FAUNISTIC STUDIES OF ODONATES (INSECTA: ODONATA) IN JOHOR, PENINSULAR MALAYSIA

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ABSTRACT

The purpose of this research is to study the diversity and distribution of odonates in Johor, Peninsular Malaysia. The method used for odonate sampling was manual collection along 1 km line transect using aerial net. Overall, a total of 2222 individuals under 84 species from 13 families and 58 genera were recorded. Family Libellulidae was the most well-represented family. Shannon Diversity Index (H') and Evenness Index (E) were highest in Endau-Rompin Johor National Park (H'= 3.155; E= 0.733) and lowest in Soga Perdana Recreational Forest (H'= 2.444; E= 0.501). To determine the site with highest conservation priority, the ecological data and entomotourism criteria was further analyzed using grid analysis. The site with highest priority was Endau-Rompin Johor National Park with a score value of 52 while the lowest priority was recorded in Sungai Sayong with a score value of 35. All these data will be helpful in assisting towards a better management of the conservation areas in Johor.

Keywords: Odonata, dragonflies, damselflies, conservation, diversity, species composition, species inventory, Johor

ABSTRAK

Tujuan kajian ini adalah untuk mengenalpasti kepelbagaian dan taburan spesies Odonata di negeri Johor, Semenanjung Malaysia. Kaedah persampelan Odonata yang digunakan adalah secara manual dengan menggunakan jaring udara di sepanjang 1 km transek yang ditetapkan di setiap kawasan kajian. Secara keseluruhan, sejumlah 2222 individu merangkumi 84 spesies daripada 13 famili dan 58 genus telah direkodkan daripada kajian ini. Famili Libellulidae merupakan famili yang paling dominan. Indeks Kepelbagaian Shannon (H') dan indeks Kesamarataan species (E) mencatatkan bacaan tertinggi di Taman Negara Johor Endau-Rompin (H'= 3.155; E= 0.733), manakala bacaan terendah direkodkan di Hutan Lipur Soga Perdana (H'= 2.444; E= 0.501). Kawasan kajian yang mempunyai keutamaan terhadap pemuliharaan dapat ditentukan menggunakan analisis grid berdasarkan kriteria-kriteria yang ditetapkan. Taman Negara Johor Endau-Rompin merupakan kawasan kajian dengan nilai keutamaan terhadap pemuliharaan yang tertinggi dengan nilai skor 52, manakala Sungai Sayong mencatatkan nilai terendah iaitu 35. Kesemua data ini dapat membantu dalam pengurusan pemuliharaan kawasan secara lebih efektif di Johor.

Kata kunci: Odonata, pepatung, jejarum, pemuliharaan, kepelbagaiaan spesies, komposisi spesies, inventori spesies, Johor

INTRODUCTION

Odonata (dragonflies and damselflies) is one of the most well-known orders of insect and one of attractive group of insects to study (Rathod et al. 2012). Order Odonata can be divided into three suborders based on their wing venation (Tofilski 2004) and the suborders are Zygoptera (damselflies), Anisoptera (dragonflies) and lastly Anisozygoptera mainly concerns the fossil remains found around the world. There are over 5800 species of odonates have been recorded and the greatest number of species were found in forested tropical region (Nelson et al. 2011; Orr 2006). Odonata is widely distributed in the tropical rainforest with the greatest numbers and diversity occur (Wahizatul-Afzan 2006).

Odonates are well known as an excellent group of indicator species (Malawani et al. 2014; Samways & Steytler 1996; Wardhani 2007) for both aquatic and terrestrial ecosystem (Brown 1997; Malawani et al. 2014) as they are very sensitive towards changes in their surrounding environment (Andrew et al., 2009) and there are species listed as 'habitat-specialist' which shows preference to specific habitat type (Sheldon & Walker 1998). As stated in Norma-Rashid (2009) there are certain species of odonates that depends on specific preferred environment and these species have important roles as indicator of water quality.

Peninsular Malaysia is one of the regions that are blessed with a variety of forested water bodies of tropical rainforest that housed high diversity and endemicity of odonates. Odonates can be found in almost all kinds of habitat including ponds, lakes, rivers, streams, swamps, bogs and marshes (Das et al. 2012). The odonates of Peninsular Malaysia have been extensively documented by Lieftinck (1954) who listed 189 species followed by Tsuda (2000) who listed 240 species and Orr (2005) reduced the list to 230 species. According to Hämäläinen et al. (1996), there are about 220 species of odonates that have been described in Peninsular Malaysia and Singapore and the highest number of species recorded from Pahang, Selangor and Perak.

There are still many parts of Johor that has never been documented. A few records can be found from previous researches including Endau-Rompin National Park (Wilson & Gibert 2006), Ayer Hitam Forest Reserve (Choong & Cheah 2013), Gunung Ledang National Park (Maryati et al. 2014) and Soga Perdana Recreational Forest (Siddiki 2015).

Odonates population in Peninsular Malaysia is subjected towards conservation due to the ongoing habitat destruction, urbanization and agricultural activities and one of the key solutions for these threats is by prioritizing of conservation areas. As reported by Clausnitzer et al. (2009) according to the global assessment of odonata, it shows that one in every 10 species of odonate is threatened with extinction. Therefore, it is important to update the recent status of odonate in terms of their distribution and locality data. Therefore, this research is part of an effort to provide a baseline data of odonates in Johor and contributes towards aiding the first step towards odonates conservation in Malaysia.

MATERIALS AND METHODS

Sampling Areas

Sampling was conducted at nine different locations in Johor with different types of forest, vegetation and microclimate which focusing in the area near to water bodies. The selection of the sampling areas was based on three criteria; (1) accessibility of the areas in terms of transportation

and safety, (2) getting support and collaboration from Johor National Park Corporation (JNPC) and Forestry Department of Johor; two of the areas proposed for sampling were managed under Johor National Park Corporation (JNPC) and six areas under management of Johor Forestry Department and one site under Department of Orang Asli Development, and (3) to compare the protected areas with unprotected areas, some poor water bodies along area of Johor River (first order and second order tributaries) were proposed. The specific locations and the descriptions for each site are shown in the Table 1, while Figure 1 shows the map of study sites. Odonate samplings (adult) were done at all nine study areas for 12 months throughout the study period. In every sampling month, the collector spends three days at every sampling area (Table 2).

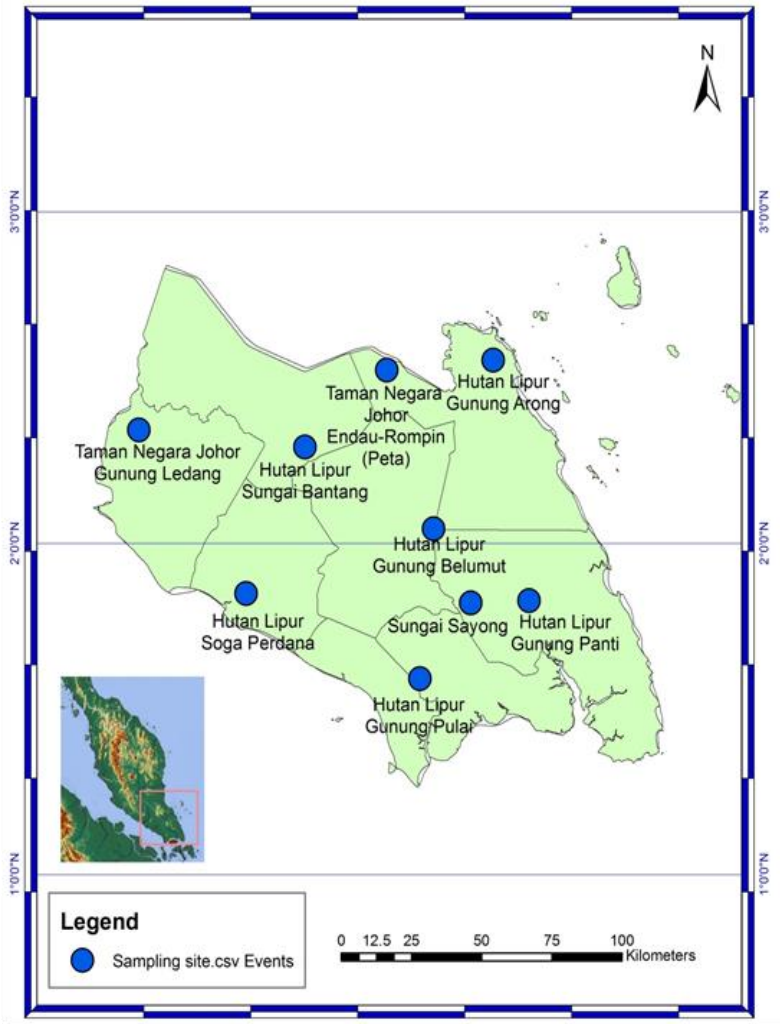

Figure 1 The sampling sites of odonates in selected water bodies of Johor generated using ArcGIS 10.4

Sampling Methods, Preservation & Identification

The sampling was made during day-time since adult odonates are usually found during day-time with fine weather conditions generally from 9 a.m. to 2 p.m. Adult odonates were collected using aerial net where it is shown that the use of sweep net is an effective method for assessing invertebrate population (Turner & Trexler, 1997). A total of 21 sampling stations was set up along 1000 meter of transects with distance between each sampling station approximately 50 meter and the sampling was done within the radius of five meter from each sampling station. Specific locations for each sampling station were recorded using GPS. The model of line transect used was illustrated as shown in Figure 2.

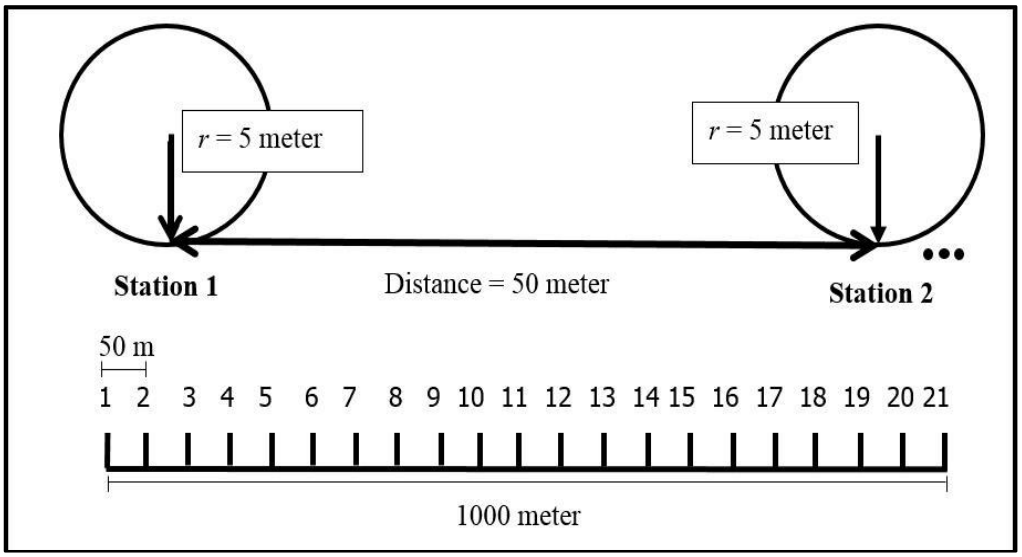

Figure 2 A schematic drawing of sampling station using a 1 km line transect

Specimens would be preserved by treatment with acetone followed by drying or immersion in ethanol. Once an odonate is captured, it can be removed from the net by using hand and if the captured odonate is not needed as a sample or after the process of identification and photographed, it was released back. For the specimens (odonate) is kept as a sample, it would be immediately placed alive in a glassine envelope to protect their wings in a good condition for identification. For every specimen that is captured or photographed, the date, name of collector and location are recorded in a label for future reference. For identification purpose, Odonates were morphologically identified up to species level using a book 'Dragonfly of Peninsular Malaysia and Singapore' by Orr (2005).

Data Analysis

The diversity of odonates was estimated by means of the Shannon index (Magurran 2004). Therefore, the Shannon's Diversity Index, H' and Evenness Index, E were calculated using software PAST v2.17. The most and least abundant species in each spot and in the area were calculated by using the abundance formula. By using a priority setting (rank) table, the site with higher diversity and fulfill the criteria for entomotourism aspect will gain the highest score ranked between one to nine (1-9) since the total number of sites in this survey was nine sites. There are several criteria for organism-based tourism as listed by Kueh (2006) and some of these criteria will be used to set up the priority table in order to rank the sampling areas according to the priority towards conservation.

RESULTS AND DISCUSSION

Diversity and Species Composition of Odonates in Johor

Overall, 2222 individuals of odonates were collected from various localities in Johor. The total number of individuals collected for suborder Anisoptera was 1368 while 854 was Zygoptera. Similarly, Mamat et al. (2012) reported higher abundance of Anisoptera (701) compared to Zygoptera (597) in the survey from various locations in Selangor. The reason for high dispersal of Anisoptera were explained by several authors (Norma-Rashid et al., 2001; Orr et al., 2004) due to the abilities to tolerate with disturbances and shorter life cycle. In contrast, most of Zygopteran was stenotopic species that favor shade and has requirements for their habitats to survive such as high oxygen concentration for the larvae to survive (Norma-Rashid 2009).

The total number of species collected from this study was 84 species (58 genera) represented by 13 families. From 13 families collected, there are 10 families (39 species) belongs to suborder Zygoptera (damselflies) and three families (45 species) for suborder Anisoptera (dragonflies). This represents 36% of odonate fauna that has been recorded in Peninsular Malaysia according to 231 confirmed species by Orr (2005) and 25% of the odonate fauna in Malaysia (342 species) as stated in Orr et al. (2004).

Table 3 shows the species composition of odonates in Johor according to the families listed with prior towards their taxonomic classification. The classification was based on Dijkstra et al. (2013) and revision by Dijkstra et al. (2014). Libellulidae was the most dominant family represented by 44.0%, followed by Platycnemididae (11.9%), Coenagrionidae (10.7%), Chlorocyphidae (7.1%), Aeshnidae (6.0%), Calopterygidae (4.8%), Euphaeidae, Platystictidae and Gomphidae (3.57% respectively), while Devadattidae, Lestidae, Argiolestidae and Philosinidae (1.2% respectively). Similarly, in most of the researches conducted in Peninsular Malaysia (Wilson & Gibert, 2006; Norma-Rashid, 2009; Choong & Cheah, 2013, Farizawati et al., 2014; Maryati et al., 2014) shows that Libellulidae was the most dominant family that can be found in almost everywhere. From this survey, it shows that most of the libellulids were stenotopic (sun-loving) species which often occurs in open aquatic habitats. As stated in Mamat et al. (2012) Libellulidae was a common family dominating the open lentic habitats. In general, there are 75 confirmed species of Libellulidae as listed by Orr (2005) and from this survey, 37 species (26 genera) has been successfully recorded from various localities in Johor. In contrast, family Devadattidae, Lestidae, Argiolestidae and Philosinidae were represented by a single species. In fact, Orr et al. (2004) stated that Lestidae was poorly distributed in Peninsular Malaysia.

The most dominant genera collected were *Orthetrum, Rhyothemis, Prodasineura, Vestalis, Pseudagrion* and *Coeliccia*. Meanwhile, in terms of species with highest abundance recorded was *Neurothemis fluctuans*, followed by *Orthetrum chrysis, Vestalis amoena, Trithemis aurora* and *Tyriobapta torrida*. Most of the authors (Norma-Rashid et al. 1996; Norma-Rashid 2009; Mamat et al. 2012; Orr 2005) stated that *Neurothemis fluctuans* was the most common species or cosmopolitan species that can be found in almost all kinds of aquatic habitats due to their high range of dispersal and distributions in Peninsular Malaysia. In fact, there are several authors reported the occurrence of *Neurothemis fluctuans* from neighboring islands including Sarawak (Dow 2012) and Medan, Indonesia (Siregar & Bakti 2016). These researches might be the supporting fact to explain the wide range of distribution for *Neurothemis fluctuans* throughout the region.

Orthetrum chrysis is a common libellulids that dominated open stagnant waters including the disturbed habitats and often observed to coexist with the other libellulids including *Trithemis aurora* and *Tyriobapta torrida*. The ability to tolerate with the disturbed habitats (Mapi-ot et al. 2013) might be the key for their high rates of dispersal. *Vestalis amoena* is a common species found in clear forest streams (Orr 2005) and the records on the occurrence of *Vestalis amoena* was often reported by most researches (Choong et al. 2012; Norma-Rashid 2009; Wilson & Gibert 2006).

Tyriobapta torrida was commonly observed perched vertically on the tree trunk and it is significant with their common name the "Tree Hugger". According to Orr (2005) *Tyriobapta torrid*a is a widespread species in Sundaland and common in forest swamps. According to the observation made by the authors, *Tyriobapta torrida* was often found in lowland forest and occurs in both open and shady habitats.

The least abundant species were *Vestalis amethystina, Archibasis viola, Ischnura senegalensis, Pericnemis stictica, Protosticta foersteri, Paragomphus capricornis, Gynacantha limbalis, Oligoaeschna foliacea, Brachydiplex farinosa, Camacinia gigantea, Crocothemis servilia, Lyriothemis biappendiculata, Lyriothemis cleis, Macrodiplex cora, Rhodothemis rufa, Rhyothemis pygmaea* and *Tetrathemis platyptera.* More than 50% from the species listed above belong to family Libellulidae. In general, Libellulidae seems to be the most common species; however there are several species considered as rare according to the collection made in Johor. From the species listed above, there are few species that was recorded as rare and endemic according to (Orr, 2005). *Pericnemis stictica* is a rare coenagrionids found in forested habitats while the endemic, *Protosticta foersteri* was assessed as "Near Threatened" by IUCN Red List Categories and Criteria.

Table 4 shows the Shannon Wiener Diversity Index (H') and Evenness Index (E) value for sampling sites in Johor. The diversity of odonates in various localities in Johor was measured using the Shannon Diversity Index (H'). Rosenzweig (1995) stated that the higher values of Shannon Wiener Index indicated the higher the species diversity in the area. The highest diversity of odonates was recorded in Endau-Rompin Johor National Park with Shannon Diversity Index (H' = 3.155) followed closely by Gunung Panti Recreational Forest (H' = 3.131). Comparatively, a recent study by Rafi et al. (2017) in Palakmati stream, India shows the highest Shannon Diversity Index recorded was (H' = 2.269) and this value was relatively low compared to our findings. Meanwhile, a survey by Mamat et al. (2012) in Selangor reported that (H' = 3.220) shows a slightly higher value of Shannon Diversity Index.

The reason for higher species diversity is probably related to diversification of ecosystems and presence of various microhabitats. An assumption by Molles (1999) stated that a value that range from 1.5 to 3.5 is considered to have a moderate diversity. Therefore, the diversity of odonates in these sites can be considered as having a moderate diversity as the highest and lowest diversity index recorded in these survey falls within the range. In contrary, the lowest diversity was recorded in Soga Perdana Recreational Forest (H' = 2.444).

Similarly, the highest evenness was recorded in Endau-Rompin Johor National Park (E = 0.733) followed by Gunung Panti Recreational Forest (E = 0.654). Meanwhile, the lowest evenness was recorded in Soga Perdana Recreational Forest (E = 0.501). Cerda *et al.* (2011) stated the evenness value that closer to one indicates even distribution while a value closer to zero indicating that there is a dominant species. Therefore, odonates in Endau-Rompin Johor National Park have the most even species distribution compared to the other sites in Johor. According to the Johor Forest Management Plan (2005), Endau was listed as the dampest site in Johor that received the highest amount of annual rainfall. Due to this fact, it is suitable for odonates population as they depend on the aquatic habitats for their survival. The diversification of aquatic habitats in Endau-Rompin Johor National Park is probably the main reason for high odonate species diversity.

From the finding, it proves the theory by Magurran (2004) who states the diversity of an area increases as the richness and evenness within the community increase. The high diversity of odonates recorded in certain areas indicating a healthy ecosystem (Corbet 1999). Therefore, it can be concluded that the site with highest diversity and evenness was Endau-Rompin Johor National Park. The reason for high species diversity in Endau-Rompin Johor National Park was probably due to their current status as conservation areas with relatively undisturbed and diverse forested stream habitats.

Meanwhile, the lowest diversity and evenness was recorded in Soga Perdana Recreational Forest. Soga Perdana Recreational Forest was located near human settlement areas and causing the habitat to be exposed toward human disturbances that could affect the diversity of odonates. As reported by Rith-Najarian (1998) states that the species richness of odonates was much higher in the primary forest compared to the degraded forest and (Qayyimah et al. 2014) claimed that the presence of several species for example, *Crocothemis servilia* as recorded in Soga Perdana Recreational Forest indicating the disturbed habitats since this species is commonly observed in the human settlement areas.

Dominant and overlapping species

The dominant species was determined by the rank abundance curve (Figure 3); ranking species using abundance data. This is frequently used to identify how dominant and rare the species are (Magurran & Henderson 2011). The five most abundant species found in various water bodies of Johor were *Neurothemis fluctuans*, *Orthetrum chrysis*, *Trithemis aurora*, *Vestalis amoena* and *Tyriobapta torrida*. *Neurothemis fluctuans*, *Orthetrum chrysis*, *Trithemis aurora* and *Tyriobapta torrida* belong to family Libellulidae while *Vestalis amoena* belongs to family Calopterygidae. The dominance of family Libellulidae might be due to their wide distribution across the continent with over 1012 species recorded and thus making them second most dominant after family Coenagrionidae (Kalkman et al. 2008).

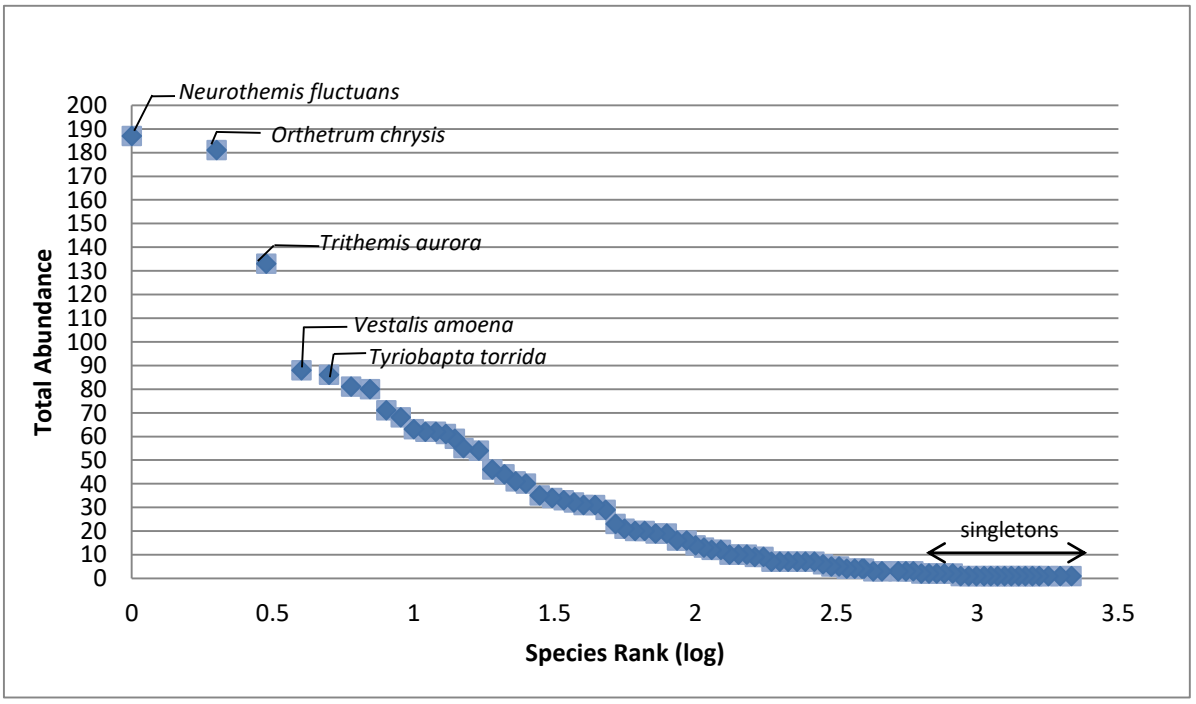

Figure 3 Rank abundance curve of odonate in selected areas of Johor

From observation made and according to the abundance data (Table 3) most sites showed similar pattern of abundance in terms of dominant species occurrence. Similarly, a survey by Zulkapli (2008) in Kunak, Sabah reported the highest abundance of libellulids especially *Orthetrum chrysis*, *Orthetrum testaceum* and *Trithemis aurora*. In a different survey by Wardhani (2009) also reported that the most common larva of libellulids collected from three different water bodies in Penang were *Neurothemis fluctuans*, *Orthetrum chrysis* and *Trithemis aurora*. Meanwhile, a survey in Selangor by Mamat et al. (2012) showed the high abundance of *Neurothemis fluctuans, Tyriobapta torrida* and *Orthetrum chrysis*.

The highest abundance of *Neurothemis fluctuans* was explained by their wide range of distribution in almost all type of aquatic habitats including the disturbed habitats and most commonly recorded from Peninsular Malaysia (Norma-Rashid et al. 1996). Orr (2005) stated that *Neurothemis fluctuans* is a cosmopolitan species that occupies a wide range of aquatic habitats. This study showed that *Neurothemis fluctuans* was found abundantly in all the nine sampling sites including the disturbed habitats. Mamat et al. (2012) working in various locations in Selangor and Siddiki (2015) in three different forest types in Johor (Taman Negara Johor Gunung Ledang, Hutan Lipur Soga Perdana and Endau-Rompin National Park) also showed that *Neurothemis fluctuans* was a dominant species collected through the survey. In fact, there are other reports of occurrence of *Neurothemis fluctuans* from neighboring islands such as in Sarawak, Borneo (Dow 2012) and Medan, Indonesia (Siregar & Bakti 2016).

Orthetrum chrysis and *Trithemis aurora* are common libellulids observed in open slow flowing streams and lentic habitats. High dispersal of libellulids in most of the water bodies was explained by the flat abdomen of their larva and thus increases their ability to move in a more solid substrate (Morse et al. 1994). *Orthetrum chrysis* and *Trithemis aurora* were also recorded in all the sampling sites with high abundance. *Orthetrum chrysis* is a widespread species in Peninsular Malaysia and was also recorded in the surrounding islands of west coast of Peninsular Malaysia including Pangkor Island, Besar Island, Carey Island and Penang Island (Farizawati et al. 2014). The other records for *Orthetrum chrysis* and *Trithemis aurora* could also be found in different surveys in Peninsular Malaysia (Mamat et al. 2012; Maryati et al. 2014; Norma-Rashid 2009; Wardhani 2007).

The most abundant Zygopteran collected throughout the survey was *Vestalis amoena.* This is a common species found in clear forest stream habitats (Orr 2005). The records on the occurrence of *Vestalis amoena* in the streams of Peninsular Malaysia were reported by most studies (Choong et al. 2012; Izzat-Husna & Ahmad 2014; Norma-Rashid 2009; Wilson & Gibert 2006). *Vestalis amoena* was often spotted perching in the sunny spots along the vegetation near stream banks.

In terms of overlapping species, there were four species found in all sites: *Neurothemis fluctuans, Orthetrum chrysis, Trithemis aurora* and *Orthetrum testaceum*. All of these species belong to the same family Libellulidae. However, *Orthetrum testaceum* were found in a moderate abundance in all sites and commonly coexist with *Orthetrum chrysis* and *Trithemis aurora*. This might be due to the similar habitat requirements and tolerance towards disturbances (Wardhani 2009). There are 17 singleton species (20%) recorded throughout the survey of which more than 50% are Libellulidae, concluding Libellulidae as the most commonly recorded species throughout the survey. However, among the singleton there are several species considered as rare. This might be due to the several limitations during the sampling including unfavorable weather.

Endemicity

The endemicity in Peninsular Malaysia as reported by Orr et al. (2004) was at 11% and all members of Platystictidae in Peninsular Malaysia are endemic. However, there are several discoveries of new and endemic species reported in Peninsular Malaysia (Choong et al. 2012; Choong & Cheah 2013; Choong 2016; Farizawati et al. 2014; Norma-Rashid 2009) and more species is expected to be discovered from time-to-time. From the survey, there are three (3) endemic species collected including *Drepanosticta fontinalis, Drepanosticta quadr*ata and *Protosticta foersteri*. As stated in Orr (2005) there are two species (*Drepanosticta fontinalis* and *Protosticta foersteri*) reported to be endemic species in Peninsular Malaysia while *Drepanosticta quadrata* was previously reported to be known in only Singapore Island. However, several authors

reported the occurrence of *Drepanosticta quadrata* in several locations of Peninsular Malaysia (Norma-Rashid 2009; Wilson & Gibert, 2006).

According to IUCN Red List Categories and Criteria, *Drepanosticta fontinalis* and *Protosticta foersteri* were assessed as "Nearly Threatened". The distribution pattern of endemic species was commonly recorded from the west Johor. The sites were Gunung Pulai Recreational Forest, Soga Perdana Recreational Forest, Sungai Bantang Recreational Forest and Gunung Ledang Johor National Park. Figure 4 shows the distribution map of endemic species throughout the survey in various localities in Johor.

The endemicity in Peninsular Malaysia is much lower compared to other records in Borneo (Orr et al. 2004) and the Philippines (Yuto et al. 2015). As explained by Malawani et al. (2014) the level of endemism was higher in aquatic habitats of the undisturbed forest streams as the habitat is more favorable to odonates. Endemic species tends to be more sensitive towards changes in their surroundings as most of these species are secretive and habitat-specialist species (Gapud 2003; Orr et al. 2004).

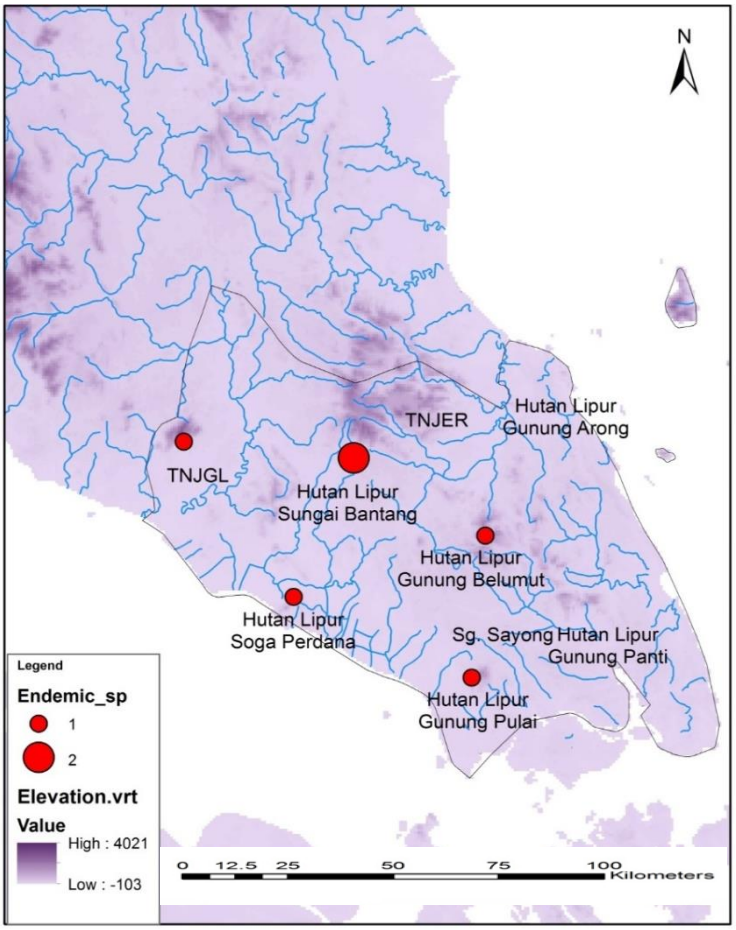

Figure 4 The distribution map of endemic species from selected water bodies in Johor

Drepanosticta is not only an endemic species that need a special focus on the conservation aspect but as well as their roles as biological indicator of good water quality. Gapud (2003) stated that *Drepanosticta* are sensitive to changes in their habitats and Orr et al. (2004) reported that *Drepanosticta* was habitat specialist species that was commonly found under the stones in riffles.

Similarly, Norma-Rashid (2009) stated that the larvae of *Drepanosticta* needs an aquatic habitat with high oxygen content and cool temperature to survive. In placing more emphasis, Samways & Steytler (1996) claimed that habitat-specialist species is an important indicator species rather than generalist species due to their strict requirements to thrive and survive in the aquatic ecosystems. Therefore, due to the presence of *Drepanosticta* we can actually make a preliminary assessment on the water quality of the aquatic habitats.

Prioritization of Conservation Areas

Table 5 shows the priority setting table for measuring the score and ranking of sampling sites with prior towards conservation. The criteria used in prioritization of conservation areas were (i) Shannon Diversity (H'), (ii) species evenness (E), (iii) habitat, (iv) endemicity, (v) safety, (vi) reliability of sightings and (vii) accessibility. Criteria I and II are solely depending on the quantitative data collected from the sampling sites, criteria III was assessed by qualitative data while criteria IV – VII which adapted from Kueh (2006) and evaluated by using both quantitative and qualitative data.

The highest priority for conservation was calculated in Endau-Rompin Johor National Park with score of 52. This protected area is managed by Johor National Park Corporation and this area fulfills most of the criteria with highest score in both quantitative and qualitative data. However, there is no endemic species collected during the survey but from it was listed in the previous survey by Wilson & Gibert (2006). In terms of odonates conservation, this area is the most important areas for odonate population due to high suitability of aquatic habitats.

In contrast, Sungai Sayong is the lowest score by 35 and makes it to the least prior toward conservation. This might be due to their low score in most of the qualitative data in terms of habitat quality of the water bodies, safety and accessibility and low species evenness recorded from this site. Based on the field observation and evaluation, the reasons to support this statement were the condition of river in Sungai Sayong was continuously threatened by the risk of pollution as this river was surrounded by oil palm plantation and due to the sand mining activities in the surrounding areas affecting the quality of river. From the quantitative data, it shows that low species evenness was recorded due to the presence of several dominant species that occurs in this site.

Despite having the lowest score in terms of conservation values and priority towards conservation, there is still a need for conservation in Sungai Sayong. Disturbance from the expansion of oil palm plantation in this area may impact the forest ecosystems and odonates population. This might be the reason for low diversity and species richness recorded from Sungai Sayong. This could be proven by the presence of several species that are commonly used as indicator for disturbed habitats. The high occurrence of *Neurothemis fluctuans* and *Brachydiplex chalybea* indicate a disturbed habitat (Orr 2005). The other indicator species spotted in this site was *Brachythemis contaminata*. Siregar (2006) reported that the high abundance of *Brachythemis contaminata* indicating a disturbed habitat due to their high tolerance towards disturbances including ability to thrive and survive in high level of acidity in aquatic habitats.

Similarly, Das et al. (2012) stated that *Brachythemis contam*inata is an indicator species that is common in human settlement areas and disturbed habitat. Sungai Sayong is an area located within the village for indigenous people near Kota Tinggi, Johor. Most part of land areas near Sungai Sayong was converted into oil palm and rubber plantation. Therefore, we can conclude that Sungai Sayong is the site with lowest priority towards conservation due to the unfavorable condition for odonate population.

According to Forestry Department of Peninsular Malaysia (2008) the remaining forested land areas in Peninsular Malaysia was 45%. From the statistics, it can be concluded that more than half of the forested land areas has been converted into agricultural farm, oil palm plantation, human settlement areas, urbanization and factories. As stated in Rivera (2000) destruction of habitats and pollution of the aquatic habitats are the main problems towards conservation. In addition, Kummer and Turner (1994) reported that high biodiversity of species was found in tropical rainforest of Southeast Asia and Malaysia (Borneo) is one of the countries in the region that is well known as one of the mega-biodiversity hotspots of the world. Therefore, a proper planning of forest management, pollution control and gazettement of protected areas is crucial for ecosystem monitoring and conservation purposes.

CONCLUSION

This study has shown that the site which is protected under Forestry Department and Johor National Park Corporation has the highest diversity and species evenness. This study has provided the baseline data of odonates in various locations in Johor and updates the previous records in several locations such as Endau-Rompin Johor National Park by Wilson & Gibert (2006) and Gunung Ledang National Park by Maryati et al. (2014). Odonate is an important biological indicator for aquatic ecosystems due to most of their life cycle was in aquatic environment.

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APPENDICES

Table 1 The sampling sites locations and descriptions.

No.	Sites	District	Type of Habitats	Management	Site Descriptions
1.	Taman Negara Johor Gunung Ledang (N 02°20.419' E 102°36.832') Elevation: 211m a.s.l.	Ledang	Mixed dipterocarp forest	Johor National Parks Corporation	Forests streams with slow and fast flowing water; sandy bottom; high shade in several stations. The depth of water is not more than 0.5m. Status: Protected area
2.	Taman Negara Johor Endau-Rompin (N 02°31.901' E 103°25.009') Elevation: 34m a.s.l.	Mersing	Lowland mixed dipterocarp and edaphic hill forest	Johor National Parks Corporation	Forested streams with slow-flowing water; some sunny spots and a lot of vegetation surrounding the aquatic habitats. Status: Protected area
3	Hutan Lipur Gunung Arong (N 02°33.158' E 103°45.334') Elevation: 53m a.s.l.	Mersing	Lowland dipterocarp forest	Forestry Department of Johor	A slow flowing river in the forest with high shade cover and sandy bottom. Some areas with stagnant water bodies and temporary rain pools were also sampled. Status: Protected area
.4.	Hutan Lipur Sungai Bantang (N 02°20.725' E 103°09.378') Elevation: 186m a.s.l.	Bekok	Lowland dipterocarp forest	Forestry Department of Johor	Fast and slow-flowing forest streams with rocks and cobbles; high shade but with some sunny spots. Status: Protected area

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No.	Sites	District	Type of Habitats	Management	Site Descriptions
5.	Hutan Lipur Soga Perdana (N 01°50.899' E 102°57.627') Elevation: 143m a.s.l.	Batu Pahat	Hill dipterocarp forest	Forestry Department of Johor	Open stagnant habitats and forest streams, limited shade; sandy bottom; narrow stream channel with slow-flowing water in forest. Status: Protected area
6.	Hutan Lipur Gunung Belumut (N 02°03.989' E 103°31.547') Elevation: 80m a.s.l.	Kahang	Highland dipterocarp forest	Forestry Department of Johor	Fast-flowing and clear forest streams; wide streams with a lot of vegetation near the streams; sandy and rocky substrates. Status: Protected area
7.	Hutan Lipur Gunung Pulai (N 01°35.465' E 103°31.113') Elevation: 120m a.s.l.	Kulai	Highland dipterocarp forest	Forestry Department of Johor	Clear and fast flowing forest streams; rocky, cobbles and sandy substrates; the streams highly exposed to the sunlight. Status: Protected area
8.	Hutan Lipur Gunung Panti (N 01°47.360' E 103°56.549') Elevation: 48m a.s.l.	Kota Tinggi	Lowland dipterocarp forest	Forestry Department of Johor	Slow-flowing streams; high shade with canopy covers; some sunny spots; muddy and sandy substrates. Status: Protected area
9.	Sungai Sayong, Sayong Pinang (N 01°48.944' E 103°41.480') Elevation: 63m a.s.l.	Kulai	Open areas; degraded habitats near the rubber plantation; second order river	Department of Orang Asli Development	Open and wide river; depth up to 1m; highly exposed towards sunlight, limited vegetation, sandy substrates. Status: Unprotected

Table 2 Schedule of odonate samplings for each study area.

Sampling sites	Sampling Period		
	1st sampling	**2nd sampling**	**3rd sampling**
Taman Negara Johor Gunung Ledang	3-5 December 2016	24-26 February 2017	25-27 April 2017
Taman Negara Johor Endau-Rompin (PETA)	18-20 November 2016	1-3 April 2017	28-30 July 2017
Hutan Lipur Gunung Arong	16-18 January 2017	29 June-1 July 2017	6-8 August 2017
Hutan Lipur Sungai Bantang	2-4 January 2017	14-16 May 2017	11-13 July 2017
Hutan Lipur Soga Perdana	24-26 December 2016	8-10 January 2017	21-23 April 2017
Hutan Lipur Gunung Belumut	24-26 March 2017	6-8 May 2017	20-22 June 2017
Hutan Lipur Gunung Pulai	19-21 August 2017	14-16 September 2017	11-13 October 2017
Hutan Lipur Gunung Panti	5-7 July 2017	10-12 August 2017	11-13 September 2017
Sungai Sayong, Sayong Pinang	21-23 July 2017	26-28 August 2017	26-28 September 2017

Table 3 The species composition of odonates from nine selected sites in Johor.

Suborder	**Families**	**No.**	**Species**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**TOTAL**
Zygoptera	Devadattidae	1	*Devadatta argyoides* Selys 1859	6	0	0	15	0	3	5	0	2	**31**
	Calopterygidae	2	*Neurobasis chinensis* Linnaeus 1758	0	40	0	0	0	0	0	0	0	**40**
		3	*Vestalis amethystina* Lieftinck 1965	0	0	0	1	0	0	0	0	0	**1**
		4	*Vestalis amoena* Selys 1853	16	27	0	12	11	0	21	0	1	**88**
		5	*Vestalis gracilis* Rambur 1842	0	0	0	0	0	0	0	0	5	**5**
	Chlorocyphidae	6	*Aristocypha fenestrella* Rambur 1842	13	0	0	17	1	0	1	0	0	**32**
		7	*Heliocypha biforata* Selys 1859	17	18	0	5	8	0	0	0	35	**83**
		8	*Heliocypha perforata* Selys 1879	5	5	0	0	0	0	0	0	0	**10**
		9	*Libellago hyalina* Selys 1859	0	0	7	0	0	0	0	0	0	**7**
		10	*Libellago lineata* Burmeister 1839	0	0	2	0	0	0	0	57	0	**59**

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Suborder	Families	No.	Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	TOTAL
		11	*Sundacypha petiolata* Selys 1859	0	0	0	0	0	0	4	0	0	**4**
	Euphaeidae	12	*Dysphaea dimidiata* Selys 1853	4	19	0	0	0	0	0	0	0	**23**
		13	*Euphaea impar* Selys 1859	6	9	0	13	2	5	18	0	13	**66**
		14	*Euphaea ochracea* Selys 1859	45	14	0	6	0	0	15	0	0	**80**
	Lestidae	15	*Lestes praemorsus* Kirby 1893	0	0	0	0	0	0	0	3	0	**3**
	Argiolestidae	16	*Podolestes orientalis* Selys 1862	0	0	0	0	2	0	0	0	0	**2**
	Philosinidae	17	*Rhinagrion macrocephalum* Selys 1862	0	1	0	0	0	0	18	0	0	**19**
	Coenagrionidae	18	*Archibasis viola* Lieftinck 1949	0	0	0	0	0	1	0	0	0	**1**
		19	*Agriocnemis nana* Laidlaw 1914	0	0	2	0	0	0	0	2	0	**4**
		20	*Argiocnemis rubescens* Selys 1877	2	0	0	0	0	0	4	1	0	**7**
		21	*Ceriagrion cerinorubellum* Brauer 1865	0	0	0	0	2	2	11	5	0	**20**
		22	*Ischnura senegalensis* Rambur 1842	0	0	0	0	0	0	0	1	0	**1**
		23	*Pericnemis stictica* Selys 1863	0	0	0	0	0	1	0	0	0	**1**
		24	*Pseudagrion microcephallum* Rambur 1842	0	0	2	0	0	10	0	5	2	**19**
		25	*Pseudagrion pruinosum* Burmeister 1839	0	2	0	0	0	0	1	0	11	**14**
		26	*Pseudagrion rubriceps* Selys 1876	0	1	0	2	0	0	0	9	0	**12**
	Platycnemididae	27	*Coeliccia albicauda* Forster 1907	1	0	0	4	2	0	7	0	0	**14**
		28	*Coeliccia didyma* Selys 1863	2	0	0	0	0	0	0	0	0	**2**
		29	*Coeliccia octogesima* Selys 1863	2	0	0	0	3	0	0	0	0	**5**
		30	*Copera marginipes* Rambur 1842	0	0	3	1	2	1	6	0	0	**13**
		31	*Copera vittata* Selys 1863	0	0	0	0	4	0	0	0	0	**4**
		32	*Indocnemis orang* Forster 1907	1	0	0	3	0	0	2	0	0	**6**
		33	*Prodasineura collaris* Selys 1860	0	0	0	0	10	0	0	0	0	**10**
		34	*Prodasineura humeralis* Selys1860	0	5	0	5	11	1	0	5	9	**36**
		35	*Prodasineura laidlawii* Forster 1907	8	0	14	30	5	0	24	0	0	**81**
		36	*Prodasineura notostigma* Selys1860	0	0	12	2	0	9	6	0	0	**29**
	Platystictidae	37	*Drepanosticta fontinalis* Lieftinck 1937	0	0	0	0	0	16	0	0	0	**16**
		38	*Drepanosticta quadrata* Selys 1860	2	0	0	1	0	1	0	0	1	**5**
		39	*Protosticta foersteri* Laidlaw 1902	1	0	0	0	0	0	0	0	0	**1**

Anisoptera	Gomphidae	40	*Ictinogomphus decoratus* Selys 1858	0	0	1	0	24	2	5	12	0	**44**
		41	*Megalogomphus sumatranus* Kruger 1899	0	3	0	0	0	0	0	0	0	**3**
		42	*Paragomphus capricornis* Forster 1914	0	0	0	0	0	0	0	0	1	**1**
	Aeshnidae	43	*Gynacantha limbalis* Karsh 1892	0	0	1	0	0	0	0	0	0	**1**
		44	*Gynacantha subinterrupta* Rambur 1842	0	0	0	5	2	0	0	0	0	**7**
		45	*Heliaeschna crassa* Kruger 1899	1	0	0	0	1	0	0	0	0	**2**
		46	*Indaeschna grubaueri* Forster 1904	1	0	0	1	0	0	0	0	0	**2**
		47	*Oligoaeschna foliacea* Lieftinck 1968	0	0	0	1	0	0	0	0	0	**1**

Suborder	**Families**	**No.**	**Species**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**TOTAL**
	Libellulidae	48	*Aethriamanta brevipennis* Rambur 1842	0	0	0	0	0	0	0	3	0	**3**
		49	*Agrionoptera insignis* Rambur 1842	1	3	1	1	1	0	0	2	0	**9**
		50	*Agrionoptera sexlineata* Selys 1879	0	0	0	0	3	0	0	0	0	**3**
		51	*Brachydiplax chalybea* Brauer 1868	0	0	10	0	17	1	5	21	0	**54**
		52	*Brachydiplax farinosa* Kruger 1902	1	0	0	0	0	0	0	0	0	**1**
		53	*Brachythemis contaminata* Fabricius 1793	0	0	0	0	0	0	0	3	0	**3**
		54	*Camacinia gigantea* Brauer 1867	0	0	0	1	0	0	0	0	0	**1**
		55	*Cratilla metallica* Brauer 1878	8	23	11	3	8	0	7	0	2	**62**
		56	*Crocothemis servilia* Drury 1770	0	0	0	0	0	1	0	0	0	**1**
		57	*Diplacodes trivialis* Rambur 1842	0	2	16	0	1	0	0	1	0	**20**
		58	*Hydrobasileus croceus* Brauer 1867	0	0	0	0	0	0	2	0	0	**2**
		59	*Lathrecista asiatica* Fabricius 1798	2	2	10	7	7	0	1	5	1	**35**
		60	*Lyriothemis biappendiculata* Selys 1878	1	0	0	0	0	0	0	0	0	**1**
		61	*Lyriothemis cleis* Brauer 1868	0	1	0	0	0	0	0	0	0	**1**
		62	Macrodiplex cora Brauer 1867	0	0	0	0	0	0	0	0	1	**1**
		63	*Nannophya pygmaea* Rambur 1842	0	0	1	0	0	0	20	12	0	**33**
		64	*Neurothemis fluctuans* Fabricius 1793	12	13	32	24	32	16	19	28	11	**187**
		65	*Orchithemis pulcherrima* Brauer 1878	1	0	2	0	12	0	0	1	0	**16**
		66	*Orthetrum chrysis* Selys 1891	28	17	14	33	18	32	11	17	14	**184**
		67	*Orthetrum glaucum* Brauer 1865	24	5	0	22	0	2	2	2	7	**64**

68	*Orthetrum sabina* Drury 1770	2	2	24	0	14	4	0	20	8	**74**
69	*Orthetrum testaceum* Burmeister 1839	7	4	4	4	3	27	5	4	5	**63**
70	*Pantala flavescens* Fabricius 1798	0	6	6	0	15	1	7	10	15	**60**
71	*Potamarcha congener* Rambur 1842	1	5	0	1	2	0	0	22	0	**31**
72	*Pseudothemis jorina* Forster 1904	0	0	0	0	2	4	0	0	1	**7**
73	*Rhodothemis rufa* Rambur 1842	0	0	0	0	0	0	0	1	0	**1**
74	*Rhyothemis obsolescens* Kirby 1889	0	0	0	0	1	0	4	2	0	**7**
75	*Rhyothemis phyllis* Sulzer 1776	6	2	8	0	14	0	3	10	5	**48**
76	*Rhyothemis pygmaea* Brauer 1867	0	0	1	0	0	0	0	0	0	**1**
77	*Rhyothemis triangularis* Kirby 1889	0	0	0	0	0	0	5	4	0	**9**
78	*Tetrathemis platyptera* Selys 1878	0	0	0	0	1	0	0	0	0	**1**
79	*Tramea transmarina* Selys 1878	0	1	2	1	0	0	0	5	12	**21**
80	*Trithemis aurora* Burmeister 1839	3	27	23	20	11	8	15	5	29	**141**
81	*Trithemis festiva* Rambur 1842	8	1	1	14	0	1	2	0	32	**59**
82	*Tyriobapta torrida* Kirby 1889	0	2	15	1	14	43	7	4	0	**86**
83	*Urothemis signata* Selys 1872	6	0	0	1	0	0	0	0	0	**7**
84	*Zygonyx iris Laidlaw* 1902	0	0	0	0	0	0	0	10	0	**10**
	TOTAL	**244**	**261**	**225**	**257**	**266**	**191**	**263**	**292**	**223**	**2222**

(S1: Taman Negara Johor Gunung Ledang; S2: Taman Negara Johor Endau-Rompin; S3: Hutan Lipur Gunung Arong; S4: Hutan Lipur Sungai Bantang; S5: Hutan Lipur Soga Perdana; S6: Hutan Lipur Gunung Belumut; S7: Hutan Lipur Gunung Pulai; S8: Hutan Lipur Gunung Panti; S9: Sungai Sayong)

Table 4 The Shannon Diversity Index (H') and Evenness Index (E) value.

Site	**Shannon Index (H')**	**Evenness Index (E)**
Taman Negara Johor Gunung Ledang	2.905	0.5709
Taman Negara Johor Endau-Rompin (Peta)	**3.155**	**0.7326**
Hutan Lipur Gunung Arong	2.851	0.6408
Hutan Lipur Sungai Bantang	2.922	0.5465
Hutan Lipur Soga Perdana	**2.444**	**0.5008**
Hutan Lipur Gunung Belumut	2.855	0.5790
Hutan Lipur Gunung Pulai	2.695	0.6169
Hutan Lipur Gunung Panti	3.131	0.6544
Sungai Sayong	2.962	0.5861

Table 5 The priority setting of sampling sites using grid score analysis.

Site / Criterion	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
H'	2.905 (5)	3.155 (9)	2.851 (3)	2.922 (6)	2.444 (1)	2.855 (4)	2.695 (2)	3.131 (8)	2.962 (7)
E'	0.571 (3)	0.733 (9)	0.641 (7)	0.547 (2)	0.501 (1)	0.580 (4)	0.617 (6)	0.654 (8)	0.586 (5)
Endemicity	1 Endemic sp. (8)	-	-	2 Endemic sp (9)	1 Endemic sp. (8)	1 Endemic sp. (8)	1 Endemic sp. (8)	-	-
Habitat (Water bodies)	(6)	(9)	(3)	(8)	(4)	(7)	(5)	(1)	(2)
Safety	(9)	(7)	(7)	(7)	(9)	(7)	(7)	(6)	(5)
Reliability of sightings	(8)	(9)	(7)	(8)	(9)	(7)	(6)	(7)	(8)
Accessibility	(7)	(9)	(9)	(8)	(9)	(8)	(9)	(9)	(8)
Score	46	52	36	48	41	45	43	39	35
Rank	**3**	**1**	**8**	**2**	**6**	**4**	**5**	**7**	**9**

(S1: Taman Negara Johor Gunung Ledang; S2: Taman Negara Johor Endau-Rompin; S3: Hutan Lipur Gunung Arong; S4: Hutan Lipur Sungai Bantang; S5: Hutan Lipur Soga Perdana; S6: Hutan Lipur Gunung Belumut; S7: Hutan Lipur Gunung Pulai; S8: Hutan Lipur Gunung Panti; S9: Sungai Sayong