RELATIONSHIP BETWEEN FRESHWATER QUALITY AND AQUATIC INSECTS ON TAGAL SYSTEM AT SG. MOYOG, PENAMPANG, SABAH, MALAYSIA

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INSTITUTE FOR TROPICAL BIOLOGY AND CONSERVATION
UNIVERSITI MALAYSIA SABAH

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ABSTRACT

Water is invaluable resource that increasingly being threatened and demand for more water of high quality for economic activities and domestic purposes is also increasing. *Tagal* in the Kadazandusun language means prohibition or forbidden from exploiting river resources by an unrelated third party and this system legally implemented since the year 2002 in Sabah. This study aimed to determine the relationship between water quality and composition as well as distribution of aquatic insect at Sg. Moyog, Sabah. Physico-chemical parameters such as pH, temperature, dissolved oxygen (DO), salinity, conductivity, total dissolved solids (TDS) were measured in this study. *Ex-situ* analysis such as chemical oxygen demand (COD), total suspended solids (TSS) and dissolved organic carbon (DOC) were also analyzed. At each stream, aquatic insects were sampled along approximately 100 m reach by using a kick net (mesh size 590 µm). Kampung Kibunut River (KB) was the least disturbed area compared to river in Kampung Notoruss River (NT) and Kampung Babagon River (BB) where both stations were slightly disturbed and disturbed respectively. Water quality values indicated that all parameters at Kampung Kibunut River (KB) are in Class I whereas at river in Kampung Notoruss River (NT) and Kampung Babagon River (BB), some of the parameters are categorized in Class IIA and Class IIB such as COD, nitrate and phosphate based on National Water Quality Standard for Malaysia (NWQS). A total of 18902 individuals were collected from six sampling station and 10 orders of aquatic insects were identified comprising of 39 families and 68 genera from Sg. Moyog. Trichoptera was the most abundant order with 62.62% and *Cheumatopsyche* spp. was the most abundant taxa (49.73%). Cluster analyses resulted in two different groups: the first group consisted of Kampung Kibunut River (KB); the second group formed by Kampung Babagon River (BB) and Kampung Notoruss River (NT). This specified that animal farms, tofu factory and recreational area from Kampung Notoruss River (NT) were grouped together with human settlements, agricultural sites and recreational area from Kampung Babagon River (BB) which varied from Kampung Kibunut River (KB) that received the least disturbance. Kruskal-Wallis test showed no significant differences between sampling locations for abundance, richness, Shannon's diversity, Simpson's diversity, EPT index and BMWP index. This indicated that despite receiving human disturbance and anthropogenic activities from Kampung Babagon River (BB) and Kampung Notoruss River (NT), there was no clear distinction from Kampung Kibunut River (KB). It proved that the *Tagal* system is an good practice that is suitable for managing the aquatic organism communities and preserving the freshwater ecosystems. Results from Canonical Correspondence analysis (CCA) indicated that most of the families from order Ephemeroptera have a strong positive association with pH, temperature and DO which indicated that Sg. Moyog has received minimal pollution as Ephemeroptera is highly sensitive to water quality degradation. The implementation of *Tagal* systems in Sg. Moyog is a good resource management systems and strengthening sustainable livelihoods in the communities.

Keywords: Physico-chemical, *tagal*, water quality, aquatic insects, anthropogenic activities

ABSTRAK

HUBUNGAN ANTARA KUALITI AIR TAWAR DAN SERANGGA AIR PADA SISTEM TAGAL DI SUNGAI MOYOG, PENAMPANG, SABAH, MALAYSIA

Air adalah sumber yang tidak ternilai yang semakin terancam dan permintaan lebih banyak air berkualiti tinggi bagi aktiviti ekonomi dan keperluan domestik. Tagal dalam bahasa Kadazandusun bermaksud larangan atau dilarang daripada mengeksploitasi sumber-sumber sungai oleh pihak ketiga yang tidak berkaitan dan sistem ini secara sah bermula sejak tahun 2002 di Sabah. Kajian ini bertujuan untuk menentukan hubungan antara kualiti air dan serangga akuatik di Sg. Moyog [Kampung Babagon (penempatan manusia, kawasan pertanian dan kawasan rekreasi), Kampung Notoruss (penternakan haiwan, kilang tauhu dan kawasan rekreasi) dan Kampung Kibunut (paling kurang terganggu). Parameter fiziko-kimia seperti pH, suhu, oksigen terlarut (DO), kemasinan, konduktiviti, jumlah pepejal terlarut (TDS) telah diukur dalam kajian ini. Analisis eks-situ seperti permintaan oksigen kimia (COD), jumlah pepejal terampai (TSS) dan karbon organik terlarut (DOC) juga dianalisis. Manakala sampel serangga akuatik diambil lebih kurang 100m dengan menggunakan jaring yang berukuran mesh 590 µm. Sungai di Kampung Kibunut adalah kawasan paling kurang terganggu berbanding sungai di Kampung Notoruss (NT) dan sungai di Kampung Babagon (BB) di mana kedua-dua stesen itu sedikit terganggu dan terganggu masing-masing. Data yang telah dikumpul menunjukkan bahawa semua parameter air sungai di Kampung Kibunut (KB) berada dalam Kelas I manakala sungai di Kampung Notoruss (NT) dan Kampung Babagon (BB), beberapa parameter dikategorikan dalam Kelas IIA dan Kelas IIB seperti COD, nitrat, nitrogen ammonia dan fosfat berdasarkan Piawaian Kualiti Air Kebangsaan Malaysia (NWQS). Sejumlah 18902 individu serangga akuatik dikumpulkan dari enam stesen persempelan yang terdiri daripada 10 order, 39 famili dan 68 genera dari Sg. Moyog. Trichoptera adalah order yang paling banyak dengan 62.62% dan Cheumatopsyche spp. adalah taksa yang paling tinggi (49.73%). Analisis kluster menghasilkan dua kumpulan yang berbeza: kumpulan pertama terdiri daripada sungai di Kampung Kibunut (KB); kumpulan kedua yang dibentuk oleh sungai di Kampung Babagon (BB) dan sungai di Kampung Notoruss (NT). Ini menyatakan bahawa sungai di Kampung Notoruss (NT) diklusterkan bersama dengan sungai di Kampung Babagon (BB) yang berbeza dari sungai di Kampung Kibunut (KB) yang mendapat sedikit gangguan. Ujian Kruskal-Wallis tidak menunjukkan perbezaan yang ketara antara lokasi persampelan untuk kelimpahan, kekayaan, kepelbagaian Shannon, kepelbagaian Simpson, indeks EPT dan indeks BMWP. Ini menunjukkan bahawa walaupun menerima gangguan dan aktiviti antropogenik manusia dari Babagon (BB) dan sungai di Kampung Notoruss (NT), tidak terdapat perbezaan yang jelas dari Kibunut (KB). Ia membuktikan bahawa sistem Tagal adalah satu amalan terbaik yang sesuai untuk mengurus komuniti organisma akuatik dan memelihara ekosistem air tawar. Hasil daripada Analisis Canonical Correspondence (CCA) menunjukkan bahawa kebanyakan famili dari order Ephemeroptera mempunyai hubungan positif yang kuat dengan pH, suhu dan DO yang mana menunjukkan bahawa Sg. Moyog telah menerima pencemaran terhad kerana Ephemeroptera sangat sensitif terhadap kemerosotan kualiti air. Pelaksanaan sistem Tagal di Sg. Moyog adalah sistem pengurusan sumber yang baik dan dapat mengukuhkan kehidupan yang mampan dalam komuniti.

Kata kunci: Fiziko-kimia, tagal, kualiti air, serangga akuatik, aktiviti antropogenik

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LIST OF ABBREVIATIONS AND SYMBOLS

pH	-	Potential of Hydrogen
mg/L	-	Milligrams Per Litre
DO	-	Dissolved Oxygen
%	-	Percentage
°C	-	Degree Celsius
m	-	Meter
>	-	More Than
<	-	Less Than
OH^-	-	Hydroxide Ion
H	-	Hydrogen
H^+	-	Hydrogen Ion
P	-	Phosphorus
N	-	Nitrogen
Km	-	Kilometer
µm	-	Micrometer
NH_4-N	-	Ammoniacal Nitrogen
NO_3^-	-	Nitrate
PO_4^{3-}	-	Phosphate
TSS	-	Total Suspended Solids
TDS	-	Total Dissolved Solids
TN	-	Total Nitrogen
DOM	-	Dissolved Organic Matter
TOM	-	Total Organic Matter
DOC	-	Dissolved Organic Matter
TOC	-	Total Organic Carbon
CDOM	-	Coloured Dissolved Organic Matter
CPOM	-	Coarse Particulate Organic Matter
FPOM	-	Fine Particulate Organic Matter
POM	-	Particulate Organic Matter
FBI	-	Family Biotic Index
BMWP	-	Biological Monitoring Work Party
ASPT	-	Average Score Per Taxon
EPT	-	Ephemeroptera, Plecoptera and Trichoptera
Sg.	-	Sungai (River)
MC-I	-	Multiple Control Impact
DA	-	Discriminant Analysis
CCA	-	Canonical Correspondence Analysis
H'	-	Index Value
NWQS	-	National Water Quality Standard
BB	-	Babagon
NT	-	Notoruss
KB	-	Kibunut

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Water is vital to the existence of all living organisms, but this invaluable resource is increasingly being threatened as the human population grows. On the other hand, there are also demands for more water of high quality for economic activities and domestic purposes (Carr & Neary, 2008). Only a small proportion of salt free freshwater is accessible to human beings. Compared to the seawater which consists of about 76% of the the water on Earth, freshwater just occupied a small fraction of water bodies which is about 1% and from that 1%, 73% of it is in the form of ice (mostly contained within the Greenland and 23% is liquid freshwater (Likens, 2010).

There is a pattern of exponential increase in water quality research due to its importance to both wildlife and humans (Varol *et al*., 2011; Wang *et al*., 2012). Organic pollution and eutrophication of surface water are currently of great environmental concern worldwide (Yang *et al*., 2016). The presence of chemical pollutants and excessive nutrients in the rivers can adversely impact the functionality of the ecosystems, such as fish mortality, causing critically low dissolved oxygen content, loss of biodiversity, and loss of aquatic plant beds. Sewage disposal, discharge from industries which are not equipped with appropriate effluent treatment facilities, land clearing and earthwork activities are the main causes of river pollution in Malaysia (Juahir *et al*., 2011).

In Sabah, river water quality is threatened by pollution caused by human activities as it is the easiest way to get rid of garbage and leftovers by dumping into the river (Lajiun, 2011). Rivers is commonly used as one of the ways for liquid and solid waste disposal (Afroz *et al.*, 2014). However, there are some indigenous system which developed by the indigenous people of Sabah to safeguarded their communities, a sustainable livelihood and the use of resources within their surrounding (Halim *et al.*, 2012) such as *Tagal* system. *Tagal* system is the resource management system that executed by indigenous communities in Sabah where the management and implementation vary between communities in terms of management structure, rules and fines but apply the same concept of the open and closed season, equal sharing of responsibility (Pacos, 2010).

Measuring the physical, chemical and biological characteristic of surface water and groundwater provide crucial information in addressing and identifying water quality problems (Palaniappan *et al.*, 2010). Water quality parameter test include total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), salinity, conductivity, pH, temperature, acidity, alkalinity, turbidity and biochemical oxygen demand (BOD) can be used to determine the level of water quality (Li and Migliaccio, 2011). Moreover, biological parameters (zooplankton, phytoplankton, fishes, macroinvertebrates, aquatic insects, and microbes) (Palaniappan *et al.*, 2010) can also determine the aquatic ecosystem (Kidd *et al.,* 2011).

Dissolved organic matter (DOM) is a heterogeneous and dynamic mixture of chemical compounds that widely exists in aquatic and terrestrial ecosystems. It represents an vital source of carbon and other imperative nutrients resources that determine the availability and diversity of living organisms with its vital role in numerous biogeochemical and ecological processes (Richey, 2005).

Classically, an investigation of water quality involves not only the physical variables but also the biological indicator (Jones *et al.*, 2001). The study of the structure and composition of aquatic insect is important in monitoring the changes of water quality and the ecological integrity of stream and river (Arimoro & Ikomi, 2009). The aquatic insect has been widely used as an indicator for monitoring water quality (Yoshimura, 2012) as its great respond to perturbation, present in a wide array of aquatic habitats, relatively easy to sample and process and standardize the method of collection and analysis have been greatly progressed (Whiles *et al*., 2010). Besides, aquatic insects are among the most directly affected and vulnerable organisms with respect to surface water pollution and constitute an important component of biodiversity in lotic systems (Verneaux *et al*., 2003). Studies by using aquatic insects as a bioindicator to anthropogenic impacts on the freshwater ecosystems have shown a general decline in aquatic insect population and a decrease in species diversity and richness (Heino, 2009).

To date, there are very limited specific research, documented data and past research done on water quality and aquatic insect study of *Sg*. Moyog to prove the condition of this river and the efficiency of the *Tagal* system in preserving a good river system. Therefore, this study aimed to fill the gaps of knowledge regarding the influence of water quality parameters towards the aquatic insect's distribution, as well as the implementation of *Tagal* system in different rivers along the *Sg*. Moyog, Penampang, Sabah.

1.2 Research Objectives

Water quality parameters and aquatic insect diversity are known to fluctuate with time and space. Intense sampling with various rivers of different characteristics is required to get precise and accurate information about the river water quality and aquatic insects at Sg. Moyog, Penampang.

The objectives of this research were:

1. To determine the water quality status of selected rivers implemented with *Tagal* system at Sg. Moyog, Penampang, Sabah by using water quality parameters.
2. To compare the diversity and composition of the aquatic insect communities of selected rivers implemented with *Tagal* system at Sg. Moyog, Penampang, Sabah.
3. To study the relationship between water quality parameters and diversity of aquatic insect communities at Sg. Moyog, Penampang, Sabah.

CHAPTER 2

LITERATURE REVIEW

2.1 Water Quality and Its Importances

In general, water quality consisted of biological, physical and chemical parameters that affect the growth and welfare of freshwater organisms (Mallya, 2007). The maintenance of good water quality is ecologically vital to the protection and survival of terrestrial and aquatic organisms. There are various parameters as well as criteria in water quality that could be practiced to measure water quality and therefore there is no definite answer to the question "what is water quality" (GEMS & Programmes, 2006). There is a range of physical, biological and chemical components that affect the water quality and many variables could be examined and measured (Carr & Neary, 2008).

By 2050, global water demand was estimated to increase up to 70% and the agricultural water usage expected to increase until 19% by the end of the year 2050 (Udimal *et al.,* 2017). Water demand is escalating for the purpose of expanding industrial and agricultural production with inclining world human population (GEMS & Programmes, 2006). According to Polunin (2008), water demand for agricultural irrigation, household uses and industrial almost invariably take precedence over environmental needs. The per capita of water use is declining at the rate that if actions are not set up to control the development, it will put lives at stake as many industries will be imposed to close down due to water shortage (Udimal *et al*., 2017).

Human have already used more than half of the renewable freshwater that is readily accessible (Postel *et al.*, 1996) and human population growth is currently the dominant factor in the increase of water withdrawals worldwide (Polunin, 2008). To date, water use has increased for many centuries, but in many major watersheds especially in the past few centuries has the scale reached the limit where natural variations in the water supply have begun to collide with human-growing use (Polunin, 2008).

Any changes that occur in natural water can be caused by natural phenomena and pollution. For instance, reduced light availability, increased occurrence of algal blooms with subsequently dissolved oxygen depletion and perturbation of the balance of organisms generally can be correlated with a decline in aquatic organisms (Bilotta *et al.,* 2008). The introduction of non-native species, changes in the temperature, salinity of water, acidity, contamination by pathogenic organisms, trace metals and human-produced and toxic chemicals could all bring deleterious effect on aquatic ecosystems and make water unsuitable for human use (Palaniappan *et al.*, 2010). Besides, the effect of environmentally contaminants on health is a great concern because exposure is associated with a number of diseases including virus infection, inflammation and cancer microbial infection (Rudneva, 2014).

Basic goods and services upon which many livelihoods depend on irrigation water, fertile floodplains for agriculture, grazing and habitat for aquatic organisms come from clean water and healthy freshwater ecosystems (Palaniappan *et al.*, 2010). The future of water quality at global scales depends on investments of individuals, communities and governments at all political levels to ensure that water resources are well preserve as well as managed in a sustainable manner (Carr & Neary, 2008).

2.2 *Tagal* System in Sabah

There are many unique indigenous systems which developed by the indigenous people of Sabah that have safeguarded their communities, a sustainable livelihood and the use of resources within their surrounding (Halim *et al*., 2012). One of the most well known practices developed by the Sabahan communities is *Tagal*. *Tagal* in the Kadazandusun language means prohibition or forbidden from exploiting river resources by an unrelated third party (Er *et al*., 2012). *Tagal* system is the resource management system that carried out by indigenous communities in Sabah where the management and implementation vary between communities in terms of rules, fines and management structure, but apply the same concept of closed and open season, equal sharing of responsibility (Pacos, 2010). Since its implementation in 2000, the system has gained much recognition for its ability not only to enhance the social environmental quality but also that of the physical environment, in particular with regard to river purity and riverine fish population (Foo & Noor, 2017). The key element of the system's success is not just the involvement of the local community in the management task but also the smart partnership between the local community with the state through the role played by the Department of Fisheries.

Way back to the mid 1990s, the *Tagal* System had been initiated as the communities were facing a hard situation due to decrease in fisheries resources. Many village leaders were concerned about this problem and started to take action to restore fish habitats as well as to control fishing activities (Siar *et al*., 2007). The system has been developed to limit the utilisation of the natural resources in order to ensure the continuous production of aquatic resources, especially, the inland fish (Foo, 2011).

When a river is being *tagal*, villagers and the public are prohibited from catching fish at sections of the river for a fixed period are disallowed from dumping rubbish and burning at the river bank or directly into it (Inus, 2014). Besides, *sogit* will be given to the wrongdoer as compensation and an opportunity to ask for forgiveness from the aggrieved party and to the whole community (Halim *et al*., 2012). The amount of *sogit* was entirely depends on the decisions of the members of *Tagal* communities selected by the kampung itself (Tangil & Amat, 2020) and *sogit* given as penalty can be in form of cash money or animal (Foo, 2011). The very first *tagal* fishing competition was held on 30 August, 2009 at Sg. Moyog, Penampang by using the barbless hooks in a catch and release fashion (Er *et al*., 2012).

2.3 Types of Sources of Pollution

Seas, estuaries, lakes, rivers and streams have been exposed to wastewaters from agricultural, industrial and domestic sources for decades (Li *et al*., 2007). According to O'Shea (2002), there are two major component sources of pollution which are point source and non-point source.

2.3.1 Point Source

Point source pollution basically its source of pollution can be seen clearly and known. The nutrients input from point sources is comparatively simple to be determined and well characterized as it is concentrated and sampling is easy (Dodds & Whiles, 2010). The major point sources of pollution to freshwater originates from the discharge of domestic wastewaters, agricultural activities or industrial wastes, such as animal husbandry (Watson & Burnett, 1995) that emit fluids of varying quality directly into urban water supplies (Ragothaman & Trivedy, 2010). Anthropogenic origin, and arise from the outfall discharge of sewage treatment works, paper mill waste and industrial plants where most organic matter enters from this source are also point source inputs (Elliott *et al*., 2002).

2.3.2 Non-Point Sources

Pollution that originates from spatially discrete sources often termed non-point source pollution (Zhang & Xu, 2011). Non-point sources can be in a form of spikes