, logistic regression was used to transform the Y into interval form [1]. Then by using least square method, the parameter in the equation (1) were estimate using the equation (2)[7].

$$\hat{\beta} = (X'X)^{-1} X'Y \qquad (2)$$

All main variables were taking into account including the interactions between the variables. Supposedly, we have k variables, so we will have all possible model as shown in equation (3).

Total number of all possible models :-

$$\sum_{j=1}^{k} j\,{}^{k}C_j \qquad (3)$$

Further, we want to identify the best model to represent the relationship between the aquatic insects and water parameter. In obtaining the best model, we considered all the possible models. Then, the best model was chosen using the eight selection criteria (8SC) [10] as listed in Table 1. The analysis was continued with the residual randomness test to justify the best model.

Table 1. Eight model selection criteria (8SC)

	Selection criteria	Formula
i	SGMASQ	$\left(\frac{SSE}{n}\right)\left[1-\left(\frac{h}{n}\right)\right]^{-1}$
ii	AIC	$\left(\frac{SSE}{n}\right)e^{\left(2h/n\right)}$
iii	FPE	$\left(\frac{SSE}{n}\right)\frac{n+h}{n-h}$
iv	GCV	$\left(\frac{SSE}{n}\right)\left[1-\left(\frac{h}{n}\right)\right]^{-2}$
v	HQ	$\left(\frac{SSE}{n}\right)(\ln n)^{2h/n}$
vi	RICE	$\left(\frac{SSE}{n}\right)\left[1-\left(\frac{2h}{n}\right)\right]^{-1}$
vii	SCHWARZ	$\left(\frac{SSE}{n}\right)n^{h/n}$
viii	SHIBATA	$\left(\frac{SSE}{n}\right)\frac{n+2h}{n}$

where :-

SSE = Sum of squares error

n = Total number of observations

h = Total number of parameters involved in the model, $(h = k + 1)$

3 Results

3.1 Water parameter

The water quality study shows that the Telipok river can be divided into two groups which are the uncontaminated and the contaminated area. The first two sampling sites (stations 1 and 2) which located at the upper streams have a clear and good water quality. It is well oxygenated (DO, 6.40 – 6.48 mg/l), good conductivity (56.66 – 58.14 µS/m), low turbidity (12.6 – 13.2 NTU) and very low with suspended solid (12 – 16 mg/l) (Table 2). This water quality placed the upper streams of the Telipok river as in Class IIA based on the INTERIM, Malaysia [8], which means it is a good water resources and no special treatment are needed.

In contrast, station 3 to station 9 shows a different state. Even though the pH along the river (station 1 to station 9) are in good condition (6.72 – 7.59), but other parameters such as DO, conductivity, turbidity and TSS are way off from the station 1 and 2 (Table 2). Its DO were within 4.64 – 5.50 mg/l, the conductivity (186.5 – 266.68 μS/m), the turbidity were in the range of 313.4 – 474.1 NTU and the suspended solid were more than 18 times higher than station 1 and 2 (288 – 540 mg/l). This means that station 3 to 9 has placed the Telipok River in the Class III and water treatment are vital before it can be used in daily activities [8].

Table 2. Water parameter value in Telipok River.

Station*	Water parameter				
	pH	Conductivity (μS/m)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Total Suspended Solid (mg/l)
1	6.72	58.14	6.48	12.6	12
2	6.88	56.66	6.40	13.2	16
3	6.68	266.58	4.64	474.1	540
4	6.84	192.14	5.28	313.4	288
5	6.95	188.48	4.7	379.1	290
6	7.00	186.5	4.7	355.3	452
7	6.97	204.08	5.5	423.1	444
8	7.52	222.44	4.9	353.2	454
9	7.59	197.06	4.8	356.5	480

*Note : All parameters were collected from five sub-sampling site in every station.

The water parameter difference between stations 1 and 2 with station 3 to 9 was believed due to effluent input from poultry and pig farming**,** quarry activities and residential area along the station 3 to 9. Even from the observation, the river water from station 3 to 9 was sometimes blackish and murky with unpleasant smells.

3.2 Aquatic insects

The basic principle in studying the aquatic insect abundance is that some of them are sensitive to pollution, especially to a condition that may affect the DO, pH, turbidity and other water parameter. As for this work, there are 5 orders of aquatic insects that have been identified exist in Telipok River. The five orders are Ephemeroptera, Pleocoptera, Tricoptera, Odonata and Diptera.

However, it seems that only a particular order can be found in certain station. The EPT orders were found mostly abundant in station 1 and 2 (Table 3). The Ephemeroptera were found only 7 in station 3, 23 in station 4, 3 in station 5, 1 in station 6, 8 and none in station 7 and 9 respectively. The Pleocoptera and Tricoptera were found only 2 in station 5 and 1 in station 4 respectively and none in the other station. Yet, aquatic insect in order Odonata and Diptera were found in all station (Table 3).

Table 3. Total number of individuals per order collected from 9 stations (with 5 sub-sampling) in Telipok River.

Aquatic Insects Order	Station								
	1	2	3	4	5	6	7	8	9
Ephemeroptera (E)	56	79	7	23	3	1	0	1	0
Pleocoptera (P)	9	1	0	0	2	0	0	0	0
Tricoptera (T)	23	7	0	1	0	0	0	0	0
Odonata (O)	8	19	14	10	38	35	41	26	39
Diptera (D)	9	17	94	49	72	48	22	29	42
Total of individuals	105	123	115	83	115	84	63	56	81
Number of Orders Present	5	5	3	4	4	3	2	4	2

Studies by entomologists [12, 13, 15] showed that the first three orders Ephemeroptera, Pleocoptera and Tricoptera were sensitive to water quality changes especially to DO and pH compare with Odonata and Diptera.

3.3 Correlation analysis

Pearson correlation analysis verify that dissolved oxygen, conductivity, turbidity and total suspended solid of Telipok River are strongly influenced the Ephemeroptera, Pleocoptera and Tricoptera profusion in Telipok River (Table 4).

Conductivity, turbidity and total suspended solid have a strong negative correlation with the EPT, but a good positive correlation were observed between the EPT with dissolved oxygen. This can be explained as due to morphology or physical of the EPT insects, which have an external respiratory surface.

Table 4. Correlation between pH, conductivity, turbidity, dissolved oxygen, total suspended solid and aquatic insects order.

Variables	pH	Conductivity	Turbidity	Dissolved Oxygen	Total Suspended Solid
E	**-0.344[a]**	**-0.784[b]**	**-0.711[b]**	**0.655 [b]**	**-0.753[b]**
P	-0.302[a]	-0.579[b]	-0.524[b]	0.513[b]	-0.554[b]
T	-0.376[a]	-0.670[b]	-0.617[b]	0.526[b]	0.627[b]
O	0.235	0.171	0.201	-0.213	0.309[a]
D	-0.121	0.494[b]	0.390[b]	-0.532[b]	-0.471

a correlation is significant at the 0.05 level.
b correlation is significant at the 0.01 level.

Their gills can be located thoracic, abdominal, caudally or at the base of their legs [6, 12, 15]. These gills can be easily clog with suspended solid (colloid or small particle that suspension in the water). Once it is clogged the gills cannot function. It cannot extract oxygen from the water, and this could be lethal to the aquatic insects. Higher suspended solid means the water become cloudier and consequently, it will increase the turbidity of the water. While dissolved oxygen is vital for survival and growth of all aerobic organism like the aquatic insects such as the EPT.

Aquatic insects in order Odonata can survived in low oxygen and high TSS because they have a close tracheal system [15], it also can easily move to water surface and obtain atmospheric oxygen by trapping a bubble of air. Meanwhile, Diptera can reduce their feeding activities and focus more on the respiratory movements. It has breathing tube which called as respiratory siphons [12,15]. This tube can reach the surface and use for inhalation of the atmospheric oxygen. Therefore if the TSS or turbidity is high, it wouldn't affect much on the Odonata and Diptera. Aquatic insects in order Ephemeroptera were discussed further on its relationship with the water parameter as it has the most highly significant correlation with all the water parameter as in Table 4.

3.4 Multiple regressions

The relationship between the Ephemeroptera (Y) and water parameter (Xi) were determined using multiple regression. Since Y was in discreet form, we used logistic regression to transform it into interval form (Z). The result from Pearson correlation analysis showed that X_1: pH, and X_4: dissolved oxygen had a positive relationship with the number of Ephemeroptera while, X_2: conductivity, X_3: turbidity, and X_5: total suspended solid had negative relationship.

Based on Table 5, the independent variables with significant correlation coefficients were chosen to be included in the multiple linear regression model which, X_1: pH, X_3: turbidity, X_4: dissolved oxygen and X_5: total suspended solid.

Table 5. Correlation between Ephemeroptera and water parameter.

Variables	Z	X_1	X_2	X_3	X_4	X_5
Z	1	0.887[b]	0.251	-0.539[a]	0.881[b]	-0.551[b]
X_1	0.887 [b]	1	-0.216	-0.414	0.971[b]	-0.412
X_2	-0.414	-0.216	1	-0.947[b]	-0.387	0.946[b]
X_3	-0.539[a]	-0.414	0.947[b]	1	-0.567[b]	0.965[b]
X_4	0.881[b]	0.971[b]	-0.387	-0.567[b]	1	-0.556[b]
X_5	-0.551[b]	-0.412	0.946 [b]	0.965 [b]	-0.556[b]	1

a correlation is significant at the 0.05 level.
b correlation is significant at the 0.01 level.

Since we had four independent variables, 32 possible models were generated and only 14 models were selected with all variables were significant (p-value< $\alpha/2$). Then, the best models were chosen from the selected models using 8SC (Table 6).

Table 6. Values of 8SC for the selected models.

Selected Models	SGMASQ	AIC	FPE	GCV	HQ	RICE	SHIBATA	SCHWARZ
Z1	0.036	0.038	0.038	0.038	0.040	0.039	0.038	0.042
Z3	0.121	0.128	0.128	0.128	0.132	0.129	0.127	0.140
Z4	0.038	0.040	0.040	0.040	0.042	0.041	0.040	0.044
Z5	0.119	0.125	0.125	0.126	0.129	0.126	0.125	0.137
Z12	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Z13.1	0.029	0.031	0.031	0.032	0.033	0.032	0.031	0.036
Z15.1	0.080	0.086	0.086	0.087	0.090	0.087	0.085	0.098
Z21.1	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.002
Z22.4	0.029	0.031	0.031	0.032	0.033	0.032	0.031	0.036
Z23.1	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.002
Z25.2	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.002
Z26.2	0.012	0.014	0.014	0.015	0.016	0.015	0.014	0.018
Z27.2	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.002**
Z30.4	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Note: Values highlighted represent the smallest value for that particular criterion

Model with a majority minimum value of the 8SC were choose as the best model. Results showed that model $Z27.2$ was the best model. The equation of the model Z 27.2 can be expressed as in Table 7. The model was abided with the assumption of randomness test.

Table 7. Equation for the best model.

$\hat{Z}$	$= -1.165 - 0.136X_1 - 0.391X_4 + 0.033X_{14} - 5.59\times10^{-5}X_{15} - 6.4\times10^{-6}X_{145}$
Standard error :	(0.165) (0.028) (0.024) (0.002) ($1.977\text{x}10^{-5}$) ($2.123\text{x}10^{-6}$)

4 Discussion and conclusion

There are many factors in the environment that can affect the ecosystem as a whole. Thus, when discussing an environmental dynamic it is advisable to look at the factors contribute together rather than as a single factor [3]. In this work we have found that the first and second order interactions were significant in the best model.

The best model obtained;

$$\hat{Z} = -1.165 - 0.136X_1 - 0.391X_4 + 0.033X_{14} - 5.59\times10^{-5}X_{15} - 6.4\times10^{-6}X_{145}$$

This suggesting that pH, dissolved oxygen and the interaction between the two parameter with the suspended solid were the crucial factors. This concurs with many studies that have been done before [12, 13]. Dissolved oxygen is the key to the abundance of Ephemeroptera as oxygen is the most important element to all living organism to stay alive. Nevertheless, slightly changes on the pH also change the existence of Ephemeroptera. Apparently, the suspended solid and turbidity alone does not hold a greater effect on the insects.

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