EFFECT OF FOREST DISTURBANCE ON THE DIVERSITY AND COMPOSITION OF ODONATA IN KALABAKAN SAFE PROJECT SITE, TAWAU, SABAH

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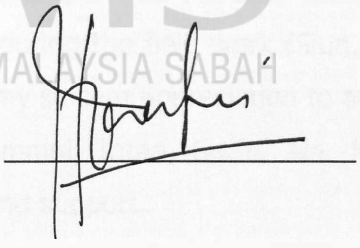

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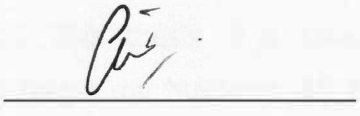

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ABSTRACT

Forest clearance usually affects the habitat and the diversity of certain species, from good to bad, including the Odonates that usually need clean water to breed. Conversion of the forest such as fragmentation and forest degradation may lead to changes in water quality. The aims of this study were: 1) to study the diversity and composition of Odonata at three different types of forest which are Old Growth Forest (OG), Secondary Forest (SF), and Oil Palm (OP) in Kalabakan SAFE Project Site, 2) to study the effect of water quality towards the composition of odonates larvae, and 3) to study the effect of canopy cover towards the species composition of Odonata. The samplings were conducted at Kalabakan SAFE Project sites which were Sg. Virgin Jungle Reserve (VJR) to represent old growth forest; Sg. Oil Palm Selangan Batu (OPSB), and Sg. Oil Palm Gaharu (OPGHR) representing oil palm plantation; and Sg. SF1 and Sg. SF2 to represent the secondary forest. Another stream at Maliau Basin Conservation Area (MBCA) was chosen to represent old growth forest together with Sg. VJR. Aerial net was used to collect adult while Surber net and D-frame net were used to collect larvae. Two stations were set for each stream (upper and lower reach) for both adult and larvae. Physical parameters (canopy cover, pH, water temperature, dissolved oxygen, salinity and conductivity) for each station were recorded. A total of 1192 individuals of adult odonates were collected (35 species, 23 genera) while for larvae, a total of 1336 individuals (13 families) were captured. For adult, *Euphaea subcostalis* was the most abundant species for Zygoptera (288 individuals) and *Trithemis festiva* was the most abundant species for Anisoptera (244 individuals). These were abundant and common species as they can easily be found at all stations. As for the larvae, Gomphidae (Anisoptera) and Euphaeidae (Zygoptera) were dominated the streams with 613 and 396 individuals respectively. SF has the highest diversity (H'=2.2083, D=0.1410, E=0.7793) for adult because of the mixture of habitat condition where they are more canopy opening, thus attract more species of odonates. OG has the highest diversity (H'=1.516, D=0.3042, E=0.591) for larvae because of the quality of the water was better than other rivers. Biological Monitoring Working Party (BMWP) index and $BMWP^{Thai}$ showed all types of forest have moderate water quality. The Malaysia Interim National Water Quality Standards (INWQS), also showed that all streams were classified as Class I. Ordination graph of Canonical Correspondence Analysis (CCA) showed that species from family Libellulidae were highly correlated with temperature, conductivity and salinity while the other three zygopteran species namely *Heliocypha biforata, Rhinocypha humeralis* and *Vestalis* sp. were highly associated with canopy cover. As for larvae, family Calopterygidae and Corduliidae were highly correlated with temperature, salinity and conductivity while other families such as Platystictidae and Chlorogomphidae were correlated with canopy cover and pH level. The changes in forest habitat affected the diversity of Odonata as the composition of odonates decreased with the forest quality. The erosion and sediment that flow into the freshwater habitat affect the quality of the streams thus affected the composition of the Odonata that depends on freshwater habitat.

ABSTRAK

KESAN GANGGUAN HUTAN TERHADAP KEPELBAGAIAN DAN KOMPOSISI ODONATA DI KALABAKAN SAFE PROJECT SITE, TAWAU, SABAH

Penebangan hutan biasanya akan memberi kesan kepada habitat dan kepelbagaian spesies tertentu, dari baik kepada buruk, termasuk Odonata yang memerlukan air bersih untuk membiak. Perubahan hutan seperti fragmentasi dan degradasi hutan boleh menyebabkan kualiti air sungai berubah. Tujuan kajian ini adalah: 1) untuk mengkaji kepelbagaian dan komposisi Odonata di tiga jenis hutan iaitu Hutan Primer (OG), Hutan Sekunder (SF), dan Ladang Kelapa Sawit (OP) di Kalabakan SAFE Project Site, 2) untuk mengkaji kesan kualiti air terhadap komposisi larva Odonata, dan 3) untuk mengkaji kesan litupan kanopi terhadap komposisi spesies Odonata. Persampelan telah dijalankan di kawasan SAFE Project di Kalabakan iaitu di Sg. Hutan Simpan Dara (VJR) untuk mewakili Hutan Primer; Sg. Selangan Batu (OPSB), dan Sg. Gaharu (OPGHR) mewakili ladang kelapa sawit; dan Sg. SF1 dan Sg. SF2 mewakili Hutan Sekunder. Satu sungai di Kawasan Pemuliharaan Lembah Maliau (MBCA) telah dipilih untuk mewakili Hutan Primer bersama-sama Sg. VJR. Perangkap jaring digunakan untuk mengumpul pepatung dewasa manakala Surber net dan D-frame net digunakan untuk persampelan larva. Dua stesen telah ditetapkan untuk setiap sungai (bahagian hulu dan hilir) untuk kedua-dua pepatung dewasa dan larva. Parameter fizikal (litupan kanopi, pH, suhu air, oksigen terlarut, saliniti dan konduksi air) bagi setiap stesen juga direkodkan. Sebanyak 1192 individu pepatung dewasa telah dikumpulkan (35 spesies, 23 genera) manakala bagi larva, sebanyak 1336 individu (13 famili) telah dikumpulkan. Untuk pepatung dewasa, Euphaea subcostalis merupakan spesies yang paling banyak direkodkan untuk Zygoptera (288 individu) dan Trithemis festiva merupakan spesies yang paling banyak untuk Anisoptera (244 individu). Spesies-spesies ini adalah spesies yang dominan dan biasa kerana mereka mudah dijumpai di semua stesen. Bagi larva, Gomphidae (Anisoptera) dan Euphaeidae (Zygoptera) mendominasi aliran sungai masing-masing dengan 613 dan 396 individu. Hutan sekunder merekodkan indeks kepelbagaian yang paling tinggi (H'=2.2083, D=0.1410 , E=0.7793) untuk pepatung dewasa kerana terdapat pelbagai jenis habitat di mana ia mempunyai bukaan kanopi yang lebih banyak, sekali gus menarik lebih banyak spesies Odonata. Hutan primer mempunyai kepelbagaian spesies yang paling tinggi (H'=1.516, D=0.3042, E=0.591) untuk larva kerana kualiti air yang lebih baik. Indeks BMWP dan BMWP^{Thai} menunjukkan bahawa kesemua jenis hutan mempunyai kualiti air yang sederhana. Piawaian Kualiti Air Kebangsaan Interim Malaysia (INWQS) juga menunjuk kesemua sungai dikelaskan kepada Kelas I. Graf Canonical Correspondence Analysis (CCA) menunjukkan bahawa spesies daripada keluarga Libellulidae dipengaruhi dengan suhu, konduksi dan saliniti air manakala tiga spesies Zygoptera iaitu Heliocypha biforata, Rhinocypha humeralis dan Vestalis sp. dipengaruhi oleh litupan kanopi. Bagi larva, keluarga Calopterygidae dan Corduliidae berkait rapat dengan suhu, saliniti dan konduksi air manakala famili seperti Platystictidae dan Chlorogomphidae dipengaruhi oleh litupan kanopi dan tahap pH. Perubahan habitat di hutan memberi kesan kepada kepelbagaian spesis Odonata di mana komposisi Odonata berkurang dengan kualiti hutan. Hakisan tanah yang memasuki sungai juga memberi kesan kepada kualiti dan habitat air sungai serta komposisi Odonata yang bergantung kepada habitat air.

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LIST OF SYMBOLS AND ABBREVIATION

°C	-	Degree Celsius
%	-	Percentage
Alt	-	Altitude
ASPT	-	Average Score per Taxa index
BMWP	-	Biological Monitoring Work Party index
CCA	-	Canonical Correspondence Analysis
cm	-	Centimeter
FR	-	Forest Reserve
Ha	-	Hectares
INWQS	-	Interim National Water Quality Standards
m	-	Meter
MBCA	-	Maliau Basin Conservation Area
mg/l	-	Milligrams per litre
mm	-	Millimeter
OG	-	Old Growth forest
OP	-	Oil Palm plantation
OPGHR	-	Oil Palm Gaharu
OPSB	-	Oil Palm Selangan Batu
PAST	-	Paleontological Statistics
SAFE	-	Stability of Altered Forest Ecosystems
SF	-	Secondary forest
Sg	-	Sungai
VJR	-	Virgin Jungle Forest Reserve

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CHAPTER 1

INTRODUCTION

1.1 Order Odonata

Dragonflies and damselflies belong to the Order Odonata that lives over 300 million years ago and among the most ancient living fauna on Earth (Moore, 1997; Silsby, 2001). This attractive insect has brilliant or bright colours on their wings and abdomen. They are known by many names in Sabah because of different ethnics and languages such as "Pepatung" (Melayu), "Tompo kiuk-kiuk" (Kadazan-Dusun) "Temperiding", "Bari-bari" (Bajau), and "Petunding" (Robiatul Munawwirah, 2004).

Order Odonata consists of three suborders which are suborder Anisoptera, suborder Zygoptera, and suborder Anisozygoptera (Moore, 1997; Silsby, 2001; Orr, 2003; Triplehorn and Johnson, 2005). Anisozygoptera is a living fossil, represented by two species, each found only in the Himalayan Mountains and Japan (Homathevi, 1995; Subramanian, 2005). Suborder Anisoptera is known as dragonflies or true dragonflies which often can be seen around the lake or river; while suborder Zygoptera is known as damselflies. Both dragonflies and damselflies can be easily differentiated in the field by looking at their wings (Orr, 2003). According to Campbell and Reece (2005), dragonflies wings will spread out when at rest while damselfly wings will be held close to their abdomen.

Odonates can be found flying over the forest, ponds, streams, rivers, and sometimes in still and sluggish water (Triplehorn and Johnson, 2005; Theischinger and Hawking, 2006). The adults are terrestrial and larvae live in aquatic environments. Larvae of odonates usually emerge from the water when mature and transform into flying adult. According to Norma-Rashid (2010), the male will find their mates for breeding and choose clean water bodies for the next generation to grow. Odonates are able to fly fast, efficient, and hunt their food while flying (Subramanian, 2005).

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Borneo is one of the islands in the world that has the richest dragonfly fauna (Orr, 2003). There are about 6000 species that have been described and spread out all over the world (Subramanian, 2005) and more than 275 species can be found only in Borneo itself (Orr, 2003). The Odonata owes their successful existence to their unique breeding behaviour and ability to colonise both aquatic and terrestrial habitats, as larval forms and adults respectively (Orr, 2003).

Odonates undergo an incomplete metamorphosis where its larvae go through several stages of instars, change their skin repeatedly and emerge as an adult outside water (Silsby, 2001; Amelia, Che Salmah, and Abu Hassan, 2006; Hickman, Roberts, Keen, Larson and Eisenhour, 2007). The larvae are generally not attractive and dull but can change colour during development (Theischinger and Hawking, 2006). If they live with live vegetation, they will be greenish but brownish when living among dead vegetation (Theischinger and Hawking, 2006).

Dragonflies are known to be sun-loving creatures which can withstand high temperatures of the sun (Norma-Rashid, 2010). Temperature, light intensity, moisture, water flow and latitude are examples of abiotic factors that affect the distribution of Odonata (Homathevi, 1995). Besides that, the pH level of water can affect the distribution of Odonata species according to their ability to withstand the different level of pH. Several species can be found in hydro areas with pH 3-4 while different species at pH 8 (Corbet, 1999). Most of the odonates spend their time resting on the banks, rocks or logs and fly when feeding, mating or when disturbed.

Odonata plays an important role as a biological indicator. Some species can be highly affected by the disturbance of their surroundings such as logging and water pollution. The larvae are suitable to be a biological indicator as they live in water habitat. They are able to indicate the quality of the water and pollution level. As predators, the larvae feed on small insects in the water, including mosquito larvae (Tribuana, 2006; Akram and Ali-Khan, 2016) and control disease like dengue fever.

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1.2 Justification

Changes in the structure of an environment caused by any events are called as disturbance (Yadav and Gupta, 2006). Disturbance includes the changes of forest and freshwater ecosystems. Landscape changes are considered as one of the major factors regarding the loss of flora and fauna (Rocabado, Claros, Bongers, Alarcon, Licona, and Poorter, 2012). Deterioration of forest ecosystem has caused many forest areas to suffer from fragmentation and edge effects (Broadbent, Asner, Keller, Knapp, Oliveira, and Silva, 2008). The effort, such as sustainable forest management was introduced in order to reduce the impact of human activity towards ecosystem (Rocabado *et al.*, 2012). However, such practice often cannot meet with human demands, thus it is hard to balance the ecological, economic and social needs (Rocabado *et al.*, 2012).

Freshwater ecosystems are critical for human survival ability and development, as it functions as water supplies, food resources, recreation and transportation (Baron, Poff, Angermeier, Dahm, Gleick, Hairston, Jackson, Johnston, Richter, and Steinman, 2002; Aylward, Bandyopadhyay, and Belausteguigotia, 2005). The increasing human population growth and economic development had impaired the freshwater environments that included rivers, lake, and wetlands. Therefore, monitoring and managing of the freshwater environment are needed due to the high demand of the freshwater ecosystem.

Usage of freshwater biota in water quality assessment and monitoring had increased in popularity since they provide spatially and temporally integrated measures of environmental health (Carter, Resh, Hannaford, and Myers, 2007). Freshwater macroinvertebrates are well-known for their roles as bioindicator in freshwater ecosystems. Bioindicator is an organism or community of organisms that possess information on its environment quality (Li, Zheng, and Liu, 2010). This relates to the particular living requirements for the indicator species, where the present and absent of indicator groups reflect any alteration of their environment. Due to their low resilience toward environmental perturbations, alteration outside of their preferred conditions will result in the change of occurrence and distribution of the indicator organism (Johnson, Wiederholm, and Rosenberg, 1993).

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Remsburg, Olson and Samways (2008) performed a research on canopy cover towards the abundance of Odonata. They found that shade alone can affect the composition of odonates and changes in canopy structure caused by logging and other disturbances strongly influence odonates habitat use. The adult odonates, specifically the perchers require riparian understory vegetation for guarding breeds territories, thermoregulate, and watch for prey from plant perches (Corbet 1999). Reduced of canopy cover has also increased the river water temperature, which affects the habitat of odonates larvae (Aweng-Eh, Ismid-Said, Maketab-Mohamed, and Ahmad-Abas, 2001).

In Sabah, many researchers of Odonata were focusing on diversity, but not the habitat disturbance. Some of the research was done in Danum Valley Conservation Area, Lahad Datu (Homathevi, 1995), Tabin Wildlife Reserve (Robiatul Munawwirah, 2004), Golden Hope Oil Palm Plantation in Tawau (Royston, 2008), Kunak (Abdul Haqim, 2008), Muaya Forest Reserve, Sipitang (Carlester Milah, 2010) and Mahua Substation, Crocker Range Park (Aqilah, 2011). Modifications of the Sabah forest landscape might affect the composition of Odonata thus this project was performed to look at the habitat disturbance towards the diversity and composition of Odonata.

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This research was focused on Kalabakan SAFE sites, as there was less research on the effect of Odonata's diversity and composition from alteration of the forest done in that area. Stability of Altered Forest Ecosystem (SAFE) is a project sponsored by the SIME Darby Foundation to study and understand the impacts of forest modification to flora and fauna. Many researchers have come down to SAFE to do their research yet fewer researchers are interested in Odonata studies. This research provides new information about the diversity and distribution of Odonata by looking at the different types of forest, especially in the disturbed environment.

1.3 Objectives

The objectives of this study are:

a. To study the diversity and composition of Odonata at three different types of forest (Old Growth Forest, Secondary Forest, and Oil Palm) within Kalabakan SAFE site.

b. To study the effect of water quality towards the composition of Odonata's larvae.

c. To study the effect of canopy cover towards the species composition of adult Odonata.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Odonata

The name Odonata is taken from the Greek word, '*odon*' which means teeth, referring to the teeth of the mandibles (Needham, Westfall, and May, 2000; Triplehorn and Johnson, 2005). Odonata is one of the earliest insects exist in this world and the earliest Odonata recorded from the Carboniferous Era (354-290 million years ago) (Silsby, 2001). Odonata that lives during the Carboniferous era were large in size compared to Odonata living today, currently measuring between 20 mm to 135 mm only (Triplehorn and Johnson, 2005). The largest known dragonflies have existed 250 million years ago, had a wingspan of 71 cm and are only available in the form of fossils (Triplehorn and Johnson, 2005). Dragonflies from Suborder Anisozygoptera began to appear in the Triassic (248-206 million years ago) and Suborder Anisoptera like Aeshnidae, Gomphidae and Petaluridae began to appear during the Jurassic (206-142 million years ago) in the form of fossils (Silsby, 2001).

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In the East, the dragonflies were treated as food for some people. Apart from Malaysia, other parts of Asia such as China, Japan, Cambodia and Indonesia take dragonflies as everyday food (Yong, 1998). In ancient time, odonates are known as a scary or devil insects and they are called with a different name such as 'Horse-stingers', 'Devil's Little Horses', or 'Darning Needles', but the name was no longer being used as it was not related to dragonflies. Dragonflies do not have poisonous stings or a needle to sew the ear of the naughty boy which is believed by the people of ancient times and their strong teeth are not able to harm humans (Needham *et al.,* 2000).

Adult odonates and larvae live in two different environment where the adult lives as flying insects while the larvae live in water. Both adults and larvae are

predators that feed on other insects such as mosquitoes; small butterflies and moth; flies; and other odonates (Triplehorn and Johnson, 2005). Odonata is easily spotted by looking at the shape and colours on the body, where the abdomen of odonates is long, tapered and has attractive colours such as red, green, yellow, or blue (Silsby, 2001).

2.2 Classification of Odonata

Order of Odonata is divided into three suborders which are suborder Anisoptera (dragonflies), suborder Zygoptera (damselfly) and suborder Anisozygoptera (Silsby, 2001). Each suborder is further divided into families (Figure 2.1). Suborder Anisozygoptera is represented by one family with two species, *Epiophlebia laidlawi* is found in the Himalayas and *Epiophlebia superstes* is only found in Japan. These two species have a morphology that usually found in the Zygoptera and Anisoptera. At present, these two species from the Himalaya and Japan are placed in Suborder Anisoptera (Orr, 2003; Rehn, 2003)

Throughout the world, there are about 6,000 species that have been identified and named (Sharma, Sundararaj, and Karibasvaraja, 2007). There are 275 species of Odonata have been identified and named in Borneo. However, according to Orr (2003), there could be more than 300 species, including the species that are still undiscovered (Orr, 2003). Species of odonates in Borneo include 15 families of which 10 of them were from the suborder Zygoptera and five others were from the suborder Anisoptera.

2.2.1 Suborder Zygoptera

The family of the suborder Zygoptera can be divided into three superfamilies, namely the Calopterygoidea, Lestoidea, and Coenagrionoidea. Calopterygoidea (or Caloptera) includes Amphipterygidae, Calopterygidae, Chlorocyphidae and Euphaeidae where all of the species have more than two 'antenodal crossveins' (Silsby, 2001). Lestoidea covers Lestidae and Megapodagrionidae where the species has two 'antenodal crossveins', strongly stalked wings and a compact network of veins at the end of the wings. The last superfamily, Coenagrionoidea includes Coenagrionidae, Platystictidae, Protoneuridae and Platycnemididae where the