RELATIONSHIP BETWEEN ABUNDANCE AND DIVERSITY OF ODONATES TO RIVER ULU GOMBAK CHARACTERISTICS

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RELATIONSHIP BETWEEN ABUNDANCE AND DIVERSITY OF ODONATES TO RIVER ULU GOMBAK CHARACTERISTICS

ABSTRACT

Ecohydraulic is considered to be a new field and yet it is emerging and becoming more distinct recently. Not many research on ecohydraulic model can be found especially those that are using adult odonates as ecological indicator. In this study, adult odonates were chosen as the ecological indicator. Their relationship with water quality status and basic hydraulic characteristic were determined for the use in developing an ecohydraulic model for the upstream of Sungai Gombak. In order to do that, the species of adult odonates were identified and quantified for all three sampling sites. Ecological indices which includes Shannon-Wiener index, Eveness and Simpson's index were then calculated. The water quality status and the basic hydraulic characteristic were recorded. The water quality status that were tested includes biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammoniacal nitrogen, phosphate, temperature, dissolved oxygen (DO), pH and also conductivity. Discharge rate of all three sites were determined based on the width, depth and velocity of the river. Pearson correlation were used to determine the relationship between water quality status and basic hydraulic characteristic with the adult odonates of each sites. A total of 11 species of adult odonates were identified during the sampling. As for the water quality, the upper stream were tested to be the cleanest while the lower stream were less clean ranging from Class I to Class III. The Pearson correlation shows that some species were significantly related by different factors. Although the relationships between the adult odonates with the water quality status and basic hydraulic characteristic were established, the ecohydraulic model for Sungai Gombak was unable to be developed due to the lack of other factors such as canopy cover and riparian vegetation. Further

study on the relationship of each species to these factors should be included in future work.

HUBUNGAN ANTARA BILANGAN DAN DIVERSITI ODONATA TERHADAP CIRI-CIRI SUNGAI ULU GOMBAK

ABSTRAK

Ekohidraulik merupakan satu bidang yang baru yang sedang berkembang. Tidak banyak kajian tentang model ekohidraulik dapat dijumpai terutamanya kajian yang menggunakan odonata dewasa sebagai penunjuk ekologi. Dalam kajian ini, odonata dewasa digunakan sebagai penunjuk ekologi. Hubungan odonata dewasa dengan kualiti air dan keadaan hidraulik sungai ini dikaji lalu digunakan untuk membina model ekohidraulik untuk Sungai Gombak. Langkah pertama adalah identifikasi species odonata dewasa yang terdapat di tapak kajian. Indek ekologi termasuk Shannon-Wiener index, Eveness dan Simpson's index kemudiannya dikira. Selain dari itu, kualiti air dan keadaan hidraulik sungai juga direkodkan. Ciri-ciri kualiti air yang dikaji termasuk "biological oxygen demand" (BOD), "chemical oxygen demand" (COD), pepejal terampai (TSS), "ammoniacal nitrogen", fosfat, suhu air, oksigen terlarut (DO), pH dan juga konduktiviti. Indek Kualiti Air (WQI) kemudiannya dikira dengan menggunakan bacaan tersebut. Discas untuk ketiga-tiga tapak kajian dikira dengan menggunakan bacaan kedalaman, kelebaran sungai dan juga kelajuan air sungai. "Pearson correlation" digunakan untuk menunjukkan siknifikasi hubungan antara kualiti air dan keadaan hidraulik dengan odonata dewasa tersebut. Terdapat jumlah sebanyak 11 spesies odonata dijumpai. Kualiti air di hulu sungai adalah paling bersih dan kualiti sungai di hilir kurang bersih jatuh dalam Kelas I hingga Kelas III. Hasil kajian menunjukkan setiap spesies dijejas oleh ciri-ciri kualiti air yang tersendiri. Walaupun hubungan odonata dewasa dengan ciri-ciri kualiti air dan keadaan hidraulik jelas terbukti, model ekohidraulik untuk Sungai Gombak tetap tidak dapat dibina disebabkan oleh kekurangan faktor-faktor lain seperti kekerapan kanopi dan tumbuh-tumbuhan riparian.

Kajian yang lebih mendalam terhadap hubungan antara setiap species dengan faktor-faktor tersebut harus dilakukan untuk kerja-kerja masa depan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AN	:	Ammoniacal Nitrogen
BOD	:	Biochemical Oxygen Demand
COD	:	Chemical Oxygen Demand
DO	:	Dissolved Oxygen
D.O.E	:	Deparment of Environment
TSS	:	Total Suspended Solid
WQI	:	Water Quality Index
%	:	Percentage
℃	:	Degree Celsius
H_0	:	Null Hypothesis

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CHAPTER 1: INTRODUCTION

1.1 General Introduction

What is ecohydraulic? Ecohydraulic is still a relatively new field which increasingly distinct recently. It is basically the combination of the study of hydraulic and ecology. According to Maddock *et al.* (2013), ecohydraulic is a field that involves biologists, ecologists, fluvial geomorphologists, sedimentologists, hydrologists, hydraulic and river engineers and water resource managers in the research on managing the sustainability of a natural ecosystems and the demands on these ecosystems by society. This contributes in the emerging of ecohydraulic models.

Ecohydraulic model is basically built by using the relationship of the community structure that inhabit around the river with the water quality and river hydraulic characteristics (Clifford, 2010; Maddock *et al.*, 2013). This community involved is known as the ecological indicator. Most of the similar studies used fish community, birds community, amphibian community or even macroinvertebrates community as the ecological indicators (Clifford, 2010; Maddock *et al.,* 2013). In this study, the adult odonates community were chosen as the ecological indicator.

Why adult odonates? Chandana *et al.* (2012) and Reece and McIntyre (2009) proposed that odonates are good ecological indicators in works that are related to water quality. According to Ballare and Ware (2011) and Smith *et al.* (2006), odonates are sensitive towards the changes in water quality. Besides water quality, they are also sensitive towards water flows or movements (Ballare & Ware, 2011; Wahizatul Afzan *et al.,* 2006) which is the basic hydraulic characteristic (Kazmann, 1965; Maddock *et al.,* 2013). The changes of water quality and hydraulic characteristic basically alter the habitat of the odonates which makes them susceptible to habitat alteration (Balzan, 2012; Chandana *et al.,* 2012). They were not only affected in the species composition in the community but also in the abundance or number of individual of each species (Chandana *et al.,* 2012; Dolny *et al.,* 2011; Smith *et al.,* 2006). Another reason why adult odonates were chosen rather than the larvae is because the adults are taxonomically well studied to the species level compared to the larvae (Grant & Samways, 2010). The adults are also conspicuous and easy to record due to their relatively large body size (Balzan, 2012; Cordoba-Aguilar & Cordero-Rivera, 2005). Cordoba-Aguilar and Cordero-Rivera (2005) also stated that they are reliable indicators due to their attachment to their reproductive sites which is also their habitat. So even if they were disturbed and fly away, they will return to their territory after a while which makes them easier to be sampled. These are the reasons why adult odonates were chosen as ecological indicators in this study.

In this study, a number of water parameters and the basic hydraulic characteristic were chosen as the independent variables to be tested upon their influence on the adult odonates community. If the development of this ecohydraulic model is a success, monitoring of water quality and the river conditions can be more time and cost saving by just based on the ecological indicators that inhabit around that particular river. Mitigation of water quality and hydraulic characteristic can also be possibly done by the guidance of this model.

1.2 Research Objectives

The aim of this research is to figure out the relationships of each species of the adult odonates with the water quality parameters and the basic hydraulic characteristic of the upstream of Sungai Gombak so that these relationships can be used in developing the ecohydraulic model for Sungai Gombak. The objectives to achieve this aim are listed as below:

- To investigate the Odonata community structure in the upstream of Sungai Gombak.
- To determine the water quality status and the basic river hydraulic characteristic.
- To correlate the ecohydraulic model based on the relationship of the adult odonates community with the water quality status and the basic river hydraulic characteristic.

CHAPTER 2: LITERATURE REVIEW

2.1 General Overview of Odonata Community

2.1.1 Odonata Taxonomy and Community Structure

The name Odonata derived from the Greek word 'odonto' which means toothed referring to the mandibles of the adult odonates (Ngiam, 2011). The order Odonata basically consists of two suborders, Anisoptera and Zygoptera (Hook, 2008; Orr, 2005; Ngiam, 2011). According to Orr (2005), Anisoptera also refers to true dragonflies while Zygoptera refers to damselflies. From the name Anisoptera and Zygoptera, which also means 'dissimilar wings' and 'similar wings' respectively, it is obvious that the members of Anisoptera have different shaped fore wings and hind wings while the members of Zygoptera have similar shaped for wings and hind wings (Orr, 2005; Ngiam, 2011). The anisopterans are large, have powerful flight and rest with their wings open while the zygopterans are smaller or have slender bodies, have weaker or fluttery flight and rest with their wings folded (Hook, 2008; Ngiam, 2011). According to Hook (2008), the anisopterans have large eyes which cover almost the entire head while the zygopterans have smaller eyes, usually with a gap between them. Ngiam (2011) stated that dragonflies, the members of Anisptera are the ones most noticed by people; which is true as most laymen considered every members of the order Odonata are dragonflies and would have thought that damselflies are another different type of insects. The body structure of the odonates basically made up of the head, thorax, two pairs of wings, three pairs of legs and a segmented abdomen with anal appendages at the end of it (Orr, 2005; Ngiam, 2011).

According to Silva *et al*., (2010) the adult odonates are closely related to water bodies especially the males. They are very territorial and will chase off their rival that attempt to challenge them over their territories (Hook, 2008). The strongest male that holds the territories with suitable niches will be chosen by the females that visit these microhabitats as mates for breeding and once the process is completed, the females will lay their eggs by various ways of ovipositing into the water of the territories (Hook, 2008; Silva *et al*., 2010). According to Ngiam (2011), the ability of adult odonates to find water bodies are due to their compound eyes as they are able to distinguish polarized light that are reflected off the water surface from the direct light reflected that are reflected from other objects. The activity of adults decreased proportionally to a decrease in light intensity which include during cloudy periods and thunderstorms (Lutz & Pittman, 1969).

The females adult odonates are generally much more difficult to identify if compared to the males and mostly are recognized by their association to the males during mating (Orr, 2005) as the females of the same genus but different species could look similar. The males are usually brightly coloured than the females (Orr, 2005; Ngiam, 2011).

2.1.2 Odonata as Ecological Indicator

According to Simaika and Samways (2009), the odonates themselves are recognized in the conservation field worldwide. Usually, the adults are chosen as the indicator species due to the reason they are conspicuous, easy to record (Balzan, 2012) and they are taxonomically well studied (Grant & Samways, 2010) to the species level compared to microinvertebrates samples which are limited to the taxonomic levels above that of species (Balzan, 2012; Smith *et al.,* 2006). Besides that, Harderson (2008) stated that there could bias if the larvae are used in studies as some of the larvae species can only be found in harder accessible microhabitats which is difficult to collect. According to Cordoba-Aguilar and Cordero-Rivera (2005), the odonates had been used to test a number of hypotheses due to their practical characteristics which includes the relatively large body size, easily manipulated in both field and laboratory, and their attachment to their reproductive sites, making them reliable habitat indicators. They are sensitive to disturbance at both large and small spatial scales which make them valuable indicators for rapid assessment of river condition (Smith *et al.,* 2006). Catling (2005) also stated that the odonates are not only good indicators in terms of diversity but also in terms of abundance or numbers.

Odonates have amphibious life history, relatively short generation time, high trophic position and diversity (Reece & McIntyre, 2009). They show some preferences to specific habitats and their distribution are affected by the differences in microhabitats (Wahizatul Afzan *et al.,* 2006). Out of the three study sites of Wahizatul Afzan *et al.,* (2006), two of the study sites show similarity in terms of species composition which was due to the similarity of microhabitats heterogeneity present. They are even used to determine the range of appropriate biotope at an artificial lake (Steytler & Samways 1994). According to Hassall and Thompson (2008), it is likely that the future impacts on odonates will largely involve spatial shift of communities and their associated ecological interactions. Due to the natural environment which had been altered by human, odonates are often confused and trapped where they were reported to be seen attracted to shiny car roofs, asphalt, solar panels and also grave stones (Umar *et al.,* 2012). According to Umar *et al.* (2012), choice experiments even shows that they can be more attracted to crude oil rather than water. This could lead to the disappearance of some of the species of odonates as Clausnitzer *et al.* (2009) stated that one in 10 species of odonates are actually threatened to the point of extinction.

2.1.3 Odonates in Other Countries or Environments

Odonates are usually collected near water but they can be found almost everywhere (Garrison *et al.,* 2006). While the odonates from the nearctic already well done, it is quite common to discover new species of odonates in the neotropical area, for example, some gomphids which are rarely seen but quite common along the agricultural bordering strips of forest along the water habitat (Garrison *et al.,* 2006). Garrison *et al.* (2006) also reported that in the tropical area, the odonates habitat includes lakes, ponds lagoons, rivers, large streams, springs, seeps, trickles, under wet leaf litter in dried-out depressions and phytotelmata.

Diapause is one of the abilities that allow some of the tropical origin odonates to invades the temperate regions which also leads to speciation processes in American taxa (Hassall & Thompson, 2008). According to Corbet (1954), the spring and summer species may have different emergence pattern but some species exhibit multiple peak s in emergence. For example, in northern Scotland, *Pyrrhosoma nymphula* exhibits two peak of emergence in a semivoltine life cycle because the larvae overwintering in one of the instars (Corbet & Harvey, 1989). In central Europe, physiological colour change in a common feature of thermoregulation in odonates, for example,the populations of *Orthetrum cancellatum* have different colouration based on the latitude to enhance the absorbance of heat in cooler regions (Hilfert-Rüppell, 1998). *Aeshna caerulea* , a boreal species, not only able to physiologically change in colour, but also able to perform basking behaviour by creating a “glasshouse” using its wings to increase the body temperature (Hassall & Thompson, 2008). Polcyn (1994) reported that the Anisoptera that inhabiting deserts exhibit higher thoracic temperature than their congeners and conspecifies from cooler habitat, which suggest that they might be capable of adapting to extreme thermal environment. On the other hand, Suhling *et al.* (2003) reported that the dragonfly assemblages that inhabiting the temporary water bodies in the African desert areas are different from those from non-desert areas and their constituent species are highly mobile and multivoltine. Odonates such as *Lestes* sp. and *Ischnura pumilio* produce drought-resistant eggs to adapt in seasonal ponds (De Block *et al.,* 2008) while *Coenagrion hastulatum* have drought-resistant larvae stage (Valtonen, 1986). Pickup and Thompson (1990) suggested that *Lestes sponsa* adapt the situation by having rapid larval development. *Coenagrion mercuriale* known as a weaker-flying British odonates were said to be able to detect changes in climate space and may disperse to appropriate habitat (Hassall & Thompson, 2008).

2.1.4 Sampling Methods of Odonates

There are two sampling methods to sample adult odonates, which are, transect survey and quadrangular or rectangular survey plot (Cordoba-Aguilar, 2008). In the transect survey method, the adult odonates were sampled while walking along the transect from one end to the other until a desirable amount of sample collected or in a given duration of time (Cleary *et al.,* 2004; Giugliano *et al.,* 2012). In the sampling carried out by Cleary *et al.* (2004), all adult odonates encountered were captured by sweep-net and preserved. However, Giugliano *et al.* (2012) did not capture every specimen encountered but only observed by using binoculars and the abundance were noted as the adult odonates were easily identified. Only a few specimens were captured by sweep-net for identification purpose when needed (Giugliano *et al.,* 2012). As for the quadrangular or rectangular survey plot, sampling were done within the marked plot area rather than along a transect (Oertli *et al.,* 2005; Stewart & Samways, 1998).

2.1.5 Ecological Indices

Ludwig and Reynolds (1988) described diversity by using two distinct components which were the total number of species in the sampling sites and also the evenness which shows the abundance among species differently distributed. The Shannon-Wiener Index is one of the mostly used index to determine the number of species in a community and at the same time, determining how evenly these species are distributed (Ludwig & Reynolds, 1988). On the other hand, Simpson's Index is measured by the probability of two random individuals selected from a community belongs to the same species (Heip *et al.,* 1998). According to Ludwig and Reynolds (1988) and Heip *et al.*

(1998), the Evenness Index independently calculate how evenly the individuals of each species were distributed without affected by the number of species in the community.

2.2 Water Quality Status

There are a lot of parameters taken or measured to determine the water quality status. According to Pushparaj Karthika and Natraj Krishnaveni (2014), dissolved oxygen is one of the primary parameters in water pollution studies where high level of dissolved oxygen indicates good water quality. Low dissolved oxygen often associated with the accumulation of sewage or biological waste (Nor Zaiha Arman *et al.*, 2013) and elevation of temperature (Pushparaj Karthika & Natraj Krishnaveni, 2014). In Singapore, dissolved oxygen level is one of the parameters recorded for ponds with good odonates diversity for reference and future comparison (Ngiam, 2011).

Besides dissolved oxygen, both biological oxygen demand (BOD) and chemical oxygen demand (COD) are affected by organic waste as well (Al-shami *et al.*, 2014). According to Pushparaj Karthika and Natraj Krishnaveni (2014), high COD levels in Kumarasamy Lake were caused by the organic substances from the sewage and domestic garbage. Al-Shami *et al.* (2014) also proved that BOD and COD were positively associated with the fluctuating asymmetry of selected traits such as antennae or other body features in certain odonate species which support the hypothesis that the fluctuating asymmetry were caused by organic pollution. According to Clarke (1993), fluctuating asymmetry may serve as an early warning of environmental stresses on organisms before the critical changes in population and community structures actually take place.

Adakole *et al.* (2008), reported that the pH of aquatic system is an important indicator of water quality able to reflect the extend of its pollution. Adakole *et al.* (2008) also stated that the pH of unpolluted aquatic system should be almost neutral but slightly alkaline. In a book called 'Dragonflies of Our Parks and Gardens' by Ngiam (2011), pH is one of the parameters that were recorded at some ponds with good odonates diversity for future reference and comparison.

In the research on the situation of benthic macroinvertebrates in Vjosa River, Sajmir Beqiraj *et al.* (2006) shows that the high concentration of phosphorous and ammonium were caused by the waste water discharge from domestic sewage, industrial effluents, erosion and agricultural drainage from fertilized land into the Vjosa watershed. Al-Shami *et al*. (2014) proved that nitrate, phosphate and ammonia caused the fluctuating asymmetry in antennae segments within the population studied. While Hofmann and Mason (2005) stated that phosphate and ammonia could affect the odonates indirectly by affecting the vegetation around or in the water bodies. On the other hand, Hamidi Abdul Aziz *et al.* (2004) stated that ammoniacal nitrogen has been identified as one of the major toxicant that could cause toxicity to most organisms and the removal of ammoniacal nitrogen from effluent was still not well-studied.

Ngiam (2011) stated that temperature is also one of the important abiotic parameters that were recorded for future reference and comparison. This can be proved by Cordoba-Aguilar and Cordero-Rivera (2005) who stated that Calopterygidae is a family that is widely distributed in all continents except for Australia and New Zealands, which possibly the only limitation was low temperatures. Chang *et al.* (2007) on the other hand proved that the increased of temperature can also caused mortality in selected species of odonates. Besides that, changes in thermal regime can also caused the shifting of community structure of macroinvertebrates (Zimmerman, 2006). Temperature stress have also been suggested to cause fluctuating asymmetry which serves as an early warning of possible critical changes in community structures (Al-Shami *et al.,* 2014; Chang *et al.,* 2007). In a research conducted by Krikton and Schultz

(2001), had proven that thermal environment of forest light gaps provided the best condition to increase the rate of maturation of damselflies enabled them to attain higher operative body temperatures which gave them metablism rate compared to the thermal condition of forest understory.

According to Avvannavar and Shrihari (2008), total suspended solid (TSS) referred to particles larger than 0.45µm which many pollutants can attached to. Kutty *et al.* (2011) also stated that it is one of the most important characteristics of wastewater. High TSS could prevent sunlight from direct penetration into water (Avvannavar & Shrihari, 2008). Conductivity on the other hand could be related to the salinity of the water (Ahmed Said *et al.,* 2004) and in a way, they were also related to TSS. This is because they were determined by the nutrient status of the water bodies (Rahul Shivaji Patil *et al.,* 2015). Bernath *et al.* (2002) reported that conductivity can affects the area for oviposition of odonates as it is the distant visual cue for adult odonates to detect polarization and reflected light of suitable habitats.

2.3 Hydraulic Characteristic

The study of hydraulic basically involves the rate of water flow and also the area and its characteristics that the water flow through (Kazmann, 1965; Maddock *et al.,* 2013). This can be express as discharge, Q, that were often used to measure the volume or amount of fluid passing through a section of a stream or river in a unit time which is also commonly called the flow rate (Buchanan & Somers, 1969). Cowell *et al.* (2003) stated that the discharge rate is usually higher in non-reclaimed stream and lower in reclaimed stream. River flows are important as they affect the dissolved oxygen content, where higher speed of river flow contributes to higher dissolved oxygen and maintain the natural physical condition of the river such as the natural sediment sizes, the channel form, the longitudinal connectivity of the channel and connectivity to the floodplain, natural feature of habitat and the diversity of it, organic matter and nutrients availability, and also the hyporheic zone (Zimmerman, 2006). Kazmann (1965) stated that hydrology is sometimes confused with hydraulic. According to him, all hydrologic measurements are hydraulic but all hydraulic measurements are not hydrologic.

2.4 Ecohydraulic

Ecohydraulic is part of river science with direct applications to river engineering and rehabilitation in degraded landscapes (Clifford *et al.*, 2010; Pasternack & Brown, 2011). It is the combination of Ecology and Hydraulic. Maddock *et al.* (2013) stated that ecohydraulic is a field that brings together biologists, ecologists, fluvial geomorphologists, sedimentologists, hydrologists, hydraulic and river engineers and water resource managers to fundamental research on managing the sustainability of a natural ecosystems and the demands on these ecosystems by society. He also stated that it is a new field but emerging and becoming more distinct recently.

Ecohydraulic models often related to fish habitat suitability which basically develop the physical condition of the water bodies, the hydraulic characteristics, which is then associated with the known species habitat preferences (Clifford *et al.*, 2010). According to Cowell *et al.* (2003), the water quality and the hydraulic characteristics are usually different among the upstream and the downstream even both sites are in the same stream.

CHAPTER 3: STUDY SITES, MATERIALS AND METHODS

3.1 Study Area

The study area of this research includes three sites or three points of Sungai Gombak as shown in Figure 3.2 below. According to Gorashi and Abdullah (2012), Gombak River is a slow flowing river where most of its part is located in the District of Gombak in the State of Selangor. The rest of the part of the river which is the lower part is located in the Capital of Malaysia, Kuala Lumpur. In other words, the Gombak River runs slightly west of south from the steep mountainous area down to the gently sloping area towards the north of Kuala Lumpur (Bishop, 1973). The upper stream of the Gombak river mainly surrounded by the forest area which is part of the Ulu Gombak Forest Reserve. According to Bishop (1973), logging activities had been suspended for many years. However, habitat destruction was caused by the existence of villages. Gorashi and Abdullah (2012) stated that according to the Department of Environment, DOE, within the Klang Valley, Gombak River is the only river in Selangor that is slightly polluted in contrast to the other rivers which are polluted due to over-development.

Figure 3.2 indicates the 3 sampling sites while Table 3.1 explains the descriptions related to these sites. Site 1, labeled as A is located near the recreational area Alang Sedayu, Batu 12 with the coordinate N 3º 18' 25.3 E 101º 44' 5.0, with an elevation of 179m. A number of human activities have been observed in this area which is primarily used as camping sites and picnic spots. Apparently, it is also a favourite spot for the locals to wash their vehicles there.

Site 2, labeled as B is located along the aboriginal settlements and the Pusat Penyelidikan Luar Universiti Malaya with the coordinate N 3º 19' 35.61 E 101º 44' 21.14, with an elevation of 223m. As this site is located alongside the aboriginal settlements, waste from the farming activities and household are discharged into the river. Since there are some distances of a few meters in between the output points and the river, the waste could have been naturally filtered before it reaches the river.

Site 3, labeled as C is located upstream nearby an Indian temple with the coordinate N 3º 19’ 52.48 E 101º 46’ 33.02, with an elevation of 541m. The temple is quite active for religious activities, the surrounding area which include the river may be used for recreation.

Figure 3.1: Map that shows the location of Gombak

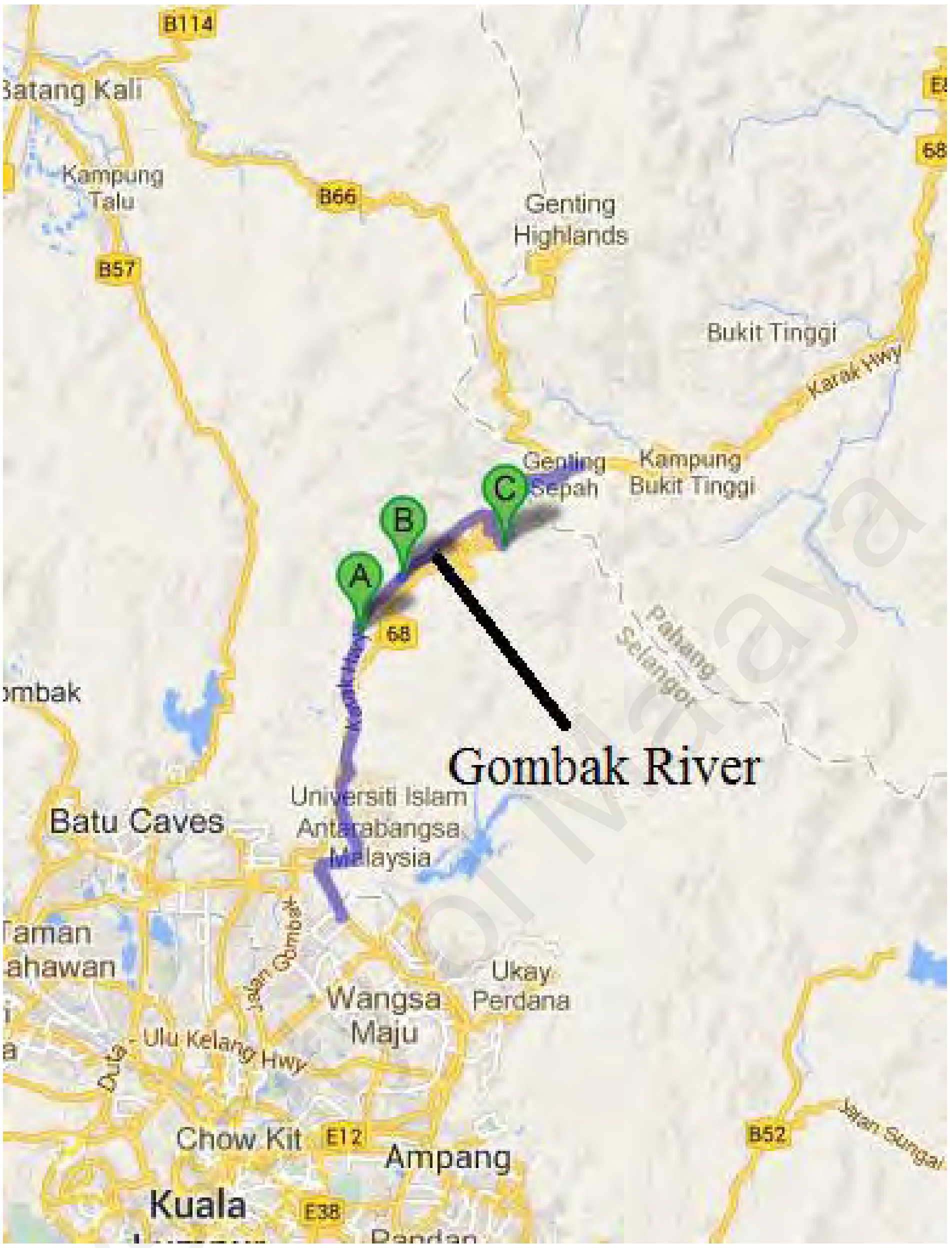

Figure 3.2: Map that shows the location of the three sampling sites (A, B and C)

Table 3.1: Description of each sampling site

Site	Label in Map	Coordinate	Elevation	Part of stream	Substrate components
Site 1	A	N 3º 18' 25.3 E 101º 44' 5.0	179m	Down stream	Mostly sands, some stones and boulders
Site 2	B	N 3º 19' 35.61 E 101º 44' 21.14	223m	Middle stream	Mostly stones and pebbles with quite a number of boulders
Site 3	C	N 3º 19' 52.48 E 101º 46' 33.02	541m	Upstream	Mostly stones and boulders.

3.2 Sampling of Specimens and Biodiversity Indices

Specimens of adult odonates were captured or collected at three different selected sites of the Gombak River by using sweep net. Line transect of 10 meters were set up and sampling was done for 2 hours duration in each session, 4 sessions each site per month. Samplings were done according to the four time periods: 8.30-10.30am, 10.30-12.30am, 1.30-3.30pm and 3.30-5.30pm. Captured specimens were kept in the labeled envelope accordingly to the site and time period. The specimens were kept in insect envelopes, left overnight to ensure fecal wastes expelled from the body to avoid molding of specimens. The specimens were pinned on pinning board and were dried in oven at 35°C overnight. All preserved specimens were identified using morphological taxonomic features with the aid of keys identifications references (Norma-Rashid, personal communication, 2013; Orr, 2005).

There following are three types of ecological indices used in the analysis. They are:

- Shannon-Wiener Index, H

$$H = -\sum[(P_i)\times \ln(P_i)]$$

Where Pi = proportion of total sample represented by species i

- Eveness, E

$$E = H / H_{max}$$

Where Hmax = ln(S) or maximum diversity possible

S = number of species or species richness

- Simpson's Index, D

$$D = \sum(P_i^2)$$

Simpson's Index of Diversity, 1- D

Simpson's Reciprocal Index, 1/D

3.3 Water Quality Recordings and Analysis

Water samples from each site were collected by using 500ml polyethylene bottles. The bottles were rinsed by using the water of the sampling sites before the water samples were collected. They were stored in icepack in the process of transporting them back to the laboratory. These water samples were tested for Biological oxygen demand (BOD), Chemical oxygen demand (COD), Total suspended solids (TSS), ammoniacal nitrogen and phosphate tests. BOD, COD and TSS were determined according to the standard method protocols (APHA, 1989). In the laboratory, the water samples were kept in the refrigerator at 4ºC. This is to stop the activities of the microorganisms in the water samples. The ammoniacal nitrogen and phosphate tests were done using the MERCK Spectroquant 114752 Ammonium Test Kit and MERCK Spectroquant 114848 Phosphate Test Kit respectively. Spectrophotometer Model MERCK Pharo 100 is used to obtain the readings of ammoniacal nitrogen and phosphate.

The readings of temperature, dissolved oxygen (DO), pH and also conductivity were taken *in-situ*. The readings of DO were obtained by using the YSI Model 550 while the readings of temperature, pH and conductivity were obtained by using the multi-parameters probe Model IQ Sciencitific.

The WQI or Water Quality Index values were calculated from the parameters recorded. By using the mean value of DO, BOD, COD, TSS, ammoniacal nitrogen and pH, the values were converted into the sub-indices or SI with the help of the best-fit equations to calculate the WQI based on the equation of DOE (1994).

$$WQI = 0.22SI_{DO} + 0.19SI_{BOD} + 0.16SI_{COD} + 0.15SI_{AN} + 0.16SI_{SS} + 0.12SI_{pH}$$

3.4 Hydraulic Characteristic

As for the hydraulic characteristics, the width (W), depth (D) and the water flow rate (N) were measured at the sampling sites. The readings of width and depth were obtained using measuring tape while readings of the flow rate were obtained by the Signal Counter OTT Z400 which is attached to the OTT C2 Small Current Meter. The area (A), velocity (Q) and discharge (D) were calculated using the following equations (Buchanan & Somers, 1969):

The area, A were calculated by multiplying the width, (W) and the depth, (D)

$$A = W \times D$$

For the velocity, Q:

$$Q = (0.1025 \times N) + 0.028$$

Where N = flow rate

For the discharge, D:

$$D = Q \times A$$

3.5 Statistical Analysis

Statistical validity was tested using Pearson Correlation (software SPSS version 22) to test the significance of the relationships between the factors and the number of individual species. In all data analysis p values equal to and less than 0.05 are considered significant, otherwise non-significant. The reason why Pearson Correlation were chosen is both the dependent and independent variables are continuous variables. Species accumulation curve (Mao Tau function), Jackknife1 and ACE were also calculated by using EstimateS Win 9.10 to show the species richness of all three sites.

Hierarchical Cluster Analysis was also tested using SPSS version 22 to shows the linkage of the sites. Both Canonical Correspondence Analysis (CCA) and Non-metric Multidimensional Scaling (nMDS) were also tested using software PAST 3.

CHAPTER 4: RESULTS

4.1 Adult Odonates Community

A total of 6 family with 1 sub-order Anisoptera (Libellulidae) and 5 sub-order Zygoptera (Euphaeidae, Chlorocyphidae, Calopterygidae, Protoneuridae and Amphipterygidae) were identified. There were 11 species with the total of 724 individuals sampled.

4.1.1 Diversity of Adult Odonates Community

The odonate samplings were analyzed for each study site and were also contrasted across the 3 sites as in Figure 4.1. Site 1 contained all 6 family groups; the abundance in descending order:

Euphaeidae (45%) > Chlorocyphidae (21%) > Libellulidae = Protoneuridae (15%) > Calopterygidae (3%) > Amphipterygidae (1%)

Site 2 too contained all 6 family groups. The abundance in descending order is as follow:

Euphaeidae (34%) > Calopterygidae (23%) > Chlorocyphidae (21%) > Libellulidae (19%) > Protoneuridae (2%) > Amphipterygidae (1%)

Site 3 however contained only 5 family groups. The abundance in descending order is as follow:

Euphaeidae (66%) > Chlorocyphidae (24%) > Calopterygidae (8%) > Protoneuridae = Amphipterygidae (1%)

Contrasting all 3 sites revealed that Euphaeidae was the most abundant and Amphipterygidae was the least represented when compared to all other family groups present. Chlorocyphidae was the overall common and evenly distributed in all 3 sites.

Interestingly, it was found that Libellulidae belonging to the sub-order Anisoptera was absent in Site 3.

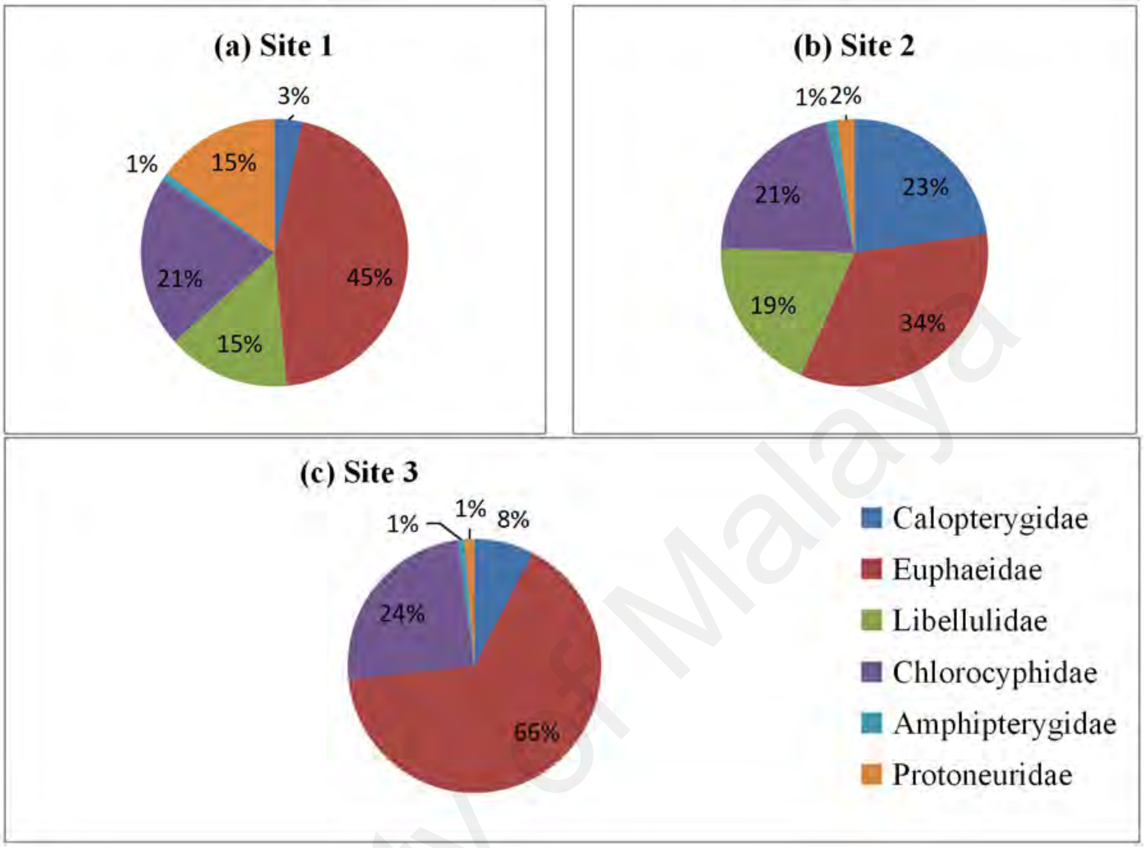

Figure 4.1: Pie charts showing the Families of odonates found in all three sites, (a) Site 1, (b) Site 2 and (c) Site 3

The annotated description listings for the species found within the study sites are as below:

4.1.1.1 *Neurobasis chinensis*

Neurobasis chinensis belonged to the Family Calopterygidae. Male *Neurobasis chinensis* (Figure 4.2) has metallic green hindwings while the female (Figure 4.3) has yellowish transparent wings bearing white 'pseudo-pterostigma'. This species can be found in site 2 in an average amount. However, both *Neurobasis chinensis* in Site 1 seemed to select specialized microhabitats and were found in low abundances.

Figure 4.1: Male *Neurobasis chinensis* body and hind wings metallic in colour

Figure 4.3: Female *Neurobasis chinensis*

4.1.1.2 *Euphae ochracea*

Euphae ochracea (Figure 4.4 and Figure 4.5) was the only member of Family Euphaeidae found during sampling. It appears to be the most abundant in all three sites. Usually, the male individuals occur more frequently compared to the female individuals.

Figure 4.4: Male *Euphae ochracea*

Figure 4.5: Female *Euphae ochracea*

4.1.1.3 *Zygonyx iris*

Zygonyx iris (Figure 4.6) was one of the members from the Family Libellulidae. Surprisingly, they can only be found in both Site 1 and Site 2. In fact, none of the Anisoptera were spotted in Site 3. *Zygonyx iris* were seen to be mating and laying eggs during sampling time. They fly rapidly and seldom perch. Several mating pairs were caught during the samplings.

Figure 4.6: Male *Zygonix iris* (left) and female *Zygonix iris* laying eggs (right)

4.1.1.4 Genus: *Rhinocypha*

For the *Rhinocypha* sp. which belonged to the Family Chlorocyphidae, only *Rhinocypha perforata* (Figure 4.7) can be found in Site 1 and only *Rhinocypha fenestrella* (Figure 4.8) can be found in Site 3 but both appeared in Site 2 where the numbers of *Rhinocypha perforata* were lower. Both species can be differentiated by the patterns and wing colourations. However, the females (Figure 4.9) look very similar.

Figure 4.7: Male *Rhinocypha perforata* at a perching position within its territory

Figure 4.8: Male *Rhinocypha fenestrella*

Figure 4.9: Female *Rhinocypha* sp. dipping ovipositor into water and depositing eggs on broken tree trunk surfaces

4.1.1.5 *Vestalis amethystina*

Vestalis amethystina belonged to the Family Calopterygidae. *Vestalis amethystina* (Figure 4.10) has clear transparent wings and their sex can only be determined by their sex organs. This species can be found in site 2 in an average amount. However, *Vestalis amethystina* (in Site 3), seemed to select specialized microhabitats and were found in low abundances.

Figure 4.10: Female *Vestalis amethystina* (left) and male *Vestalis amethystina* (right) differentiated by their sex organs

4.1.1.6 ***Devadatta argyoides***

Devadatta argyoides (Figure 4.11) occurred in all three sites but in a very low abundance. They were the only species from the family Amphipterygidae recorded during the sampling period. They were described to be robust and have dull slaty brown colour.

Figure 4.11: *Devadatta argyoides*

4.1.1.7 ***Prodasineura laidlawii***

On the other hand, *Prodasineura laidlawii* (Figure 4.12) from the Family Protoneuridae was very common in Site 1 but less common in Site 2 and Site 3. They were frequently observed displaying reproductive behaviours, such as courtship and eventually mating behavior (Figure 4.13). The species, *Prodasineura* sp. is easily recognizable from the morphological features of the blue coloured banded patterns on a dark background colour on the thoracic body parts.

Figure 4.12: Male (left) and female (right) *Prodasineura laidlawii*

Figure 4.13: *Prodasineura laidlawii* showing a tandem posture and female pre-oviposition position

4.1.1.8 *Echo modesta*

Echo modesta (Figure 4.14) was one of the three members of Family Calopterygidae that were found during sampling. However, they can only be found in Site 3. All three members of this family share a similar feature which is the metallic green colour on them but *Echo modesta* can be differentiated by the white patch on its head. Only male individuals were spotted during sampling.

Figure 4.14: Male *Echo modesta* and the white patch on its face (right)

4.1.1.9 *Trithemis festiva*

Trithemis festiva (Figure 4.15) were another species from the family Libellulidae that were only seen in Site 2. They were seen mostly resting on big boulders on the riverbanks. They were more abundant during the afternoon or evening session and were only occurred for a few months. They have dark blue pruinosed colour with clear orange streaks.

Figure 4.15: *Trithemis festiva*

4.1.1.10 ***Orthetrum glaucum***

Orthetrum glaucum (Figure 4.16) from the family Libellulidae can only be found in Site 2. They were always seen to rest on big boulders near the riverbanks. They were more abundant during the afternoon or evening session and were only occurred for a few months. Only the male individual of this species were seen throughout the period of sampling. They were blue in colour and they were pruinosed once fully mature.

Figure 4.16: *Orthetrum glaucum*

4.1.2 The Abundance of Adult Odonates Community

Overall, Site 2 is the most diverse as there were higher diversity and abundance of species. This will be further discussed and supported by the ecological indices in section 4.1.3 below. Figure 4.17 below shows the species of adult odonates found in all three sites.

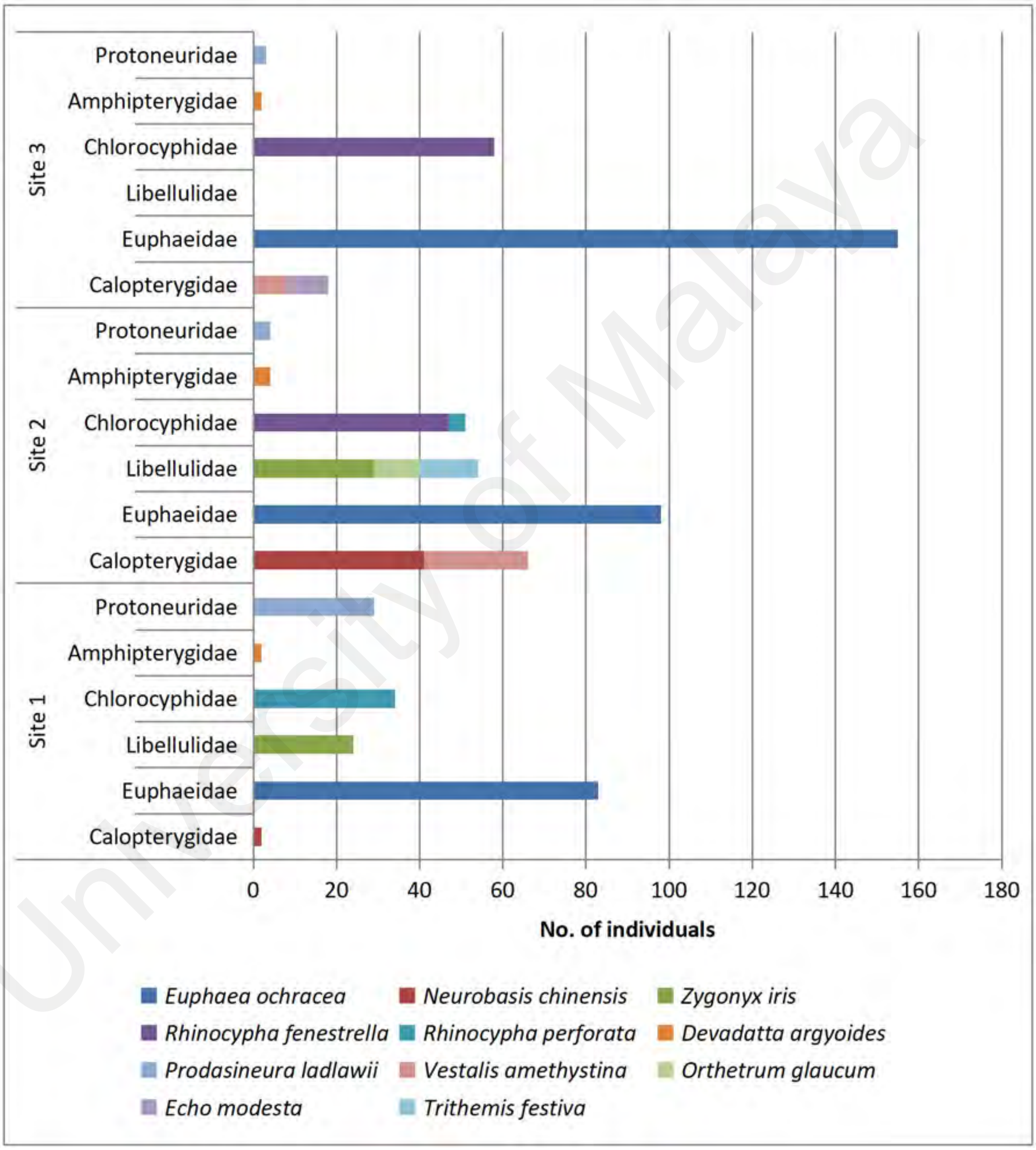

Figure 4.17: The diversity of species abundance within the family groups of adult dragonflies that were sampled in Site 1, 2 and 3

According to Figures 4.18, 4.19 and 4.20 below, most of the time, the number of catch during the evening session is more than the morning session. *Euphaea ochracea* is the only species that are equally diverse during both sessions while the *Rhinochypa* sp. depends on the weather. *Echo modesta* is one of the species that only appear during the evening session and always at the same spot in Site 3. However, during the month of February, no *Euphaea ochracea* found in Site 2 for both morning and evening session. Similarly, *Echo modesta* was absent in Site 3 during the months of February, June and August. *Rhinochypa perforata* preferred the lower stream which was Site 1 while *Rhinocypha fenestrella* seems to prefer the upper stream which was Site 3 where both of their occurrence overlap in Site 2. This type of relationship was seen in *Neurobasis chinensis* and *Vestalis amethystina* as well but in a very low abundances. *Neurobasis chinensis* were recorded in Site 1 and Site 2 while *Vestalis amethystina* were recorded in Site 2 and Site 3. Both *Zygonyx iris* and *Prodasineura laidlawii* were recorded in both Site 1 and Site 2 however the abundance of *Prodasineura laidlawii* was very low in Site 2. *Orthetrum glaucum* and *Trithemis festiva* were the only two species that were recorded only in Site 2

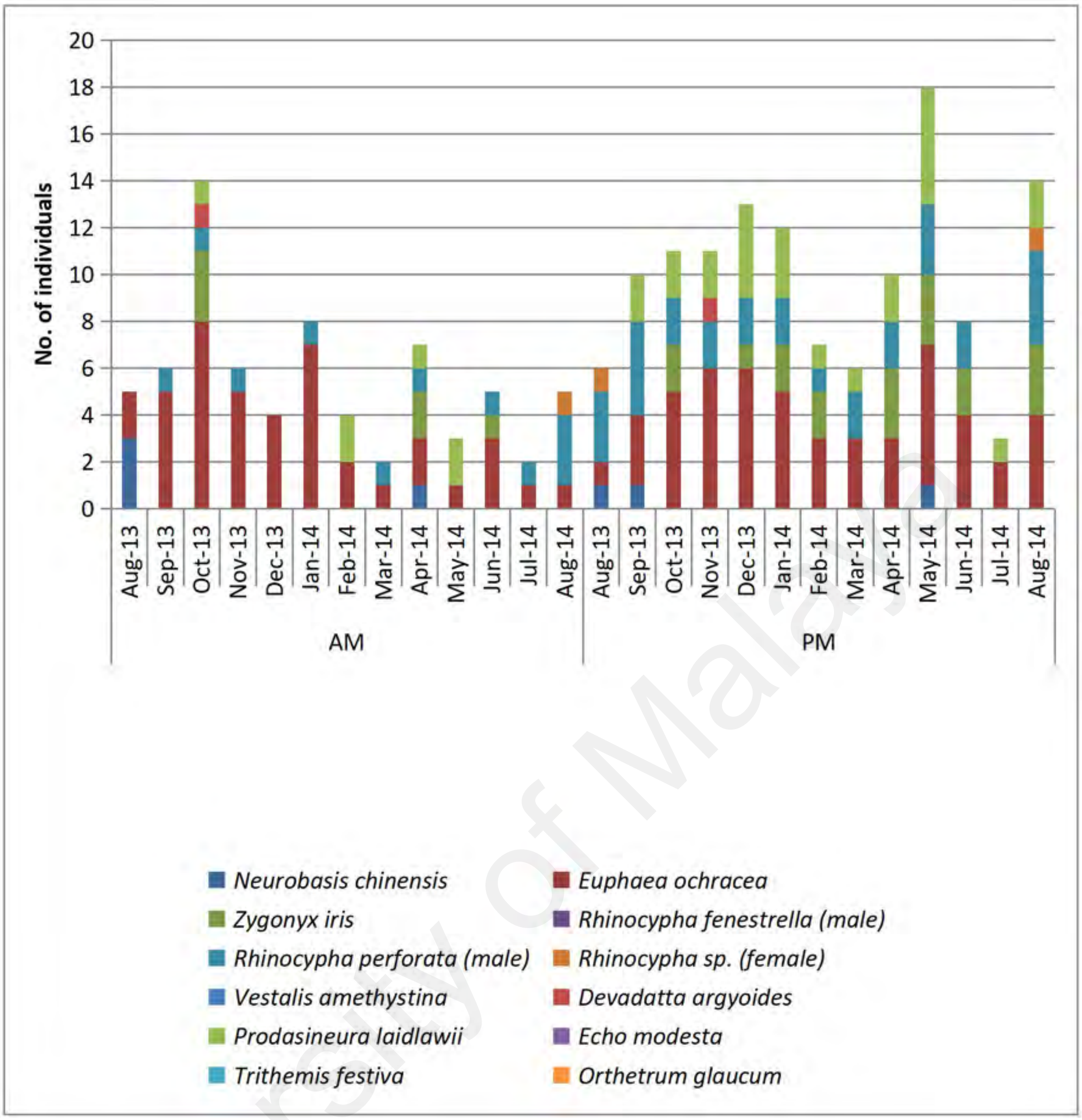

Figure 4.18: Comparison of adult odonates in Site 1 during morning and evening session

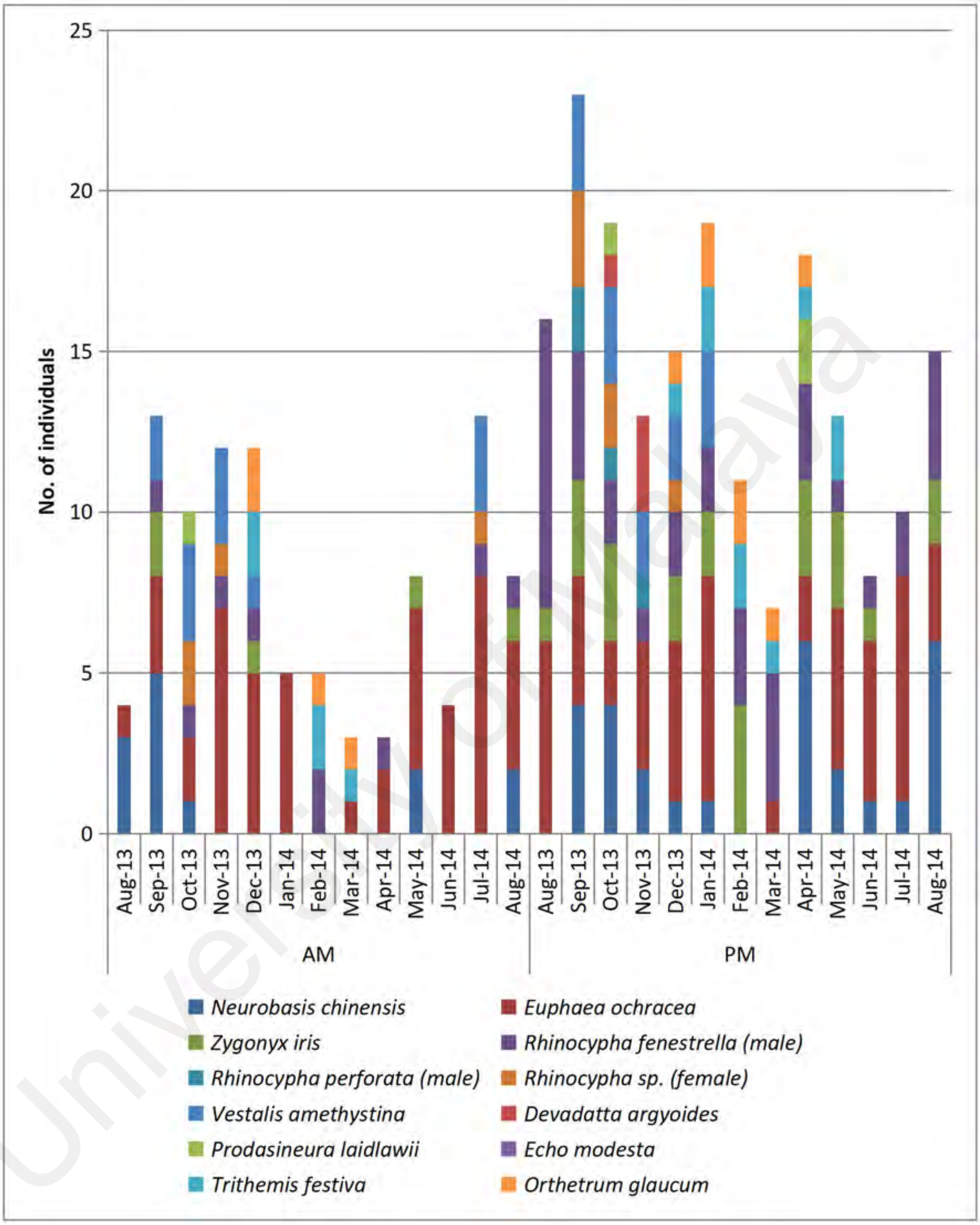

Figure 4.19: Comparison of adult odonates in Site 2 during morning and evening session

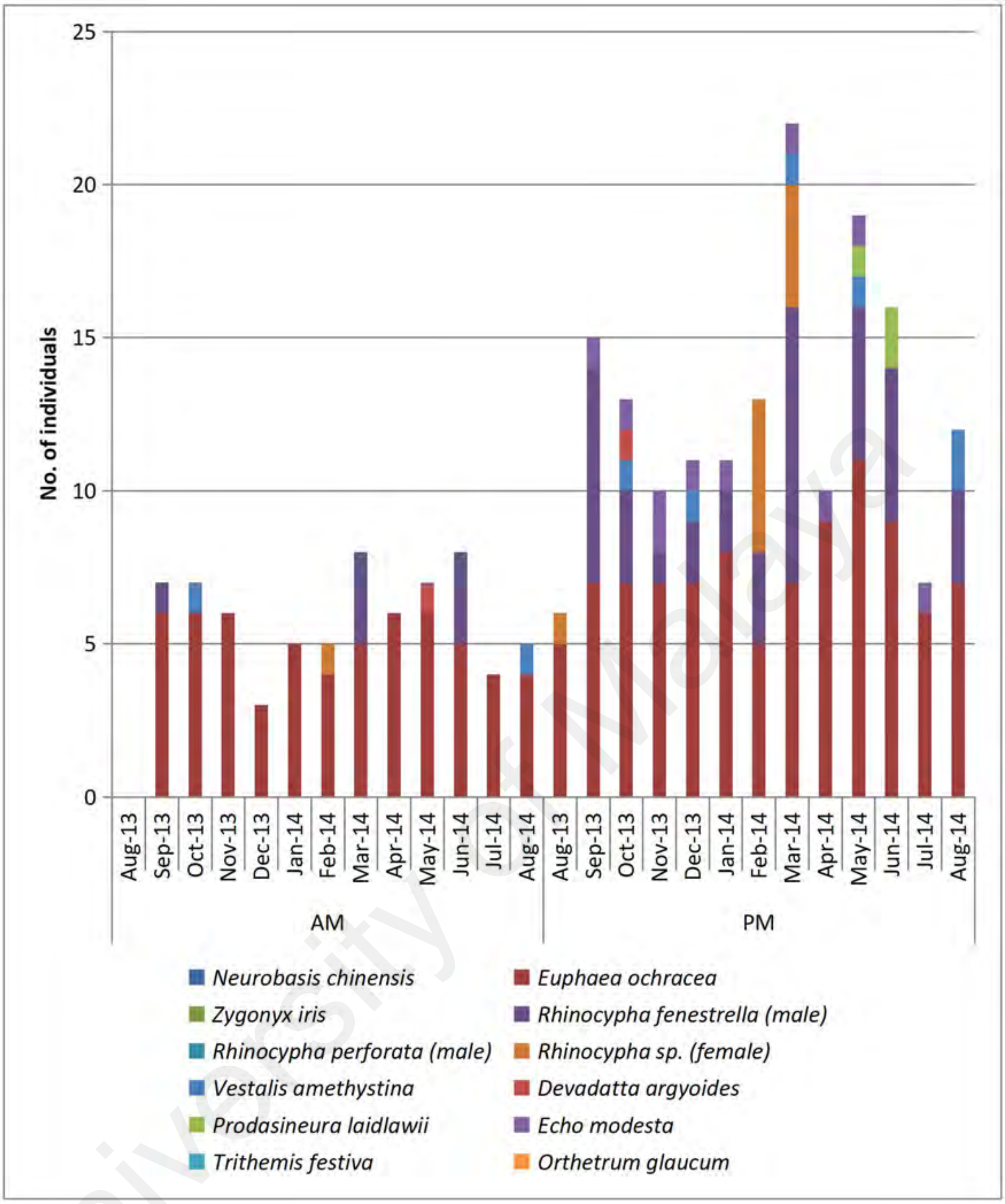

Figure 4.20: Comparison of adult odonates in Site 3 during morning and evening session

Table 4.1 below shows the significance value of Independent T-test calculated to prove the significant differences between the number of individual of each species between the morning and evening session.

Euphaea ochracea is one of the species that show significant differences in numbers between the morning and evening session where the numbers are significantly higher during the evening session (M = 5.05, SD = 2.42) than the morning session (M = 3.85, SD = 2.18), $t(76)$ = -2.31, p = 0.024. On the other hand, the numbers of *Neurobasis chinensis* are similar during the morning session (M = 0.65, SD = 1.29) and evening session (M = 1.19, SD = 1.81), $t(50)$ = -1.23, p = 0.223. The numbers of *Zygonyx iris* also show significant differences as well where the morning session (M = 0.42, SD = 0.81) are significantly lower than the evening session (M = 1.62, SD = 1.30), $t(50)$ = -3.97, p < 0.001. Similarly, the numbers of *Rhinocypha fenestrella* are significantly higher during the evening session (M = 3.00, SD = 2.43) compared to the morning session (M = 0.73, SD = 1.00), $t(50)$ = -4.40, p < 0.001. The same goes to *Rhinocypha perforata* where the numbers are significantly higher during the evening session (M = 1.27, SD = 1.31) than the morning session (M = 0.42, SD = 0.70), $t(50)$ = -2.90, p = 0.006. In contrast, *Devadatta argyoides* shows similar number during the morning session (M = 0.05, SD = 0.22) and evening session (M = 0.15, SD = 0.54), $t(76)$ = -1.10, p = 0.276. *Prodasineura laidlawii* however are significantly higher in numbers during the evening session (M = 0.82, SD = 1.23) than the morning session (M = 0.18, SD = 0.51), $t(76)$ = -3.00, p = 0.004. Moving on to *Vestalis amethystina*, they have similar numbers during the morning session (M = 0.54, SD = 1.03) and the evening session (M = 0.73, SD = 1.08), $t(50)$ = -0.66, p = 0.514. *Orthetrum glaucum* too have similar numbers during the morning session (M = 0.31, SD = 0.63) and the evening session (M = 0.54, SD = 0.78), $t(24)$ = -0.83, p = 0.414. As for *Echo modesta,* non of them were sampled during the morning session (M = 0, SD = 0) as they were only sampled during the evening session (*M* = 0.77, *SD* = 0.60), $t(24) = -4.63$, $p < 0.001$. Last but not least, the numbers of *Trithemis festiva* are similar during the morning session (*M* = 0.38, *SD* = 0.77) and during the evening session (*M* = 0.69, *SD* = 0.85), $t(24) = -0.97$, $p = 0.344$.

Table 4.1: Significance value of Independent T-test by SPSS

Species	Significance Value
Neurobasis chinensis	0.223
Euphaea ochracea	0.024*
Zygonyx iris	<0.001*
Rhinocypha fenestrella	<0.001*
Rhinocypha perforata	0.006*
Vestalis amethystina	0.514
Devadatta argyoides	0.276
Prodasineura laidlawii	0.004*
Echo modesta	<0.001*
Trithemis festiva	0.344
Orthetrum glaucum	0.414

* T-test shows significant differences in number between morning and evening session, $p<0.05$

4.1.3 Biodiversity Indices

Table 4.2 below shows the biodiversity indices calculated for all three sampling sites. According to the Shannon-Wiener Index, Site 2 with the highest value of H is the most diverse among the three sites, followed by Site 1 and lastly Site 3. This can be supported by the value of Simpson's index of diversity and the value of Simpson's reciprocal index. As for the evenness, Site 2 has the highest value as well followed by Site 1 and then Site 3. This show the times of occurrence of each species in Site 2 are more even than Site 1 followed by Site 3. The Simpson's Index on the other hand shows higher value of dominance in Site 3 followed by Site 1 and then Site 2

Table 4.2: The biodiversity indices calculated for each sites

Ecological Indices	Site 1	Site 2	Site 3
Shannon-Wiener Index, H	1.4445	1.9528	1.0851
Evenness, E	0.7423	0.8144	0.5576
Simpson's Index, D	0.2979	0.1869	0.47657
Simpson's Index of Diversity, 1-D	0.7021	0.8131	0.52343
Simpson's Reciprocal Index, 1/D	3.3568	5.3505	2.0983

4.2 Water Quality Status & Hydraulic Characteristic

4.2.1 Dissolved Oxygen (DO)

Figure 4.21 below shows the dissolved oxygen (DO) of the three sites. The value of DO between the three sites are quite similar except for August 2013, November 2013 and February 2014. The DO for both August and November 2013 for Site 3 were much higher than the other two sites while the DO for Sites 2 on February 2014 was much lower compared to the other two sites. These three sites shared the same pattern for DO except during August 2013. The DO of Site 3 were extremely high compared to the other two sites.

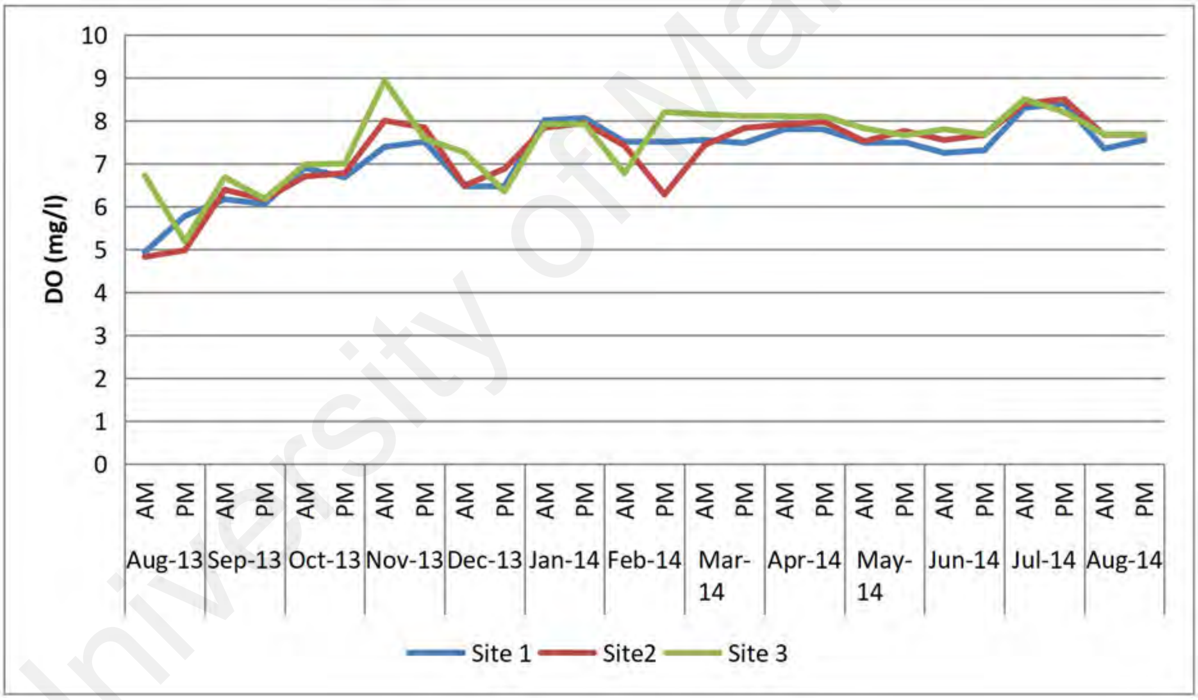

Figure 4.21: Dissolved oxygen of water samples of the three sampling sites

4.2.2 Biochemical Oxygen Demand (BOD)

Figure 4.22 below shows the biochemical oxygen demand (BOD) for the three sampling sites. The BOD of the three sites are not constant and showed fluctuations throughout the sampling periods. However, during April 2014, the BOD seems to hike to their peak especially for Site 1 and Site 2. The BOD for these two sites were extremely high which could be due to the rotten fruits that dropped from the nearby trees or the household waste from the aboriginal settlements.

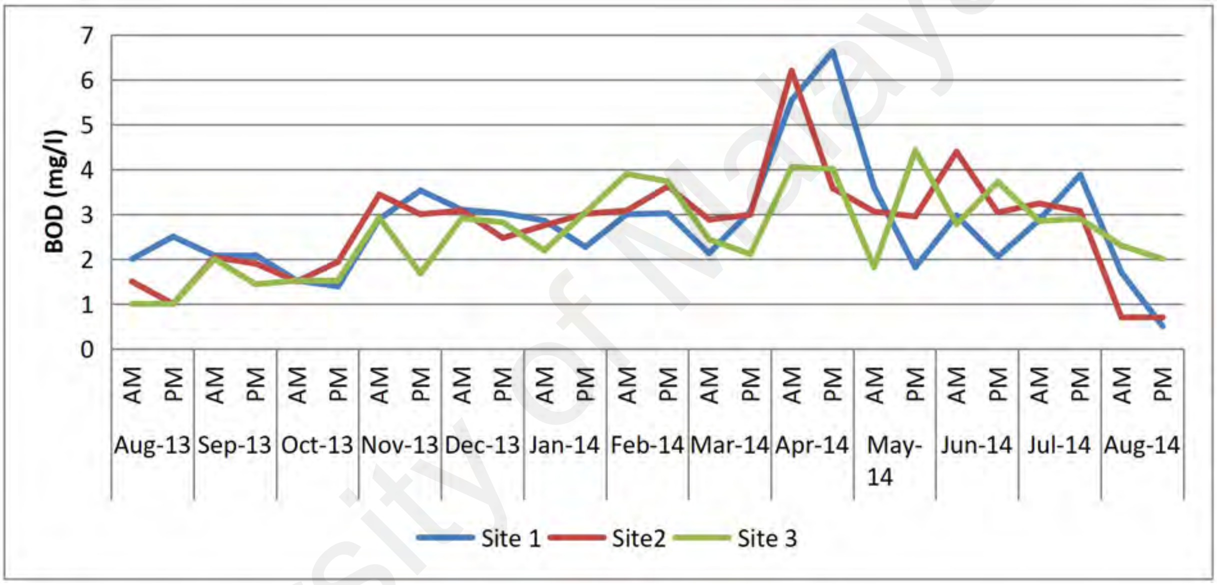

Figure 4.22: Biochemical oxygen demand of water samples of the three sampling sites

4.2.3 Chemical Oxygen Demand (COD)

Figure 4.23 below shows the chemical oxygen demand (COD) of the three sampling sites. Most of the time, the COD of Site 3 is the lowest, followed by Site 2 and then Site 1 which is the highest. However, there are exceptions. During the month of March and August 2014, Site 2 seems to have the highest COD among the three sites especially during August 2014, where the COD for both Site 1 and Site 2 which are extremely high. There is no doubt for both Site 1 and Site 2 to have higher COD once awhile as there are a lot of activities such as picnics and the locals were spotted washing their motorcycles too. As for July 2014, the COD of Site 3 seems to have increased to a value which is higher than its usual value. This could be due to the visitors from the temple that were spotted to be relaxing around that area. According to one of the visitors, praying rituals were being held at Site 3 as well.

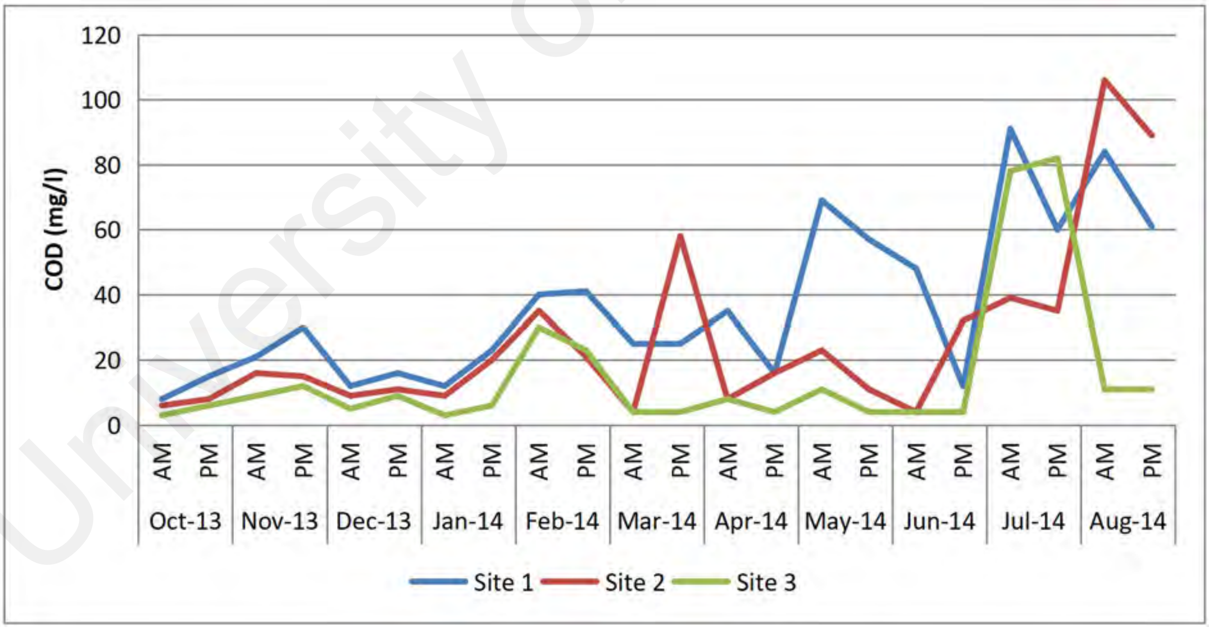

Figure 4.23: Chemical oxygen demand of the water samples of the three sampling sites

4.2.4 pH

Figure 4.24 shows the pH value of the water samples of the three sampling sites. The pH value of the three sites do not differ much and oscillating around each other all the time except during March, April and June. During March, the differences of the pH values for all three sites could be differentiated; where Site 1 water turns to acidic. As for April, the pH values for Site 1 and Site 3 were similar, but the value for Site 2 became alkaline. The alkalinity could be caused by the soup used by the locals to wash their motorcycle or even from the household. For the month of June, all three sites had alkaline values, where the pH were all above 8. This could be either due to some kind of unknown discharge or activities from the upper part of the river or due to the error from the multi-parameters probe.

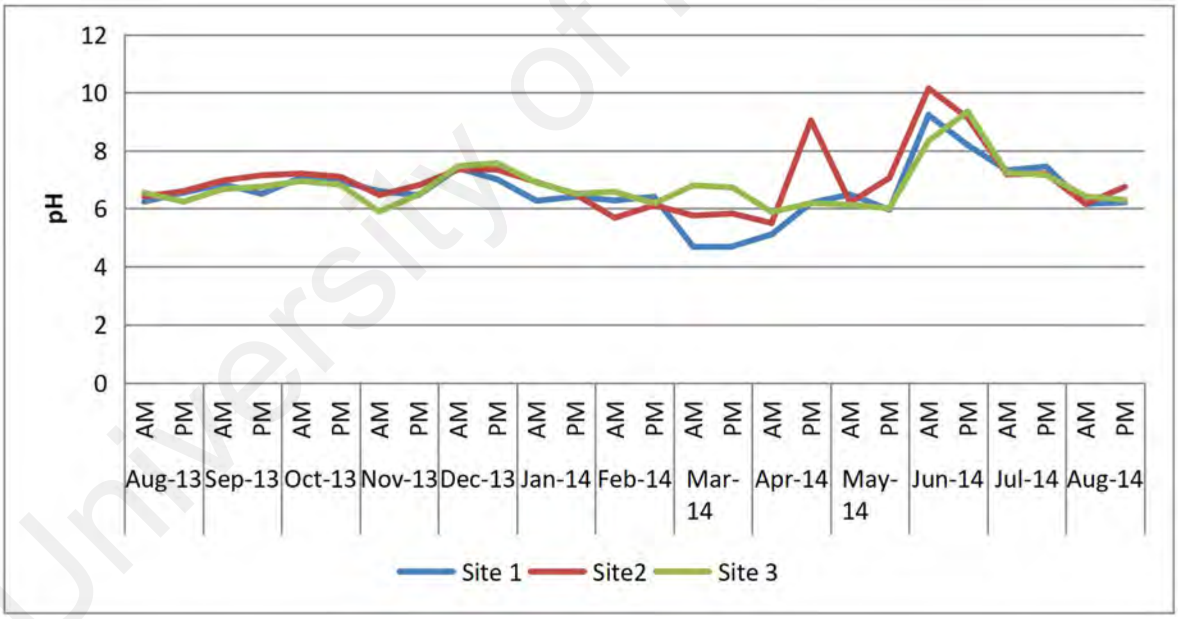

Figure 4.24: pH value of water samples of the three sampling sites

4.2.5 Phosphate

Figure 4.25 shows the phosphate level of the sampling sites. The phosphate level of all three sites seems to be quite inconsistent. The phosphate level of Site 1 fell within the range in between 0-0.15 ppm. However, during September and October, the phosphate level exceed that range but they never exceed 0.2ppm. As for Site 2, the usual range of phosphate level falls in between 0-0.1ppm except during September and October where the value increased to 0.2ppm. The phosphate level of Site 3 usually does not exceed 0.1ppm but during September and December, they increased and falls in between 0.15-0.2ppm. The higher level of phosphate could be caused by humans and animals wastes that reside around the area.

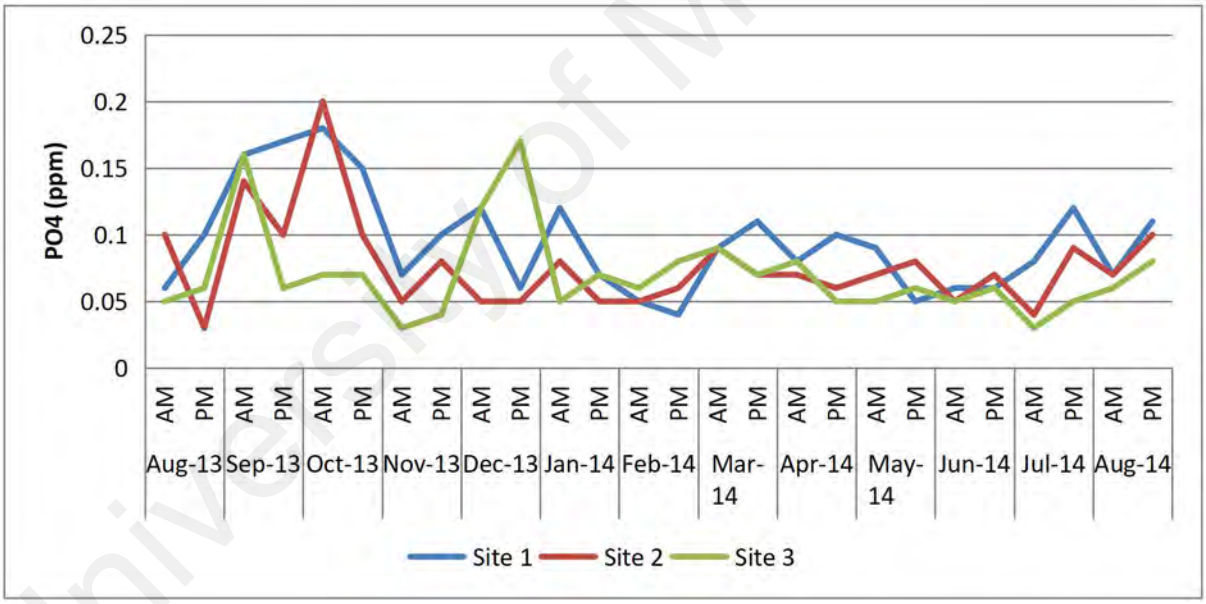

Figure 4.25: Phosphate level of water samples of the three sampling sites

4.2.6 Ammoniacal Nitrogen

Figure 4.26 shows the ammoniacal nitrogen level of the three sampling sites. The ammoniacal nitrogen level of Site 3 seems to be more consistent compared to Site 1 and Site 2. Site 1 showed clear fluctuations but they never exceed 0.1mg/l. Site 2 had less fluctuations but with a peak value that reached 0.1mg/l during February. The highest value of ammoniacal nitrogen of Site 3 was 0.05mg/l. However, during March the value exceeded 0.08mg/l.

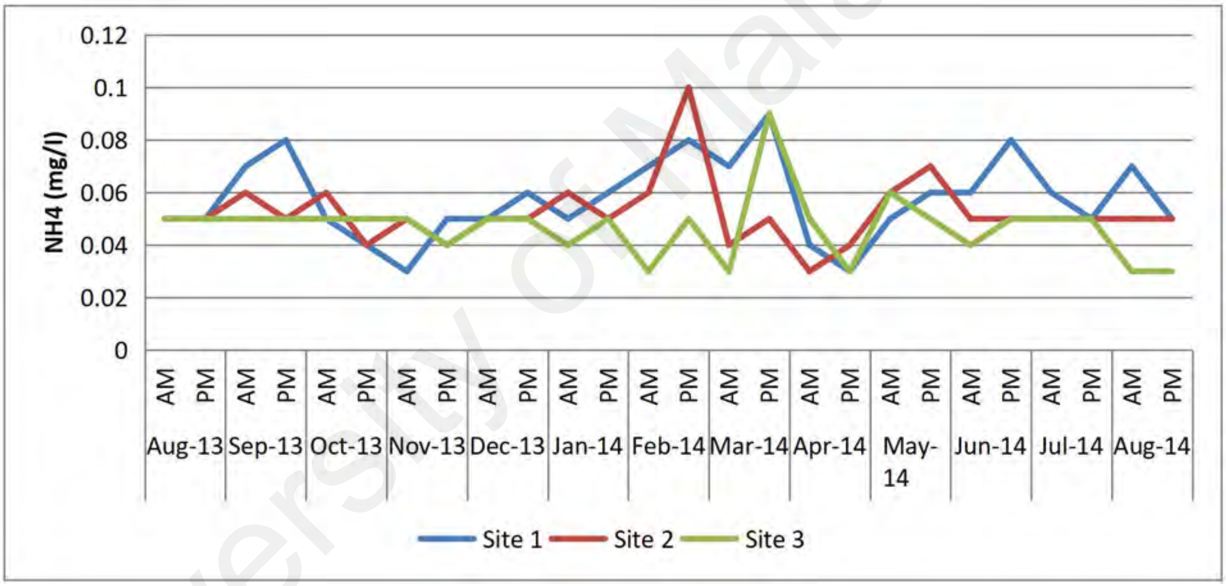

Figure 4.26: Ammoniacal nitrogen of the water samples of the three sampling sites

4.2.7 Temperature

Figure 4.27 below shows the water temperature of all three sampling sites. The water temperature of Site 3 was the lowest when compared to all three sites and they never exceed 24°C. Most of the time, the water temperature of Site 1 is higher than Site 2. The highest water temperature recorded never exceed 27°C which is during February and March which could be due to the weather as according to the rainfall report, these two months have the lowest amount of rainfall.

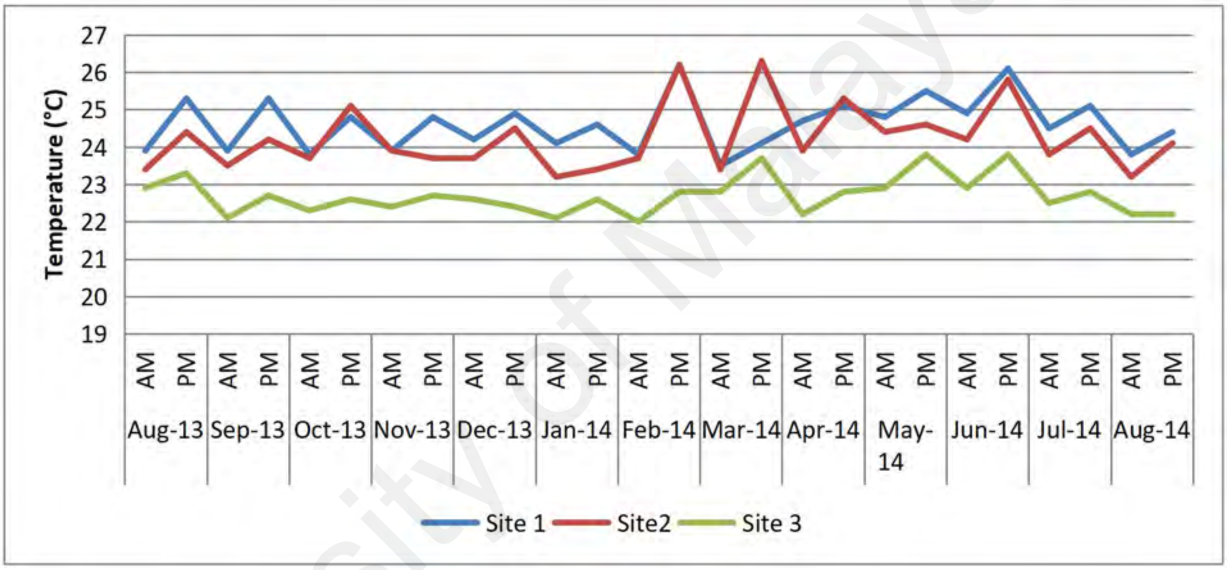

Figure 4.27: Water temperature of the three sampling sites

4.2.8 Total Suspended Solid (TSS)

Figure 4.28 below shows the total suspended solid (TSS) for all three sampling sites. Site 1 usually has the highest TSS level followed Site 2 and then Site 3. The value are quite consistent and usually never exceed 50mg/l. However, during June the TSS value of Site 1 increased dramatically almost reaching 200mg/l. This could be due to the wash off from the watershed since Site 1 is the most disturbed by human activities.

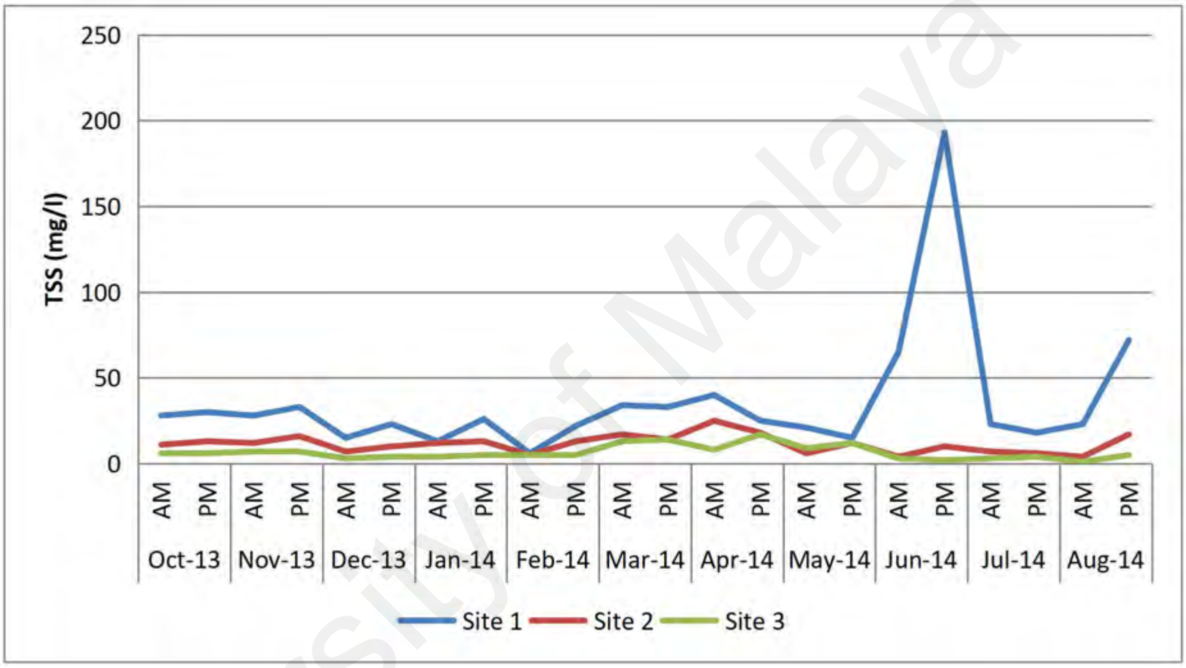

Figure 4.28: Total suspended solid of the three sampling sites

4.2.9 Conductivity

Figure 4.29 shows the conductivity of all three sampling sites. The conductivity of Site 1 are always extremely high compared to Site 2 and Site 3 where Site 3 usually has the lowest conductivity among all three sites. The conductivity of both Site 2 and Site 3 are quite consistent too. During March 2014, the conductivity recorded at Site 1 were extremely high exceeding 100mg/l.

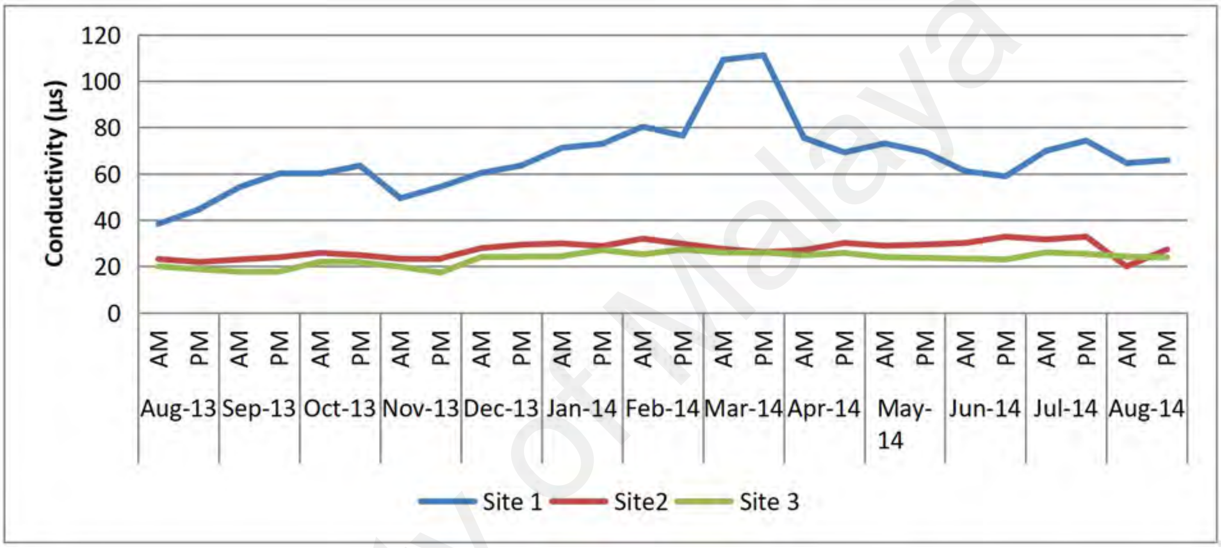

Figure 4.29: Conductivity of the water samples of the three sampling sites

4.2.10 Water Quality Index (WQI)

Figure 4.30 shows the Water Quality Index (WQI) of all three sampling. The WQI of Site 3 is the highest followed by Site 2 and Site 1 which is the lowest. However, during July, the WQI of Site 2 surpassed the WQI of Site 3. Usually, they maintained at category of Class II which is suitable for recreational use with body contact. However, there are a few months where Site 3 were in the category of Class I which is suitable for water supply. During the month of June, Site 3 dropped into the category of Class III which is suitable for fishery.

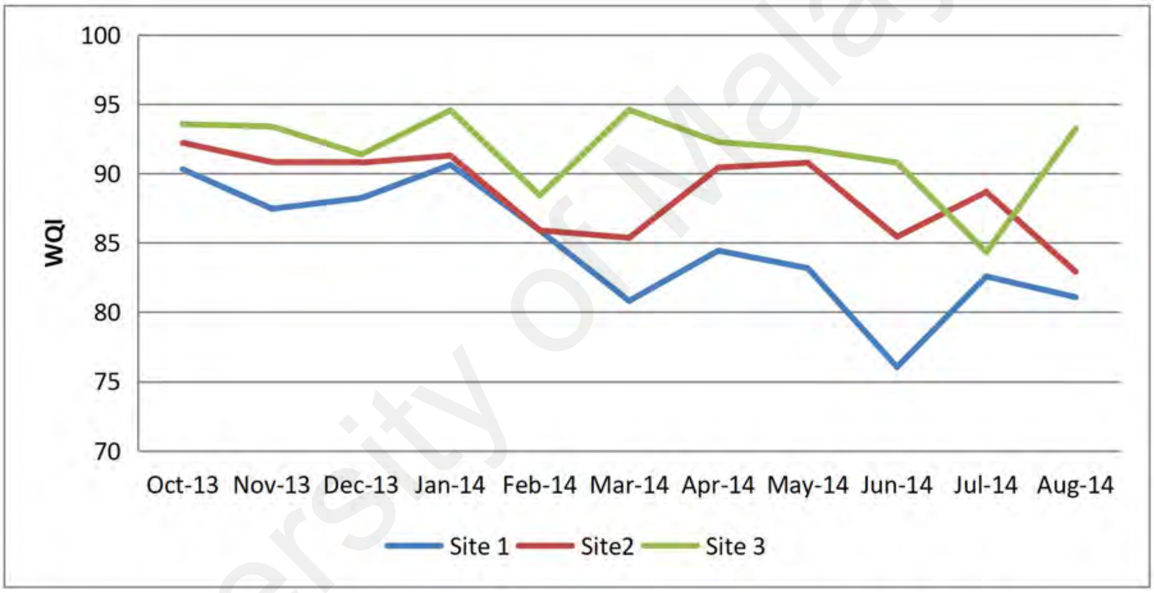

Figure 4.30: Water Quality Index of the three sampling sites

4.2.11 Discharge

Figure 4.31 below shows the discharge of all three sampling sites. The discharge of Site 3 are always the highest followed by Site 2 and then Site 1. However, during October, the discharge of Site 3 dropped in between of Site 2 and Site 1. The trend of the discharge of all the three sites seems to be very similar. For example, when the discharge of Site 3 increased during January, the discharge of both Site 2 and Site 1 increased during that month too. When the discharge of Site 3 decreased during the following month, both the discharge of Site 2 and Site 1 decreased too.

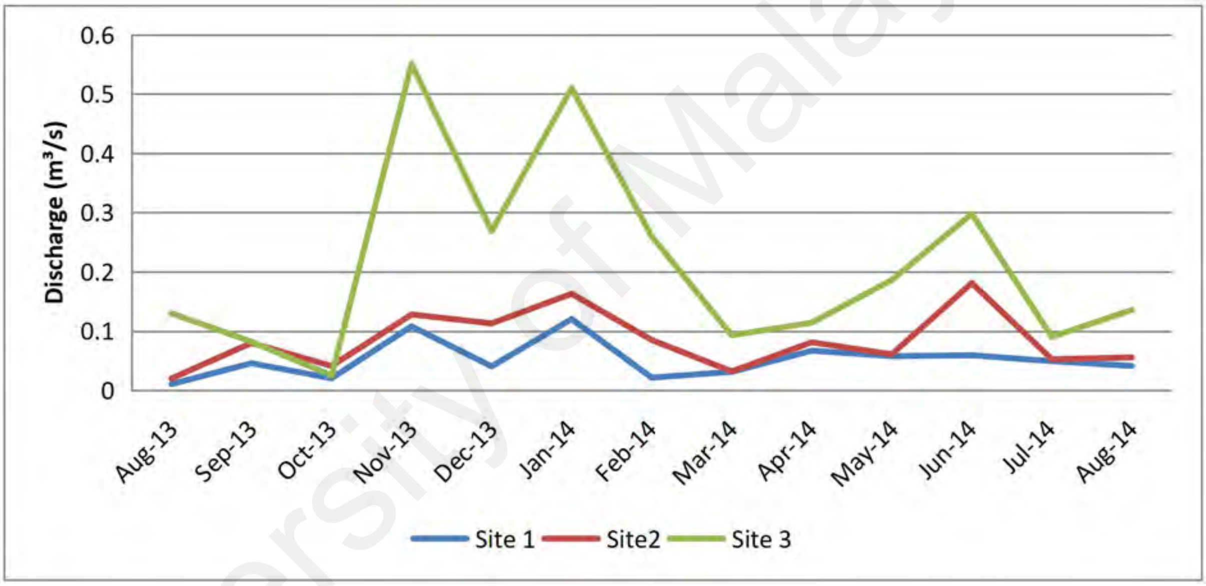

Figure 4.31: Discharge of the three sampling sites

Table 4.3 below shows the mean value of each water quality status and hydraulic characteristic that had been recorded during the sampling period. Kruskal-Wallis test was used (SPSS) to determine the significance differences or similarity among the water quality status and hydraulic characteristic values of all three sites by accepting or rejecting the null hypothesis:

H_0: There is no significant differences among the value of the three sites.

When the $p < 0.05$, the null hypothesis was rejected. The values that were marked with '*' in the table shows that there were significant differences in the value between the sites.

As we can see from Table 4.3, the BOD, DO and pH of all the three sites have no significant differences among each other. However, the mean BOD was the highest in Site 1 followed by Site 2 and then Site 3. The mean DO were the opposite where it was the highest in Site 3, followed by Site 2 and then Site 1. As for the mean pH, it was the highest in Site 2, followed by Site 3 and then Site 1 where all three sites fall in the slightly acidic range.

As for the temperature, conductivity, TSS, COD and WQI, there were significant differences of these water parameters among all three sites. The mean value of all these parameters were the highest in Site 1 followed by Site 2 and then Site 3 except for WQI. The mean value of WQI was the highest in Site 3 followed by Site 2 and the Site 1.

The *p* value that were calculated for both phosphate and ammoniacal nitrogen were less than 0.05. However, there were only significant differences between the phosphate level of Sites 1 and 3 while there were no significant differences in the value between Sites 1 and 2 and between Sites 2 and 3. These show that the phosphate level of Site 2 were similar to both Site 1 and Site 3. The mean value of phosphate level was the highest in Site 1 followed by Site 2 and then Site 3. The same goes for the ammoniacal nitrogen, where there were significant differences in the value between Sites 1 and 3 while there were no significant differences between Sites 1 and 2 and between Sites 2 and 3. These show that the ammoniacal nitrogen of Site 2 were similar to both Site 1 and Site 3. The mean value of ammoniacal nitrogen was the highest in Site 1 while the mean value for Site 2 and Site 3 were the same.

There were no significant differences between the discharge in Sites 1 and 2. However, there were significant differences between the discharge in Sites 2 and 3 and between Site 1 and 3. These shows that the discharge in Site 1 and Site 2 were more similar. The mean value of the discharge shows that the discharge of Site 1 was the lowest, followed by Site 2 and then Site 3.

Table 4.3: The mean value of water quality status and hydraulic characteristic for all three sampling sites

Parameters	Site 1	Site 2	Site 3	*p*	*p*		
					Sites 1 & 2	Sites 2 & 3	Sites 1 & 3
Dissolved Oxygen (DO)	7.2	7.25	7.51	0.164	0.481	0.213	0.067
Biochemical Oxygen Demand (BOD)	2.77	2.74	2.58	0.731	0.701	0.458	0.621
Chemical Oxygen Demand (COD)	36	26	15	<0.001*	0.04*	0.009*	<0.001*
pH	6.57	6.95	6.78	0.522	0.276	0.602	0.487
Phosphate	0.1	0.08	0.07	0.017*	0.055	0.275	0.007*
Ammoniacal Nitrogen	0.06	0.05	0.05	0.01*	0.112	0.72	0.004*
Temperature	24.6	24.2	22.7	<0.001*	0.029*	<0.001*	<0.001*
Total Suspended Solid (TSS)	36	11	7	<0.001*	<0.001*	0.002*	<0.001*
Conductivity	67.36	27.32	23.21	<0.001*	<0.001*	<0.001*	<0.001*
Water Quality Index (WQI)	84.6038	88.6018	91.6611	<0.001*	0.017*	0.017*	0.001*
Discharge	0.0517	0.0841	0.2111	0.001*	0.069	0.007*	0.001*

*Kruskal-Wallis shows significant differences between sites, $p < 0.05$

4.3 Statistical Analysis

Pearson Correlation was done by using SPSS. All the factors were tested on the number of individual of each species. The results will show if there are significant relationship between the factors and the individual species by accepting or rejecting the null hypothesis:

H_0: There were no significant relationship between the factor with the individual species.

If the results show significant relationship, the type of relationship can also be determined by the *r* value which range between -1.0 to 1.0. If the *r* value is positive, it is a positive relationship which means the higher the value of the factor, the higher the number of individual of the species. If the *r* value is negative, it is a negative relationship which means the higher the value of the factor, the lower the number of individual of the species.

From Table 4.4 below, there are several species that were related to several factors. Those that are marked with '*' have *p* value that are less than 0.05 where the null hypothesis are rejected.

From the Pearson correlation analyzed, there were no relationship shown between *Neurobasis chinensis*, *Devadatta argyoides*, *Trithemis festiva* and *Orthetrum glaucum* with any of the factors. *Euphaea ochracea* show negative relationships with temperature, $r(37) = -0.574$, $p < 0.001$; conductivity, $r(37) = -0.321$, $p = 0.046$; and COD, $r(31) = -0.434$, $p = 0.012$ while they show positive relationship with discharge, $r(37) = 0.425$, $p = 0.007$. On the other hand, *Zygonyx iris* show positive relationship with temperature, $r(37) = 0.516$, $p = 0.001$ and negative relationship with discharge, $r(37) = -0.32$, $p = 0.047$. Both *Rhinocypha fenestrella*, $r(37) = -0.545$, $p < 0.001$ and *Vestalis amethystina*,

$r(37) = -0.326$, $p = 0.043$ were showing negative relationship with conductivity. *Rhinocypha perforata* alone show significant relationship with 5 factors. Among the 5 factors, the only one factor that shows negative relationship with *Rhinocypha perforata* is discharge, $r(37) = -0.347$, $p = 0.031$ while temperature, $r(37) = 0.456$, $p = 0.004$; conductivity, $r(37) = 0.703$, $p < 0.001$; phosphate, $r(37) = 0.45$, $p = 0.004$; and TSS, $r(31) = 0.595$, $p < 0.001$ show positive relationship with *Rhinocypha perforata*. *Prodasineura laidlawii* were positively related to both temperature, $r(37) = 0.469$, $p = 0.003$ and conductivity, $r(37) = 0.622$, $p < 0.001$. Last but not least, *Echo modesta* were tested to be negatively related to both temperature, $r(37) = -0.659$, $p < 0.001$ and conductivity, $r(37) = -0.392$, $p = 0.014$ but positively related to discharge, $r(37) = 0.579$, $p < 0.001$.

Table 4.4: The significance value or p value calculated through Pearson Correlation by SPSS

Species	Factors				
	BOD	DO	Temperature	pH	Conductivity
Neurobasis chinensis	0.365	0.137	0.253	0.731	0.138
Euphaea ochracea	0.865	0.054	<0.001*	0.253	0.046*
Zygonyx iris	0.705	0.507	0.001*	0.955	0.169
Rhinocypha fenestrella	0.286	0.465	0.087	0.545	<0.001*
Rhinocypha perforata	0.416	0.246	0.004*	0.272	<0.001*
Vestalis amethystina	0.424	0.878	0.467	0.561	0.043*
Devadatta argyoides	0.815	0.755	0.875	0.868	0.454
Prodasineura laidlawii	0.333	0.889	0.003*	0.553	<0.001*
Echo modesta	0.683	0.137	<0.001*	0.626	0.014*
Trithemis festiva	0.281	0.879	0.142	0.494	0.273
Orthetrum glaucum	0.308	0.824	0.226	0.585	0.305

*Pearson Correlation shows odonates significantly affected by parameters, $p<0.05$

Table 4.4: continued

Species	Factors				
	Phosphate	Ammoniacal nitrogen	Discharge	TSS	COD
Neurobasis chinensis	0.236	0.608	0.157	0.601	0.201
Euphaea ochracea	0.496	0.055	0.007*	0.157	0.012*
Zygonyx iris	0.182	0.348	0.047*	0.065	0.401
Rhinocypha fenestrella	0.618	0.62	0.731	0.083	0.162
Rhinocypha perforata	0.004*	0.058	0.031*	<0.001*	0.087
Vestalis amethystina	0.304	0.371	0.661	0.265	0.104
Devadatta argyoides	0.512	0.294	0.709	0.87	0.229
Prodasineura laidlawii	0.145	0.676	0.153	0.522	0.385
Echo modesta	0.261	0.362	<0.001*	0.161	0.177
Trithemis festiva	0.169	0.126	0.621	0.472	0.56
Orthetrum glaucum	0.167	0.39	0.729	0.547	0.579

*Pearson Correlation shows odonates significantly affected by parameters, $p<0.05$

Species accumulation curves (Mao Tau function) were calculated using EstimateS Win 9.10. Figure 4.32 below shows the species accumulation curves (Mao Tau function) that reflects the species richness of all three sites. The species accumulation curves for all three sites shows that all the species from the sites were collected during sampling as all the curves reach plateau in the end.

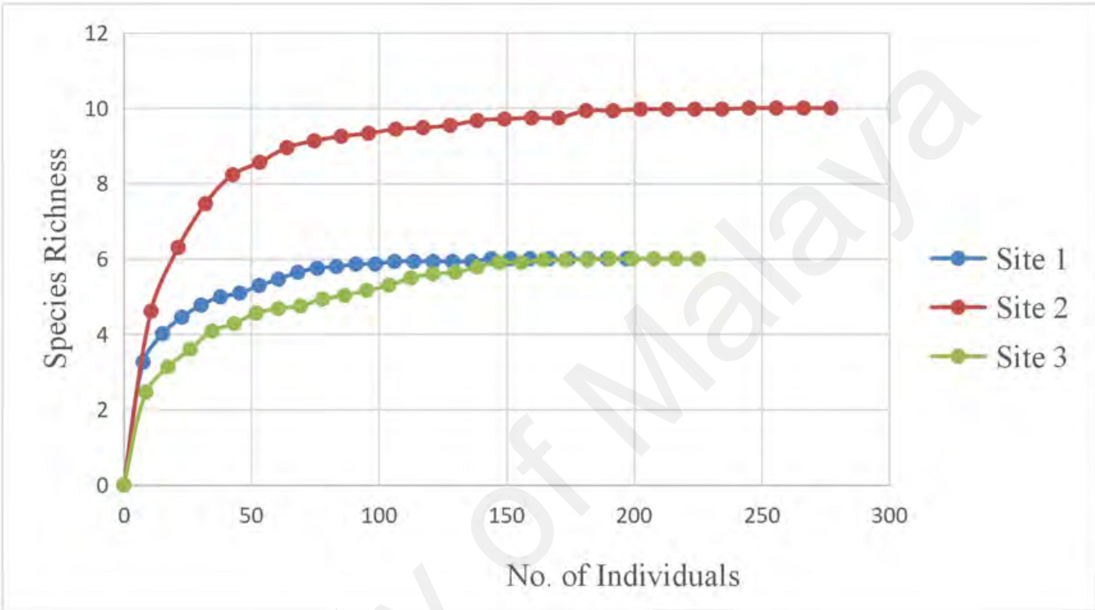

Figure 4.32: Species accumulation curves (Mao Tau function) for all three sites

Table 4.5 below shows the predicted species richness of all three sites by Jackknife1 and ACE as estimators which were also calculated by using EstimateS Win 9.10. Jackknife1 and ACE prediction of species richness for Site 2 is the highest, 10.33 and 6.11 respectively followed by Site 1, 6.09 and 6.11 respectively, and lastly for Site 3, 6.03 and 5.88 respectively. Based on the species richness predicted, the sampling effort in Site 1 was 98.5% (6 out of 6.09 species collected), 96.8% in Site 2 (10 out of 10.33 species collected) and 99.5% in Site 3 (6 out of 6.03 species collected).

Table 4.5: Jackknife1 and ACE prediction of species richness for all sites

Sites	Jackknife1	ACE
Site 1	6.09	6.11
Site 2	10.33	9.82
Site 3	6.03	5.88

Figure 4.33 below shows the dendrograms plotted through the hierarchical cluster analysis. These dendrograms show the linkage between sites based on the adult odonates assemblages and environmental variables respectively. The dendrogram of study sites linkage based on the adult odonates assemblages shows that Site 1 and Site 2 are more similar compared to Site 3 while the dendrogram based on environmental variables shows that Site 2 and Site 3 are more similar compared to Site 1.

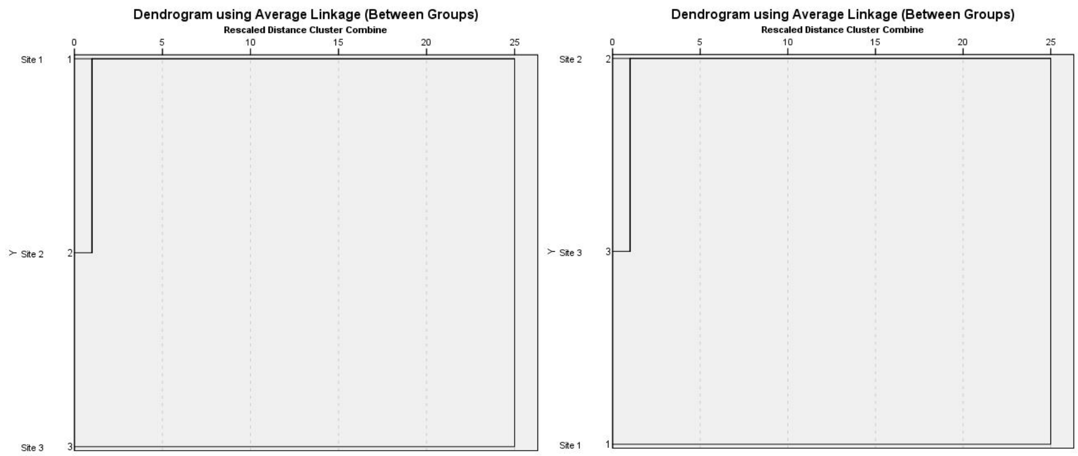

Figure4.33: Dendrograms of study sites linkage based on adult odonates assemblages (left) and environmental variables (right)

Figure 4.34 below shows the Canonical Correspondence Analysis (CCA) ordination diagram. The diagram shows that both *Prodasineura laidlawii* and *Rhynocypha perforata* were closely related to three water parameters which are total suspended solid (TSS), conductivity and ammoniacal nitrogen. *Zygonyx iris* on the other hand closely related to Biochemical Oxygen Demand (BOD) and temperature while *Devadatta argyoides* and *Vestalis amethystina* were close to pH. *Euphae ochracea* seems to be closely related to both dissolved oxygen (DO) and discharge while the distance between pH, discharge and DO towards *Rhynocypha fenestrella* were almost the same. *Echo modesta, Neurobasis chinensis, Orthetrum glaucum* and *Trithemis festiva* hardly related to any of the water parameters. Table 4.6 below shows the correlation coefficient of Axis 1 and Axis 2 for every variables.

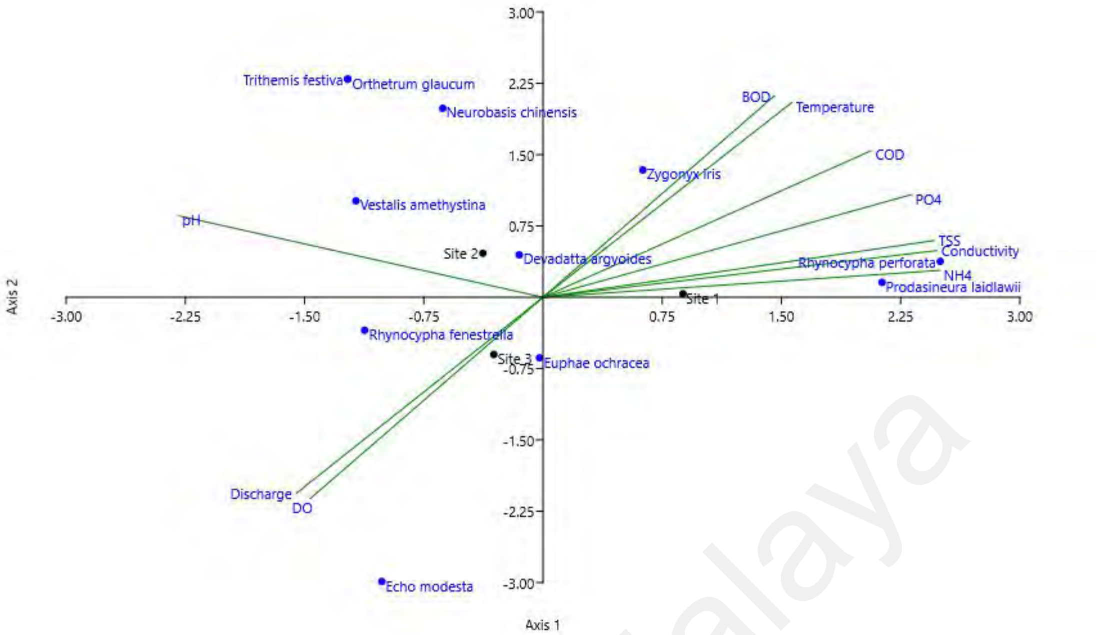

Figure 4.34: Canonical Correspondence Analysis (CCA) ordination diagram with adult odonates, environmental variables (water quality status and hydraulic characteristic) and sampling sites

Table 4.6: Correlation coefficient of Axis 1 and 2 for every variables

Variables		Correlation coefficient	
		Axis 1	Axis 2
Parameters	Dissolved Oxygen	-0.585704	-0.846753
	Biochemical Oxygen Demand	0.582948	0.848555
	Chemical Oxygen Demand	0.825496	0.616681
	pH	-0.915411	0.342395
	Phosphate	0.927882	0.43218
	Ammoniacal nitrogen	0.998818	0.113192
	Temperature	0.625666	0.81897
	Total suspended solid	0.238711	0.238711
	Conductivity	0.99117	0.196503
	Discharge	-0.619778	-0.823266
Odonates	*Neurobasis chinensis*	-0.630854	1.98681
	Euphae ochracea	-0.0221715	-0.636413
	Zygonyx iris	0.627977	1.33944
	Rhynocypha fenestrella	-1.12152	-0.346788
	Rhynocypha perforata	2.49886	0.377305
	Vestalis amethystina	-1.17681	1.01379
	Devadatta argyoides	-0.150061	0.446591
	Prodasineura laidlawii	2.13323	0.157033
	Echo modesta	-1.0142	-2.98792
	Trithemis festiva	-1.22884	2.29434
	Orthetrum glaucum	-1.22884	2.29434

Figure 4.35 below shows the Non-metric multidimensional scaling (nMDS) ordination diagram. From the diagram, it is obvious that dissolved oxygen (DO) and discharge increase towards Site 3 while all other parameters decrease in Site 3 except for pH. As for Site 1 all the parameters increase towards Site 1 except for pH, DO and discharge while pH is the only parameter that slightly increase towards Site 2. Table 4.7 below shows the correlation coefficient for every parameter.

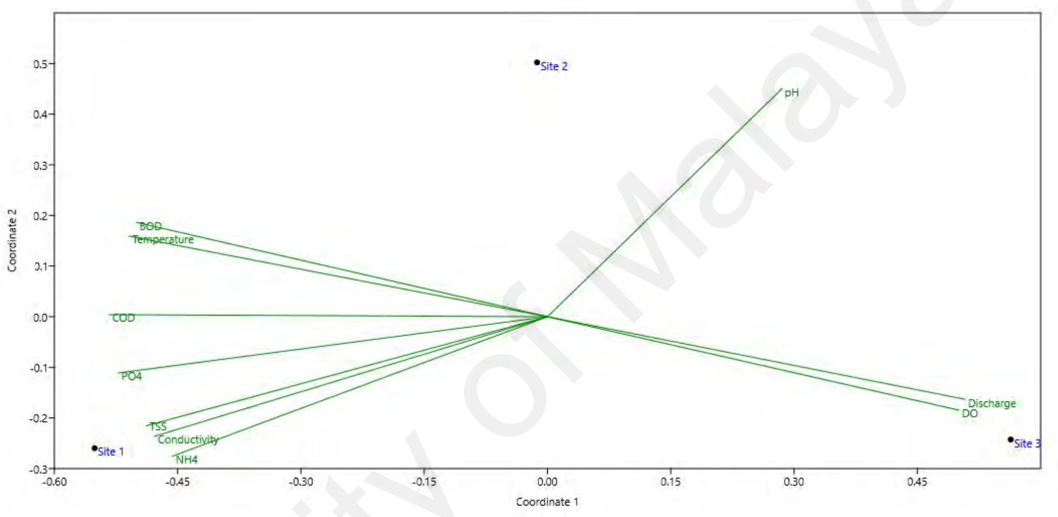

Figure 4.35: Non-metric multidimensional scaling (nMDS) ordination diagram

Table 4.7: Correlation coefficient of Axis 1 and Axis 2 for each parameter

Parameters	Correlation coefficient	
	Axis 1	Axis 2
Dissolved Oxygen	0.93828	-0.34588
Biochemical Oxygen Demand	-0.9371	0.34906
Chemical Oxygen Demand	-0.99997	0.0078394
pH	0.53512	0.84478
Phosphate	-0.97808	-0.20824
Ammoniacal nitrogen	0.85604	-0.51692
Temperature	-0.95447	0.29832
Total suspended solid	-0.91486	-0.40378
Conductivity	-0.89654	-0.44295
Discharge	0.95219	-0.3055

CHAPTER 5: DISCUSSIONS

Throughout the sampling period, there were six families found in both Site 1 and Site 2 with six species and ten species respectively while there were only five families found in Site 3 with only six species. These can be supported by the biodiversity indices calculated above which shows Site 2 > Site 1 > Site 3 in terms of diversity. On the other hand, the WQI calculated shows that the value of Site 3, located upstream, was the highest, Site 3 > Site 2 > Site 1. According to Cowell *et al.* (2003) the upper stream should be less polluted than the lower stream. There were a numbers of findings which could support the reasons why Site 3 which was the most unpolluted but having the lowest diversity while Site 2 which was slightly polluted compared to Site 3 but having the highest diversity. This was consistent with findings by Pushparaj Karthika and Natraj Krishnaveni (2014), who found that there were less distribution of odonates at the less polluted site due to the absent of vegetation around the sampling site. According to Chandana *et al.* (2012), the lack of habitat heterogeneity, flow rate and the openness of an area affected the diversity of odonates. These supported the reason why Site 2 and Site 1 were more diverse than Site 3 which lacked habitat heterogeneity, with highest flow rate and was much more covered with trees.

Based on the T-test analyzed, there were 6 species (*Euphaea ochracea, Zygonyx iris, Rhinocypha fenestrella, Rhinocypha perforata, Prodasineura laidlawii* and *Echo modesta*) that were significantly more abundant during the evening session compared to the morning session. During the period of this study, there were no studies about this were encountered. However, similar studies that required sampling of the odonates usually were done during warm sunny days. Chandana *et al.* (2012) stated that the sampling period for their studies were done between 9 a.m. until 4 p.m. Norma-Rashid *et al.* (2001) also stated that their sampling were done between 10 a.m. until 6 p.m. This is because the adult odonates activity increased proportionally to the increase of light intensity (Lutz *et al.,* 1969). According to Ngiam (2011), odonates require the heat of the sun to warm up before their daily activities as they are ectotherms or cold bloded. This is the reason why they were less abundant during the morning session as they have to warm up first.

The Evenness index showed that Site 2 was the most evenly distributed in terms of the odonate species in the order of Site 2 > Site 1 > Site 3, while the Simpson's Index which shows the dominance was reasonably in the opposite order of Site 3 > Site 1 > Site 2. The dominant species of all the three sites was *Euphaea ochracea* as the species was most abundant in all three sites. *Euphaea ochracea* were negatively related to temperature, conductivity and COD while they were positively related to discharge. Although they were negatively related to three water quality statuses, they were still the most abundant. This result is supported by Subramaniam (2010) that stated that they were a widespread species and not known to be facing any major threats as it belonged to the category of Least Concern. However , during the month of February, there were no *Euphaea ochracea* recorded at all. During that period, the temperature recorded was the highest as well and according to the rainfall readings from Malaysian Meteorological Department, the amount of rainfall and numbers of raindays were the lowest during February. This is also supported by Subramaniam (2005) that stated that Zygoptera prefer shaded places compared to Anisoptera as shaded places have lower temperature. This also explains why the number of *Euphaea ochracea* was the highest in Site 3 among all three sites as Site 3 was relatively more shaded. The is also a possibility where *Euphaea ochracea* were so abundant due to their positive relationship with the discharge. Their capability of thriving in high discharge area could help them to disperse their eggs covering much bigger area. A blog post by Dennis Farrell stated that a female was seen to submerge itself into fast-flowing river and oviposited for around 25 seconds. This can be supported by Reels and Dow (2006) who stated that submerged oviposition could be the common behavior for the members of Euphaeidae.

Neurobasis chinensis and *Vestalis amethystina* seems to share a very special relationship and they were both in the same family, Calopterygidae. *Neurobasis chinensis* were recorded at the lower stream which was Site 1 while *Vestalis amethystina* were recorded at the upper stream which was Site 3 where both overlap in the middle stream at Site 2. Okuyama *et al.* (2013) explained that it was habitat segregation which was also seen in the *Mnais* damselflies which could be due to the adaptation to reduce interspecific reproduction, resource partitioning or due to heterogeneous insolation within a forest. According to Dow (2009a), *Neurobasis chinensis* were capable of thriving in disturbed or secondary habitats and agricultural land, this explained their abundance in Site 2 where there were aboriginal settlement with a number of agricultural activities around the area. While the Pearson Correlation proved that there were no significant relationship between *Neurobasis chinensis* with any of the water quality statuses and hydraulic characteristic. Their numbers were quite low in Site 1 which could be due to the reason that the water of Site 1 was not as clear as Site 2 as according to Orr (2005), they preferred clear, swift streams as well. Although they were said to be able to survive in slightly disturbed area and also agricultural land, they could be facing some unknown threat. According to Lok (2008) and Norma-Rashid *et al.* (2008), they were last seen during 1962 in Singapore and were never been collected again since then. In other word, this species could also serve as a good indicator but further study have to be done to determine what could cause the disappearance of this species. The Pearson Correlation analyzed proved that *Vestalis amethystina* were having significant negative relationship with conductivity and they seems to prefer the upper stream which was Site 3 and Site 2 but in a very low abundance. According to Orr (2003) and Lok (2008), *Vestalis amethystina* favored clear forest stream with good water quality, as with Site 3 which have the best water quality of all three sites and lowest conductivity.

Rhinocypha perforata and *Rhinocypha fenestrella* too possibly shared the special relationship that were described as habitat segregation by Okuyama *et al.* (2013). In fact, the possibility of them sharing this relationship was much more higher than *Neurobasis chinensis* and *Vestalis amethystina* because the *Rhinocypha* damselflies were much more closely related and the females were very difficult to be differentiated among the members of the same genus which is why habitat segregation was needed to reduce interspecific reproduction. According to Wilson (2009), *Rhinocypha perforata* selected streams and rivers in low hills and mountains which showed why they were recorded in Site 1 which was the lower stream while Sharma (2010a) stated that *Rhinocypha fenestrella* prefers rocky forest streams which described that of Site 3. Orr (2005) stated that *Rhinocypha perforata* mostly found in exposed areas which best describes Site 1 and Site 2 while *Rhinocypha fenestrella* prefer clear, swift streams which best describes Site 2 and Site 3. This supports the outcome of the Pearson Correlation which shows that *Rhinocypha perforata* were positively related to temperature as exposed areas have higher temperature. That statement by Orr (2005) also supports the outcome of Pearson Correlation that shows *Rhinocypha fenestrella* negatively related to conductivity as conductivity is determined by the nutrient status of the water (Ahmed Said *et al.,* 2004; Rahul Shivaji Patil *et al.,* 2015). The lower the nutrient level, the lower the conductivity and the lower the nutrient, the higher possibility that the water will be clearer. Indirectly, clear streams or rivers mean having low conductivity which describes Site 2 and Site 3 that having lower conductivity and clearer water compared to Site 1.

Echo modesta was the only species that were only recorded in Site 3 but in a very low numbers. According to the Pearson Correlation analyzed, they were negatively related to temperature and conductivity and positively related to discharge. This might explain why they can only be seen in Site 3 which has the highest discharge and lowest temperature and conductivity compared to the other two sites. According to Dow (2011b), *Echo modesta* usually can be found around small rocky forest stream in hilly or mountainous area which best described Site 3. Dow (2011b) also stated that this species could be threatened by deforestation which might also explained that why it was not found in Site 1 and Site 2 which were more disturbed with human activities. On the other hand, Orr (2005) stated that *Echo modesta* usually perched above water in deep shade on clear, forest streams which support the result of this work as they were usually found in their common shady spot in Site 3 which also has the lowest temperature and canopy covers and also having low conductivity. This was also proved by the Pearson Correlation analyzed that shows they were negatively related to temperature and conductivity as canopy covers contribute to low temperature and low conductivity contributes to clear streams. Morover, Norma-Rashid (2009) described *Echo modesta* as an elusive species that prefer specific environment such as streams with well shaded areas and high canopy cover. During sampling period, they were only seen to perch at the same particular area. In future work, measurement of canopy cover and riparian vegetation should be included in the study so that the preferences of each species of adult odonates on these parameters can be determined. Without doubt, *Echo modesta* can be a perfect indicator due to their specific preferences of habitat.

According to the Pearson Correlation analyzed, *Prodasineura laidlawii* were positively related to temperature and also conductivity and Dow (2011c) stated that they were capable of surviving in disturbed forest habitat which supports the finding of their high abundance in Site 1 while their density in Site 2 and Site 3 were much more lower. Due to their preferences of slightly polluted streams, monitoring their numbers could serve as an early warning if their sighting increased. During sampling period, they were seen to perch and copulate around the areas with not so clear water in Site 1 which were also high in conductivity. This is why they are also suitable to be used as an indicator. Although *Devadatta argyoides* were recorded in all three sites but in a very low density, they were proved to have no significant relationship with any of the parameters from the Pearson Correlation analyzed. This result is supported by Dow (2011a) and Orr (2005) who stated that their habitat were usually small forest streams including those in disturbed forest and also by Norma-Rashid (2009) who stated that they were common in rivers with rocks and boulders which describes the characteristics of all three sites.

Zygonyx iris, Orthetrum glaucum and *Trithemis festiva* were the only members from the suborder Anisoptera recorded. The Pearson Correlation analyzed shows that *Zygonyx iris* were positively related to temperature and negatively related to discharge. According to Orr (2005) and Sharma (2010), *Zygonyx iris* were capable of breeding in swift rocky streams including those in open areas and agricultural lands. This could be the reason why they were recorded only in Site 1 and Site 2 which were both open areas with less canopy covers which indicate higher temperature. Moreover, there were agricultural activities in Site 2 as well. Nair (2011) also stated that they were good indicators for pure fast flowing rivers and general habitat quality. These were also contradicting from the result that shows that they were negatively related to discharge where they were supposed to be capable of breeding in swift or fast flowing rivers such as Site 3. The only explanation is that the canopy cover of Site 3 limits their capability as they prefer higher temperature to warm up since they were having relatively bigger body size. Based on the Pearson Correlation, both *Orthetrum glaucum* and *Trithemis festiva* have no significant relationship with any of the parameters. Dow (2009b), Nair (2011) and Orr (2005) reported that *Orthetrum glaucum* were usually common in ponds ditches and other lenthic habitat in open areas. The only explanation of their occurrence would be the heterogeneous habitat where there were some small part of the river around Site 2 that were isolated due to the blockage of a few boulders that make them more lenthic or slow moving and also the openness of Site 2. The rate of occurrence and also the abundance of *Trithemis festiva* were almost the same to that of *Orthetrum glaucum.* Dow (2009c) and Nair (2011) stated that they can be found near all types of flowing waters but Orr (2005) found them in larger streams in open area with swift, clear water which supported the results obtained where they were recorded in Site 2 with open area and clear water.

CHAPTER 6: CONCLUSION

In conclusion, out of the three objectives of this study, two of them had been achieved while the last objective was not fully achieved. Although the relationship between the adult odonates with the water quality status and hydraulic characteristic had been determined, but the model was not built.

The adult odonates community of all the three sites had been studied. A total of 11 species from 6 families of adult odonates had been sampled and identified during the sampling period in all three sampling sites. The biodiversity indices calculated shows that Site 2 was the most diverse and also evenly distributed, with the total of 6 families and 10 species followed by Site 1, with the total of 6 families and 6 species and the Site 3, with the total of 5 families with 6 species, with *Euphae ochracea* as the dominant species of all three sites. The numbers of Zygoptera were higher than Anisoptera which were absence in Site 3. On the other hand, *Echo modesta* which were considered as elusive species occurred only in Site 3.

The status of water quality of all three sampling sites had been determined as well. From the calculated WQI, Site 3 had the highest WQI value which indicates that Site 3 was the cleanest site of all three sites followed by Site 2 and the Site 1. Most of the time, the WQI of all three sites indicate that they were in Class II which was suitable for recreational use with body contact. However, there were a few months where Site 3 was in the category of Class I which was suitable for water supply and Site 1 was in the category of Class III which was suitable for fishery. The BOD, DO and pH values obtained from all three sites shows no significant differences while there were significant differences between the temperature, TSS, conductivity and COD of all the three sampling sites. On the other hand, there were significant differences in the amoniacal nitrogen and phosphate level between Site 1 and Site 3 only.

The hydraulic characteristic that were determined shows that the discharge of Site 3 were the highest which were also significantly different from the discharge of Site 1 and Site 2. Although the discharge of Site 2 were higher than Site 1, there were no significant difference between the value of the two sites.

The relationship between the status of water quality and hydraulic characteristic to the target adult odonates had been determined as well. Each species shows different preferences in the status of water quality and hydraulic characteristic. *Neurobasis chinensis*, *Devadatta argyoides*, *Trithemis festiva* and *Orthetrum glaucum* have no significant relationship with any of the parameters. Although *Euphae ochracea* were the most abundant, they were significantly related to four of the parameters. They fact that they were positively related to discharge and their oviposition behavior helps them to strive in fast flowing rivers is amazing. *Echo modesta* were the only species that were spotted only in Site 3 which was a shaded area with canopy cover, low temperature and also higher in discharge. They were usually spotted perching at the same area. In contrast, the Anisptera which consist of *Zygonyx iris, Orthetrum glaucum* and *Trithemis festiva* prefer the more open area. *Prodasinuera laidlawii* occurred in all three sites as well. However, they were more abundant in Site 1 which had the highest conductivity. They prefers slightly polluted environment with not so clear water. On the other hand, *Rhinocypha perforata* and *Rhinocypha fenestrella* could share a relationship described as habitat segregation. Both were present in Site 2 but only *Rhinocypha perforata* were sampled in Site 1 and *Rhinocypha fenestrella* in Site 3. *Neurobasis chinensis* were described to be capable of surviving in disturbed or agricultural area which support the result that they were sampled in both Site 1 and Site 2, while *Vestalis amethystina* prefers good water quality where they were more abundant in Site 3.

Unfortunately, the ecohydraulic model for Sungai Gombak was unable to be developed due to the lack of other factors although the relationships between the adult odonates with the water quality status and hydraulic characteristic were established. Factors such as riparian vegetation and canopy cover should be considered in future studies. Besides that, the behavior of the adult odonates helps in the understanding of how they could survive in the habitat of their preferences as we had seen how the female *Euphaea ochracea* could submerge itself into fast flowing river for oviposition which could be the reason why they prefer high discharge river. Another important factor is the interaction between the adult odonates. According to Lancaster and Downes (2010), the study of ecohydraulic often ignore the interaction between the organisms which is one of the weaknesses of ecohydraulic. For example, the relationships between the adult odonates with the water quality status and hydraulic characteristic had been established but are there any relationships between the different species of the odonates? If yes, did these relationships affect the relationships between them with the water quality status and hydraulic characteristic? In conclusion, it is much more complicated to build a reliable model. This shows how important the study of ecology and also biodiversity that most people overlooked.

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APPENDIX

Appendix A

RIVER CLASSIFICATION

a) Class Based (DOE Water Quality Index Classification)

PARAMETER	UNIT	CLASS I	II	III	IV	V
Biochemical Oxygen Demand	mg/l	< 1	1 - 3	3 - 6	6 - 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 - 25	25 - 50	50 - 100	> 100
Ammonical Nitrogen	mg/l	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Disolved Oxygen	mg/l	> 7	5 - 7	3 - 5	1 - 3	< 1
pH		> 7	6 - 7	5 - 6	< 5	< 5
Total Suspended Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI		>92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	<31.0

b) Pollution Status Based (DOE Water Quality Classification Based On WQI)

WQI	River Status
0-59	Polluted
60-80	Slightly Polluted
81-100	Clean

WATER QUALITY CLASSES & USES
(NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA)

Class 1	Conservation of natural environment, Water Supply I - practically no treatment necessary, Fishery I - very sensitive aquatic species.
Class IIA	Water supply II - conventional treatment required, Fishery II - sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water supply III - extensive treatment required, Fishery III - common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above

Appendix B

The following shows three tables represent three sites and the calculation of ecological indices of the three sites.

Site 1

Species	No.	P_i	P_i^2	$P_i \ln(P_i)$
Neurobasis chinensis	7	0.0348	0.0012	-0.1169
Euphaea ochracea	94	0.4677	0.2187	-0.3554
Zygonyx iris	24	0.1194	0.0143	-0.2538
Rhinocypha fenestrella	0	0	0	0
Rhinocypha perforata	40	0.199	0.0396	-0.3213
Rhinocypha sp.	3	0.0149	0.0002	-0.0627
Vestalis amethystina	0	0	0	0
Devadatta argyoides	2	0.01	0.0001	-0.0461
Prodasineura laidlawii	31	0.1542	0.0238	-0.2883
Echo modesta	0	0	0	0
Trithemis festiva	0	0	0	0
Orthetrum glaucum	0	0	0	0
Total	201	1	0.2979	-1.4445

a) Shannon-Wiener Index, H = 1.4445

b) Eveness, E = 1.4445/ln(7) = 0.7423

c) Simpson's Index, D = 0.2979

   i. Simpson's Index of Diversity, 1-D = 1-0.2979 = 0.7021

   ii. Simpson's Reciprocal Index, 1/D = 1/0.2979 = 3.3568

Site 2

Species	No.	P_i	P_i^2	$P_i ln(P_i)$
Neurobasis chinensis	41	0.1429	0.02	-0.278
Euphaea ochracea	98	0.3415	0.1166	-0.3669
Zygonyx iris	29	0.101	0.0102	-0.2316
Rhinocypha fenestrella	47	0.1638	0.0268	-0.2963
Rhinocypha perforata	4	0.0139	0.0002	-0.0594
Rhinocypha sp.	10	0.0348	0.0012	-0.1169
Vestalis amethystina	25	0.0871	0.0076	-0.2126
Devadatta argyoides	4	0.0139	0.0002	-0.0594
Prodasineura laidlawii	4	0.0139	0.0002	-0.0594
Echo modesta	0	0	0	0
Trithemis festiva	14	0.0488	0.0024	-0.1474
Orthetrum glaucum	11	0.0383	0.0015	-0.1249
Total	287	0.9999	0.1869	-1.9528

a) Shannon-Wiener Index, H = 1.9528

b) Eveness, E = 1.9528/ln(11) = 0.8144

c) Simpson's Index, D = 0.1869

   i. Simpson's Index of Diversity, 1-D = 1-0.1869 = 0.8131

   ii. Simpson's Reciprocal Index, 1/D = 1/0.1869 = 5.3505

Site 3

Species	No.	P_i	P_i^2	$P_i \ln(P_i)$
Neurobasis chinensis	0	0	0	0
Euphaea ochracea	155	0.6568	0.4314	-0.2761
Zygonyx iris	0	0	0	0
Rhinocypha fenestrella	47	0.1992	0.0398	-0.3214
Rhinocypha perforata	0	0	0	0
Rhinocypha sp.	11	0.0466	0.0022	-0.1429
Vestalis amethystina	8	0.0339	0.0011	-0.1147
Devadatta argyoides	2	0.0085	0.00007	-0.0405
Prodasineura laidlawii	3	0.0127	0.0002	-0.0555
Echo modesta	10	0.0424	0.0018	-0.134
Trithemis festiva	0	0	0	0
Orthetrum glaucum	0	0	0	0
Total	236	1.0001	0.47657	-1.0851

a) Shannon-Wiener Index, H = 1.0851

b) Eveness, E = 1.0851/ln(7) = 0.5576

c) Simpson's Index, D = 0.47657

i. Simpson's Index of Diversity, 1-D = 1-0.47657 = 0.52343

ii. Simpson's Reciprocal Index, 1/D = 1/0.47567 = 2.0983

Appendix C

JABATAN METEOROLOGI MALAYSIA

Records of Daily Rainfall Amount (08:00 - 08:00 MST)

Station:	JAKOA GOMBAK	**Unit:**	millimetre
Latitude:	3° 17' N	**Year:**	2013
Longitude:	101° 44' E		
Elevation:	108.9 m		

Date	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.0	2.4	0.0	8.0	0.4	0.0	27.8	0.2	40.8	0.0	0.0	4.0
2	0.0	0.2	17.0	0.2	30.0	1.2	1.8	0.0	1.2	0.0	17.4	33.6
3	29.2	2.2	0.0	1.2	40.6	0.0	0.8	0.0	18.4	0.0	43.2	2.2
4	12.6	2.0	0.0	0.0	7.6	0.8	42.0	0.0	0.4	0.0	2.4	0.2
5	0.6	0.0	0.0	0.0	17.0	19.4	0.4	0.0	40.4	0.0	4.6	6.0
6	0.0	28.4	0.0	1.6	22.2	4.0	8.6	0.0	0.0	0.0	0.4	41.2
7	0.0	2.4	0.0	3.6	11.0	36.0	0.0	0.0	12.2	0.0	6.2	4.6
8	0.0	89.2	0.4	0.0	13.8	0.0	5.4	3.2	8.0	0.2	3.4	0.0
9	0.8	0.0	8.4	13.8	0.0	6.0	0.0	0.0	23.0	4.2	9.4	2.4
10	0.0	0.0	2.4	32.0	0.0	0.0	1.0	1.2	0.0	1.4	31.2	2.2
11	1.6	0.0	1.2	0.4	0.0	0.0	0.0	2.2	31.4	0.0	18.8	0.0
12	0.0	8.6	0.2	0.4	0.0	0.0	5.6	4.8	0.0	7.2	0.0	3.8
13	1.0	0.4	18.2	5.2	0.0	0.0	7.2	0.0	33.8	0.0	24.8	0.0
14	10.8	5.0	0.0	0.4	1.2	0.0	0.0	0.0	24.0	6.6	24.8	0.0
15	0.0	0.2	0.0	0.0	32.6	0.0	0.0	0.0	0.0	0.0	2.2	0.0
16	0.0	0.0	6.6	0.0	0.0	0.2	5.0	0.6	0.0	0.0	7.8	0.0
17	0.0	0.0	0.0	4.0	67.4	0.0	14.4	0.0	0.0	11.2	8.6	0.0
18	0.0	15.8	0.0	0.0	0.6	0.0	1.6	0.8	0.0	33.2	1.4	0.8
19	0.2	3.4	0.0	6.4	0.2	0.0	0.0	17.2	0.0	20.6	23.8	0.0
20	0.0	0.2	7.4	0.0	0.0	0.0	0.0	0.0	0.0	15.6	0.8	13.0
21	0.6	9.8	0.0	8.4	0.0	0.0	0.0	14.8	0.0	0.6	0.0	4.6
22	0.0	0.0	5.6	34.4	0.0	0.0	0.0	29.8	0.0	11.0	0.0	0.0
23	3.2	0.6	0.0	29.2	0.2	0.0	0.0	0.8	0.0	24.8	0.0	0.0
24	6.2	8.6	5.8	28.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	5.2
25	7.0	59.2	6.0	0.8	0.4	1.0	4.6	0.4	0.0	8.6	2.4	0.0
26	0.0	19.4	6.4	1.0	0.6	1.0	3.6	0.0	4.8	0.4	2.6	0.6
27	0.0	11.8	0.0	0.0	24.0	1.6	0.0	0.0	18.6	4.6	2.4	0.0

28	0.0	0.2	59.8	7.4	7.2	0.0	0.0	26.2	0.0	15.6	6.8	0.0
29	0.0		2.2	10.6	0.4	0.0	0.0	2.0	21.4	0.2	0.8	0.0
30	0.0		5.2	1.2	9.0	0.0	0.0	8.2	0.0	0.4	0.0	0.0
31	0.0		0.0		0.6		0.0	4.6		5.0		0.0
Total	**73.8**	**270.0**	**152.8**	**198.4**	**287.4**	**71.2**	**129.8**	**117.0**	**278.4**	**171.4**	**246.2**	**124.4**
No. of Raindays	**12**	**21**	**16**	**22**	**22**	**10**	**15**	**16**	**14**	**19**	**23**	**15**

JABATAN METEOROLOGI MALAYSIA

Records of Daily Rainfall Amount (08:00 - 08:00 MST)

Station: JAKOA GOMBAK

Unit: millimetre

Latitude: 3° 17' N

Year: 2014

Longitude: 101° 44' E

Elevation: 108.9 m

Date	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.0	0.0	0.0	0.2	0.0	13.6	22.4	0.0	0.0	43.2	19.2	1.0
2	0.0	0.0	0.0	1.8	0.4	44.0	0.8	0.2	8.4	1.4	0.0	0.2
3	22.8	0.0	0.0	12.6	0.4	0.2	19.0	3.8	0.0	Def.	0.0	0.8
4	18.4	0.0	0.0	0.4	0.0	33.0	5.8	0.0	0.8	48.2	0.2	1.0
5	4.8	0.0	0.0	12.0	2.4	6.4	0.0	0.0	1.2	0.0	5.0	1.6
6	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.4	0.0	21.6	1.2
7	0.8	0.0	0.0	0.0	2.2	0.0	1.0	8.0	0.0	0.0	28.0	3.8
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	5.2
9	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.0	0.0	3.2	10.0
10	8.8	0.0	0.0	0.0	45.4	0.0	0.0	2.0	0.0	0.0	10.6	8.8
11	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.2	23.4	0.2	1.0	0.8
12	0.0	0.6	0.0	0.0	34.8	0.0	0.0	4.2	6.2	10.0	8.8	0.0
13	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.6	7.0	0.0	19.8	0.0
14	0.0	0.0	0.0	4.6	4.0	0.0	0.0	41.0	0.8	36.4	3.8	0.2
15	0.0	0.0	15.4	9.6	0.4	0.0	0.0	0.0	1.6	6.6	4.4	0.0
16	0.0	0.0	13.6	0.8	3.6	0.0	0.0	62.2	0.2	0.0	0.8	0.8
17	0.0	0.0	8.6	0.8	12.8	0.0	4.6	0.0	0.0	0.4	0.0	0.0
18	0.0	0.0	1.2	0.0	2.8	0.0	0.0	13.8	13.6	4.4	0.0	0.0
19	0.0	50.2	0.0	1.0	40.6	0.0	0.0	2.2	22.2	28.4	0.0	0.0
20	0.0	0.0	1.2	0.6	25.0	0.0	0.0	0.8	11.8	37.8	0.0	0.6
21	0.0	0.0	4.6	0.2	4.2	0.0	0.0	0.6	0.2	10.4	28.6	0.8
22	0.0	0.0	0.0	1.8	1.6	0.0	6.8	1.8	0.0	26.8	25.4	19.4
23	0.0	0.0	0.0	0.0	0.2	0.0	2.0	0.2	6.0	0.2	10.6	9.0
24	0.0	0.0	0.0	0.4	2.2	0.0	0.4	6.8	26.6	0.4	3.6	0.4
25	0.0	0.0	4.0	0.0	8.8	0.0	0.0	15.0	28.4	0.4	3.8	25.2
26	0.0	0.0	0.0	0.4	7.6	9.0	0.0	5.4	0.6	4.6	49.0	25.4
27	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0	1.6	7.0	14.8	9.2
28	0.0	0.0	2.2	1.4	10.8	0.0	0.0	0.2	0.0	14.4	3.2	7.6
29	0.0		25.8	2.4	41.0	0.0	32.0	0.0	2.8	2.4	8.2	13.8

30	0.0		0.0	0.0	3.2	0.0	38.0	15.8	7.6	11.8	1.2	0.0
31	0.0		0.0		3.4		0.2	1.0		36.2		0.0
Total	**81.8**	**50.8**	**76.6**	**52.6**	**257.8**	**109.2**	**133.0**	**186.6**	**193.4**	**Def.**	**276.2**	**146.8**
No. of Raindays	**7**	**2**	**9**	**19**	**23**	**8**	**12**	**22**	**22**	**Def.**	**24**	**23**

JABATAN METEOROLOGI MALAYSIA

Appendix D

Independent T-test to test the significant differences between the number of individual during the morning and evening sessions.

Neurobasis chinensis

	Session	N	Mean	Std. Deviation	Std. Error Mean
N.Chinensis	am	26	.65	1.294	.254
	pm	26	1.19	1.812	.355

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
N.Chinensis	Equal variances assumed	1.331	.254	-1.233	50
	Equal variances not assumed			-1.233	45.249

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
N.Chinensis	Equal variances assumed	.223	-.538	.437
	Equal variances not assumed	.224	-.538	.437

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
N.Chinensis	Equal variances assumed	-1.415	.339
	Equal variances not assumed	-1.418	.341

Euphaea ochracea

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
E.ochracea	am	39	3.8462	2.18293	.34955
	pm	39	5.0513	2.41649	.38695

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
E.ochracea	Equal variances assumed	.075	.786	-2.311	76
	Equal variances not assumed			-2.311	75.228

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
E.ochracea	Equal variances assumed	.024	-1.20513	.52145
	Equal variances not assumed	.024	-1.20513	.52145

Independent Samples Test

		t-test for Equality of Means: 95% Confidence Interval of the Difference	
		Lower	Upper
E.ochracea	Equal variances assumed	-2.24369	-.16657
	Equal variances not assumed	-2.24386	-.16639

Zygonyx iris

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
Z.Iris	am	26	.4231	.80861	.15858
	pm	26	1.6154	1.29852	.25466

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Z.Iris	Equal variances assumed	11.616	.001	-3.974	50
	Equal variances not assumed			-3.974	41.854

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower
Z.Iris	Equal variances assumed	.000	-1.19231	.30000	-1.79488
	Equal variances not assumed	.000	-1.19231	.30000	-1.79779

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference Upper
Z.Iris	Equal variances assumed	-.58974
	Equal variances not assumed	-.58682

Rhinocypha fenestrella

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
R.Fenestrella	am	26	.7308	1.00231	.19657
	pm	26	3.0000	2.43311	.47717

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
R.Fenestrella	Equal variances assumed	8.292	.006	-4.397	50
	Equal variances not assumed			-4.397	33.247

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
R.Fenestrella	Equal variances assumed	.000	-2.26923	.51607
	Equal variances not assumed	.000	-2.26923	.51607

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
R.Fenestrella	Equal variances assumed	-3.30579	-1.23267
	Equal variances not assumed	-3.31889	-1.21957

Rhinocypha perforata

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
R.Perforata	am	26	.4231	.70274	.13782
	pm	26	1.2692	1.31325	.25755

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
R.Perforata	Equal variances assumed	15.834	.000	-2.897	50
	Equal variances not assumed			-2.897	38.233

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
R.Perforata	Equal variances assumed	.006	-.84615	.29211
	Equal variances not assumed	.006	-.84615	.29211

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
R.Perforata	Equal variances assumed	-1.43286	-.25944
	Equal variances not assumed	-1.43737	-.25494

Vestalis amethystina

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
V.amethystina	am	26	.5385	1.02882	.20177
	pm	26	.7308	1.07917	.21164

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
V.amethystina	Equal variances assumed	.445	.508	-.658	50
	Equal variances not assumed			-.658	49.886

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
V.amethystina	Equal variances assumed	.514	-.19231	.29241
	Equal variances not assumed	.514	-.19231	.29241

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
V.amethystina	Equal variances assumed	-.77963	.39501
	Equal variances not assumed	-.77966	.39505

Devadatta argyoides

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
D.argyoides	am	39	.0513	.22346	.03578
	pm	39	.1538	.53991	.08645

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
D.argyoides	Equal variances assumed	4.921	.030	-1.096	76
	Equal variances not assumed			-1.096	50.647

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
D.argyoides	Equal variances assumed	.276	-.10256	.09357
	Equal variances not assumed	.278	-.10256	.09357

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
D.argyoides	Equal variances assumed	-.28892	.08379
	Equal variances not assumed	-.29044	.08531

Prodasineura laidlawii

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
P.laidlawii	am	39	.1795	.50637	.08108
	pm	39	.8205	1.23271	.19739

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
P.laidlawii	Equal variances assumed	23.415	.000	-3.004	76
	Equal variances not assumed			-3.004	50.469

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower
P.laidlawii	Equal variances assumed	.004	-.64103	.21340	-1.06604
	Equal variances not assumed	.004	-.64103	.21340	-1.06955

Independent Samples Test

		t-test for Equality of Means 95% Confidence Interval of the Difference
		Upper
P.laidlawii	Equal variances assumed	-.21601
	Equal variances not assumed	-.21251

Echo modesta

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
E.modesta	am	13	.0000	.00000	.00000
	pm	13	.7692	.59914	.16617

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
E.modesta	Equal variances assumed	25.065	.000	-4.629	24
	Equal variances not assumed			-4.629	12.000

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
E.modesta	Equal variances assumed	.000	-.76923	.16617	-1.11219
	Equal variances not assumed	.001	-.76923	.16617	-1.13129

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
E.modesta	Equal variances assumed	-.42627
	Equal variances not assumed	-.40717

Trithemis festiva

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
T.festiva	am	13	.3846	.76795	.21299
	pm	13	.6923	.85485	.23709

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
T.festiva	Equal variances assumed	.908	.350	-.965	24
	Equal variances not assumed			-.965	23.729

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
T.festiva	Equal variances assumed	.344	-.30769	.31871	-.96548
	Equal variances not assumed	.344	-.30769	.31871	-.96588

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
T.festiva	Equal variances assumed	.35010
	Equal variances not assumed	.35050

Orthetrum glaucum

Group Statistics

	Session	N	Mean	Std. Deviation	Std. Error Mean
O.glaucum	am	13	.3077	.63043	.17485
	pm	13	.5385	.77625	.21529

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
O.glaucum	Equal variances assumed	1.656	.210	-.832	24
	Equal variances not assumed			-.832	23.031

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
O.glaucum	Equal variances assumed	.414	-.23077	.27735	-.80319
	Equal variances not assumed	.414	-.23077	.27735	-.80447

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
O.glaucum	Equal variances assumed	.34165
	Equal variances not assumed	.34293

Appendix E

Kruskal-Wallis to test the significant differences of the parameters between sites.

Overall (BOD, DO, Temperature, pH, Conductivity, Phosphate and AN)

Ranks

	Site	N	Mean Rank
BOD	1	26	39.73
	2	26	41.87
	3	26	36.90
	Total	78	
DO	1	26	34.17
	2	26	38.37
	3	26	45.96
	Total	78	
Temperature	1	26	56.85
	2	26	46.73
	3	26	14.92
	Total	78	
pH	1	26	35.75
	2	26	42.88
	3	26	39.87
	Total	78	
Conductivity	1	26	65.50
	2	26	34.15
	3	26	18.85
	Total	78	
PO4	1	26	49.15
	2	26	37.77
	3	26	31.58
	Total	78	
NH4	1	26	48.33
	2	26	39.71
	3	26	30.46
	Total	78	

Test Statistics[a,b]

	BOD	DO	Temperature	pH	Conductivity	PO4	NH4
Chi-Square	.627	3.617	48.550	1.299	57.278	8.174	9.298
df	2	2	2	2	2	2	2
Asymp. Sig.	.731	.164	.000	.522	.000	.017	.010

Sites 1 & 2 (BOD, DO, Temperature, pH, Conductivity, Phosphate and AN)

Ranks

	Site	N	Mean Rank
BOD	1	26	25.69
	2	26	27.31
	Total	52	
DO	1	26	25.02
	2	26	27.98
	Total	52	
Temperature	1	26	31.08
	2	26	21.92
	Total	52	
pH	1	26	24.21
	2	26	28.79
	Total	52	
Conductivity	1	26	39.50
	2	26	13.50
	Total	52	
PO4	1	26	30.50
	2	26	22.50
	Total	52	
NH4	1	26	29.67
	2	26	23.33
	Total	52	

Test Statistics[a,b]

	BOD	DO	Temperature	pH	Conductivity	PO4	NH4
Chi-Square	.148	.497	4.759	1.186	38.267	3.669	2.522
df	1	1	1	1	1	1	1
Asymp. Sig.	.701	.481	.029	.276	.000	.055	.112

Sites 2 & 3 (BOD, DO, Temperature, pH, Conductivity, Phosphate and AN)

Ranks

	Site	N	Mean Rank
BOD	2	26	28.06
	3	26	24.94
	Total	52	
DO	2	26	23.88
	3	26	29.12
	Total	52	
Temperature	2	26	38.31
	3	26	14.69
	Total	52	
pH	2	26	27.60
	3	26	25.40
	Total	52	
Conductivity	2	26	34.15
	3	26	18.85
	Total	52	
PO4	2	26	28.77
	3	26	24.23
	Total	52	
NH4	2	26	29.88
	3	26	23.12
	Total	52	

Test Statistics[a,b]

	BOD	DO	Temperature	pH	Conductivity	PO4	NH4
Chi-Square	.550	1.550	31.646	.272	13.267	1.194	3.231
df	1	1	1	1	1	1	1
Asymp. Sig.	.458	.213	.000	.602	.000	.275	.072

Sites 1 & 3 (BOD, DO, Temperature, pH, Conductivity, Phosphate and AN)

Ranks

	Site	N	Mean Rank
BOD	1	26	27.54
	3	26	25.46
	Total	52	
DO	1	26	22.65
	3	26	30.35
	Total	52	
Temperature	1	26	39.27
	3	26	13.73
	Total	52	
pH	1	26	25.04
	3	26	27.96
	Total	52	
Conductivity	1	26	39.50
	3	26	13.50
	Total	52	
PO4	1	26	32.15
	3	26	20.85
	Total	52	
NH4	1	26	32.15
	3	26	20.85
	Total	52	

Test Statistics[a,b]

	BOD	DO	Temperature	pH	Conductivity	PO4	NH4
Chi-Square	.244	3.351	37.008	.484	38.266	7.347	8.191
df	1	1	1	1	1	1	1
Asymp. Sig.	.621	.067	.000	.487	.000	.007	.004

Overall (TSS and COD)

Ranks

	Site	N	Mean Rank
TSS	1	22	53.20
	2	22	30.30
	3	22	17.00
	Total	66	
COD	1	22	45.39
	2	22	34.55
	3	22	20.57
	Total	66	

Test Statistics[a,b]

	TSS	COD
Chi-Square	40.148	18.547
df	2	2
Asymp. Sig.	.000	.000

Sites 1 & 2 (TSS and COD)

Ranks

	Site	N	Mean Rank
TSS	1	22	31.77
	2	22	13.23
	Total	44	
COD	1	22	26.48
	2	22	18.52
	Total	44	

Test Statistics[a,b]

	TSS	COD
Chi-Square	22.982	4.227
df	1	1
Asymp. Sig.	.000	.040

Sites 2 & 3 (TSS and COD)

Ranks

	Site	N	Mean Rank
TSS	2	22	28.57
	3	22	16.43
	Total	44	
COD	2	22	27.52
	3	22	17.48
	Total	44	

Test Statistics[a,b]

	TSS	COD
Chi-Square	9.882	6.788
df	1	1
Asymp. Sig.	.002	.009

Sites 1 & 3 (TSS and COD)

Ranks

	Site	N	Mean Rank
TSS	1	22	32.93
	3	22	12.07
	Total	44	
COD	1	22	30.41
	3	22	14.59
	Total	44	

Test Statistics[a,b]

	TSS	COD
Chi-Square	29.083	16.748
df	1	1
Asymp. Sig.	.000	.000

Overall (Discharge)

Ranks

	Site	N	Mean Rank
Discharge	1	13	12.08
	2	13	18.69
	3	13	29.23
	Total	39	

Test Statistics[a,b]

	Discharge
Chi-Square	14.969
df	2
Asymp. Sig.	.001

Sites 1 & 2 (Discharge)

Ranks

	Site	N	Mean Rank
Discharge	1	13	10.77
	2	13	16.23
	Total	26	

Test Statistics[a,b]

	Discharge
Chi-Square	3.314
df	1
Asymp. Sig.	.069

Sites 2 & 3 (Discharge)

Ranks

	Site	N	Mean Rank
Discharge	2	13	9.46
	3	13	17.54
	Total	26	

Test Statistics[a,b]

	Discharge
Chi-Square	7.249
df	1
Asymp. Sig.	.007

Sites 1 & 3 (Discharge)

Ranks

	Site	N	Mean Rank
Discharge	1	13	8.31
	3	13	18.69
	Total	26	

Test Statistics[a,b]

	Discharge
Chi-Square	11.982
df	1
Asymp. Sig.	.001

Appendix F

Pearson Correlation to test the relationships between the independent and dependent variables.

Neurobasis chinensis

Correlations

		N.chinensis	BOD	DO	Temperature	pH
N.chinensis	Pearson Correlation	1	-.149	-.242	.188	.057
	Sig. (2-tailed)		.365	.137	.253	.731
	N	39	39	39	39	39
BOD	Pearson Correlation	-.149	1	.458**	.226	.049
	Sig. (2-tailed)	.365		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	-.242	.458**	1	-.115	.014
	Sig. (2-tailed)	.137	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	.188	.226	-.115	1	.138
	Sig. (2-tailed)	.253	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	.057	.049	.014	.138	1
	Sig. (2-tailed)	.731	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.242	.151	.077	.549**	-.256
	Sig. (2-tailed)	.138	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	.194	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.236	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	-.085	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.608	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.231	.120	.314	-.537**	.131
	Sig. (2-tailed)	.157	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
N.chinensis	Pearson Correlation	-.242	.194	-.085	-.231
	Sig. (2-tailed)	.138	.236	.608	.157
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*N.chinensis*
TSS	Pearson Correlation	1	.145	-.094
	Sig. (2-tailed)		.419	.601
	N	33	33	33
COD	Pearson Correlation	.145	1	.229
	Sig. (2-tailed)	.419		.201
	N	33	33	33
N.chinensis	Pearson Correlation	-.094	.229	1
	Sig. (2-tailed)	.601	.201	
	N	33	33	33

Euphaea ochracea

Correlations

		E.ochracea	BOD	DO	Temperature	pH
E.ochracea	Pearson Correlation	1	-.028	.311	-.574**	.187
	Sig. (2-tailed)		.865	.054	.000	.253
	N	39	39	39	39	39
BOD	Pearson Correlation	-.028	1	.458**	.226	.049
	Sig. (2-tailed)	.865		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	.311	.458**	1	-.115	.014
	Sig. (2-tailed)	.054	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	-.574**	.226	-.115	1	.138
	Sig. (2-tailed)	.000	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	.187	.049	.014	.138	1
	Sig. (2-tailed)	.253	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.321*	.151	.077	.549**	-.256
	Sig. (2-tailed)	.046	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	-.112	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.496	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	-.310	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.055	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	.425**	.120	.314	-.537**	.131
	Sig. (2-tailed)	.007	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
E.ochracea	Pearson Correlation	-.321*	-.112	-.310	.425**
	Sig. (2-tailed)	.046	.496	.055	.007
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*E.ochracea*
TSS	Pearson Correlation	1	.145	-.252
	Sig. (2-tailed)		.419	.157
	N	33	33	33
COD	Pearson Correlation	.145	1	-.434*
	Sig. (2-tailed)	.419		.012
	N	33	33	33
E.ochracea	Pearson Correlation	-.252	-.434*	1
	Sig. (2-tailed)	.157	.012	
	N	33	33	33

Zygonyx iris

Correlations

		Z.iris	BOD	DO	Temperature	pH
Z.iris	Pearson Correlation	1	.063	-.110	.516**	.009
	Sig. (2-tailed)		.705	.507	.001	.955
	N	39	39	39	39	39
BOD	Pearson Correlation	.063	1	.458**	.226	.049
	Sig. (2-tailed)	.705		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	-.110	.458**	1	-.115	.014
	Sig. (2-tailed)	.507	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	.516**	.226	-.115	1	.138
	Sig. (2-tailed)	.001	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	.009	.049	.014	.138	1
	Sig. (2-tailed)	.955	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	.225	.151	.077	.549**	-.256
	Sig. (2-tailed)	.169	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	.218	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.182	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	.154	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.348	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.320*	.120	.314	-.537**	.131
	Sig. (2-tailed)	.047	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
Z.iris	Pearson Correlation	.225	.218	.154	-.320*
	Sig. (2-tailed)	.169	.182	.348	.047
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*Z.iris*
TSS	Pearson Correlation	1	.145	.325
	Sig. (2-tailed)		.419	.065
	N	33	33	33
COD	Pearson Correlation	.145	1	.151
	Sig. (2-tailed)	.419		.401
	N	33	33	33
Z.iris	Pearson Correlation	.325	.151	1
	Sig. (2-tailed)	.065	.401	
	N	33	33	33

Rhinocypha fenestrella & Rhinocypha perforata

Correlations

		R.fenestrella	*R.perforata*	BOD	DO	Temperature
R.fenestrella	Pearson Correlation	1	-.480**	-.175	-.121	-.278
	Sig. (2-tailed)		.002	.286	.465	.087
	N	39	39	39	39	39
R.perforata	Pearson Correlation	-.480**	1	-.134	-.190	.456**
	Sig. (2-tailed)	.002		.416	.246	.004
	N	39	39	39	39	39
BOD	Pearson Correlation	-.175	-.134	1	.458**	.226
	Sig. (2-tailed)	.286	.416		.003	.167
	N	39	39	39	39	39
DO	Pearson Correlation	-.121	-.190	.458**	1	-.115
	Sig. (2-tailed)	.465	.246	.003		.486
	N	39	39	39	39	39
Temperature	Pearson Correlation	-.278	.456**	.226	-.115	1
	Sig. (2-tailed)	.087	.004	.167	.486	
	N	39	39	39	39	39
pH	Pearson Correlation	.100	-.180	.049	.014	.138
	Sig. (2-tailed)	.545	.272	.766	.934	.403
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.545**	.703**	.151	.077	.549**
	Sig. (2-tailed)	.000	.000	.358	.642	.000
	N	39	39	39	39	39
PO4	Pearson Correlation	-.082	.450**	-.246	-.341*	.127
	Sig. (2-tailed)	.618	.004	.131	.033	.443
	N	39	39	39	39	39
NH4	Pearson Correlation	-.082	.306	-.232	-.167	.399*
	Sig. (2-tailed)	.620	.058	.156	.309	.012
	N	39	39	39	39	39
Discharge	Pearson Correlation	.057	-.347*	.120	.314	-.537**
	Sig. (2-tailed)	.731	.031	.465	.051	.000
	N	39	39	39	39	39

Correlations

		pH	Conductivity	PO4	NH4	Discharge
R.fenestrella	Pearson Correlation	.100	-.545**	-.082	-.082	.057
	Sig. (2-tailed)	.545	.000	.618	.620	.731
	N	39	39	39	39	39
R.perforata	Pearson Correlation	-.180	.703**	.450**	.306	-.347*
	Sig. (2-tailed)	.272	.000	.004	.058	.031
	N	39	39	39	39	39
BOD	Pearson Correlation	.049	.151	-.246	-.232	.120
	Sig. (2-tailed)	.766	.358	.131	.156	.465
	N	39	39	39	39	39
DO	Pearson Correlation	.014	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.934	.642	.033	.309	.051
	N	39	39	39	39	39
Temperature	Pearson Correlation	.138	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.403	.000	.443	.012	.000
	N	39	39	39	39	39
pH	Pearson Correlation	1	-.256	-.026	-.113	.131
	Sig. (2-tailed)		.115	.875	.492	.426
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.256	1	.252	.454**	-.376*
	Sig. (2-tailed)	.115		.122	.004	.018
	N	39	39	39	39	39
PO4	Pearson Correlation	-.026	.252	1	.101	-.303
	Sig. (2-tailed)	.875	.122		.543	.061
	N	39	39	39	39	39
NH4	Pearson Correlation	-.113	.454**	.101	1	-.297
	Sig. (2-tailed)	.492	.004	.543		.066
	N	39	39	39	39	39
Discharge	Pearson Correlation	.131	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.426	.018	.061	.066	
	N	39	39	39	39	39

Correlations

		TSS	COD	*R.fenestrella*	*R.perforata*
TSS	Pearson Correlation	1	.145	-.307	.595**
	Sig. (2-tailed)		.419	.083	.000
	N	33	33	33	33
COD	Pearson Correlation	.145	1	-.249	.302
	Sig. (2-tailed)	.419		.162	.087
	N	33	33	33	33
R.fenestrella	Pearson Correlation	-.307	-.249	1	-.494**
	Sig. (2-tailed)	.083	.162		.003
	N	33	33	33	33
R.perforata	Pearson Correlation	.595**	.302	-.494**	1
	Sig. (2-tailed)	.000	.087	.003	
	N	33	33	33	33

Vestalis amethystina

Correlations

		V.amethystina	BOD	DO	Temperature	pH
V.amethystina	Pearson Correlation	1	-.132	-.025	-.120	.096
	Sig. (2-tailed)		.424	.878	.467	.561
	N	39	39	39	39	39
BOD	Pearson Correlation	-.132	1	.458**	.226	.049
	Sig. (2-tailed)	.424		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	-.025	.458**	1	-.115	.014
	Sig. (2-tailed)	.878	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	-.120	.226	-.115	1	.138
	Sig. (2-tailed)	.467	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	.096	.049	.014	.138	1
	Sig. (2-tailed)	.561	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.326*	.151	.077	.549**	-.256
	Sig. (2-tailed)	.043	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	.169	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.304	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	-.147	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.371	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.073	.120	.314	-.537**	.131
	Sig. (2-tailed)	.661	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
V.amethystina	Pearson Correlation	-.326*	.169	-.147	-.073
	Sig. (2-tailed)	.043	.304	.371	.661
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*V.amethystina*
TSS	Pearson Correlation	1	.145	-.200
	Sig. (2-tailed)		.419	.265
	N	33	33	33
COD	Pearson Correlation	.145	1	-.288
	Sig. (2-tailed)	.419		.104
	N	33	33	33
V.amethystina	Pearson Correlation	-.200	-.288	1
	Sig. (2-tailed)	.265	.104	
	N	33	33	33

Devadatta argyoides

Correlations

		D.argyoides	BOD	DO	Temperature	pH
D.argyoides	Pearson Correlation	1	-.039	.052	-.026	-.027
	Sig. (2-tailed)		.815	.755	.875	.868
	N	39	39	39	39	39
BOD	Pearson Correlation	-.039	1	.458**	.226	.049
	Sig. (2-tailed)	.815		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	.052	.458**	1	-.115	.014
	Sig. (2-tailed)	.755	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	-.026	.226	-.115	1	.138
	Sig. (2-tailed)	.875	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	-.027	.049	.014	.138	1
	Sig. (2-tailed)	.868	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.124	.151	.077	.549**	-.256
	Sig. (2-tailed)	.454	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	.108	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.512	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	-.172	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.294	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.062	.120	.314	-.537**	.131
	Sig. (2-tailed)	.709	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
D.argyoides	Pearson Correlation	-.124	.108	-.172	-.062
	Sig. (2-tailed)	.454	.512	.294	.709
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*D.argyoides*
TSS	Pearson Correlation	1	.145	-.030
	Sig. (2-tailed)		.419	.870
	N	33	33	33
COD	Pearson Correlation	.145	1	-.215
	Sig. (2-tailed)	.419		.229
	N	33	33	33
D.argyoides	Pearson Correlation	-.030	-.215	1
	Sig. (2-tailed)	.870	.229	
	N	33	33	33

Prodasineura laidlawii

Correlations

		P.laidlawii	BOD	DO	Temperature	pH
P.laidlawii	Pearson Correlation	1	.159	.023	.469**	-.098
	Sig. (2-tailed)		.333	.889	.003	.553
	N	39	39	39	39	39
BOD	Pearson Correlation	.159	1	.458**	.226	.049
	Sig. (2-tailed)	.333		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	.023	.458**	1	-.115	.014
	Sig. (2-tailed)	.889	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	.469**	.226	-.115	1	.138
	Sig. (2-tailed)	.003	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	-.098	.049	.014	.138	1
	Sig. (2-tailed)	.553	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	.622**	.151	.077	.549**	-.256
	Sig. (2-tailed)	.000	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	.238	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.145	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	.069	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.676	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.233	.120	.314	-.537**	.131
	Sig. (2-tailed)	.153	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
P.laidlawii	Pearson Correlation	.622**	.238	.069	-.233
	Sig. (2-tailed)	.000	.145	.676	.153
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*P.laidlawii*
TSS	Pearson Correlation	1	.145	.115
	Sig. (2-tailed)		.419	.522
	N	33	33	33
COD	Pearson Correlation	.145	1	.156
	Sig. (2-tailed)	.419		.385
	N	33	33	33
P.laidlawii	Pearson Correlation	.115	.156	1
	Sig. (2-tailed)	.522	.385	
	N	33	33	33

Echo modesta

Correlations

		E.modesta	BOD	DO	Temperature	pH
E.modesta	Pearson Correlation	1	-.067	.242	-.659**	-.081
	Sig. (2-tailed)		.683	.137	.000	.626
	N	39	39	39	39	39
BOD	Pearson Correlation	-.067	1	.458**	.226	.049
	Sig. (2-tailed)	.683		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	.242	.458**	1	-.115	.014
	Sig. (2-tailed)	.137	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	-.659**	.226	-.115	1	.138
	Sig. (2-tailed)	.000	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	-.081	.049	.014	.138	1
	Sig. (2-tailed)	.626	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.392*	.151	.077	.549**	-.256
	Sig. (2-tailed)	.014	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	-.184	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.261	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	-.150	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.362	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	.579**	.120	.314	-.537**	.131
	Sig. (2-tailed)	.000	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
E.modesta	Pearson Correlation	-.392*	-.184	-.150	.579**
	Sig. (2-tailed)	.014	.261	.362	.000
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*E.modesta*
TSS	Pearson Correlation	1	.145	-.250
	Sig. (2-tailed)		.419	.161
	N	33	33	33
COD	Pearson Correlation	.145	1	-.241
	Sig. (2-tailed)	.419		.177
	N	33	33	33
E.modesta	Pearson Correlation	-.250	-.241	1
	Sig. (2-tailed)	.161	.177	
	N	33	33	33

Trithemis festiva

Correlations

		T.festiva	BOD	DO	Temperature	pH
T.festiva	Pearson Correlation	1	.177	-.025	.240	-.113
	Sig. (2-tailed)		.281	.879	.142	.494
	N	39	39	39	39	39
BOD	Pearson Correlation	.177	1	.458**	.226	.049
	Sig. (2-tailed)	.281		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	-.025	.458**	1	-.115	.014
	Sig. (2-tailed)	.879	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	.240	.226	-.115	1	.138
	Sig. (2-tailed)	.142	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	-.113	.049	.014	.138	1
	Sig. (2-tailed)	.494	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.180	.151	.077	.549**	-.256
	Sig. (2-tailed)	.273	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	-.225	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.169	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	.249	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.126	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.082	.120	.314	-.537**	.131
	Sig. (2-tailed)	.621	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
T.festiva	Pearson Correlation	-.180	-.225	.249	-.082
	Sig. (2-tailed)	.273	.169	.126	.621
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*T.festiva*
TSS	Pearson Correlation	1	.145	-.130
	Sig. (2-tailed)		.419	.472
	N	33	33	33
COD	Pearson Correlation	.145	1	-.105
	Sig. (2-tailed)	.419		.560
	N	33	33	33
T.festiva	Pearson Correlation	-.130	-.105	1
	Sig. (2-tailed)	.472	.560	
	N	33	33	33

Orthetrum glaucum

Correlations

		O.glaucum	BOD	DO	Temperature	pH
O.glaucum	Pearson Correlation	1	.167	-.037	.198	-.090
	Sig. (2-tailed)		.308	.824	.226	.585
	N	39	39	39	39	39
BOD	Pearson Correlation	.167	1	.458**	.226	.049
	Sig. (2-tailed)	.308		.003	.167	.766
	N	39	39	39	39	39
DO	Pearson Correlation	-.037	.458**	1	-.115	.014
	Sig. (2-tailed)	.824	.003		.486	.934
	N	39	39	39	39	39
Temperature	Pearson Correlation	.198	.226	-.115	1	.138
	Sig. (2-tailed)	.226	.167	.486		.403
	N	39	39	39	39	39
pH	Pearson Correlation	-.090	.049	.014	.138	1
	Sig. (2-tailed)	.585	.766	.934	.403	
	N	39	39	39	39	39
Conductivity	Pearson Correlation	-.168	.151	.077	.549**	-.256
	Sig. (2-tailed)	.305	.358	.642	.000	.115
	N	39	39	39	39	39
PO4	Pearson Correlation	-.226	-.246	-.341*	.127	-.026
	Sig. (2-tailed)	.167	.131	.033	.443	.875
	N	39	39	39	39	39
NH4	Pearson Correlation	.142	-.232	-.167	.399*	-.113
	Sig. (2-tailed)	.390	.156	.309	.012	.492
	N	39	39	39	39	39
Discharge	Pearson Correlation	-.057	.120	.314	-.537**	.131
	Sig. (2-tailed)	.729	.465	.051	.000	.426
	N	39	39	39	39	39

Correlations

		Conductivity	PO4	NH4	Discharge
O.glaucum	Pearson Correlation	-.168	-.226	.142	-.057
	Sig. (2-tailed)	.305	.167	.390	.729
	N	39	39	39	39
BOD	Pearson Correlation	.151	-.246	-.232	.120
	Sig. (2-tailed)	.358	.131	.156	.465
	N	39	39	39	39
DO	Pearson Correlation	.077	-.341*	-.167	.314
	Sig. (2-tailed)	.642	.033	.309	.051
	N	39	39	39	39
Temperature	Pearson Correlation	.549**	.127	.399*	-.537**
	Sig. (2-tailed)	.000	.443	.012	.000
	N	39	39	39	39
pH	Pearson Correlation	-.256	-.026	-.113	.131
	Sig. (2-tailed)	.115	.875	.492	.426
	N	39	39	39	39
Conductivity	Pearson Correlation	1	.252	.454**	-.376*
	Sig. (2-tailed)		.122	.004	.018
	N	39	39	39	39
PO4	Pearson Correlation	.252	1	.101	-.303
	Sig. (2-tailed)	.122		.543	.061
	N	39	39	39	39
NH4	Pearson Correlation	.454**	.101	1	-.297
	Sig. (2-tailed)	.004	.543		.066
	N	39	39	39	39
Discharge	Pearson Correlation	-.376*	-.303	-.297	1
	Sig. (2-tailed)	.018	.061	.066	
	N	39	39	39	39

Correlations

		TSS	COD	*O.glaucum*
TSS	Pearson Correlation	1	.145	-.109
	Sig. (2-tailed)		.419	.547
	N	33	33	33
COD	Pearson Correlation	.145	1	-.100
	Sig. (2-tailed)	.419		.579
	N	33	33	33
O.glaucum	Pearson Correlation	-.109	-.100	1
	Sig. (2-tailed)	.547	.579	
	N	33	33	33