# Diversity and Habitat Preferences of Dragonflies (Order: Odonata) in Selangor, Peninsular Malaysia

Noorhidayah-Mamat (1), Norma-Rashid Y (1,2), Zulqarnain Mohamed (1)

(1) Institute of Biological Science, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

(2) Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138

Corresponding author. Phone : +6012-3517507,

E-mail : nhidayahm@siswa.um.edu.my

**Abstract**

A rich collection of 1298 individuals belonging to 54 species from 9 families of Odonata were successfully collected in Selangor. Anisopterans (701 individuals) were found to be more abundant than Zygopterans (597 individuals). Libellulidae (Suborder: Anisoptera) was the most abundant family of odonates in Selangor with 49.11% recorded. Frequency distribution of species showed that *Euphaea ochracea* was the most abundant followed by *Neurobasis chinensis* and *Neurothemis fluctuans*. Preference habitat of odonates was tropical lowland rainforest (TLR) area where high species diversity was found compared to the open areas (OP). This was supported by the higher richness index (R) value in the TLR of 7.26 compared to the OP with 4.46. Similarly, diversity indices (H') and evenness indices (R) showed higher values in TLR with 3.22 and 0.8 than in the OP with 2.83 and 0.7.

**Keywords**: Odonata, diversity, distribution, preference habitat, Selangor

## 1. Introduction

Dragonflies (Odonata) are one group which is known as taxonomically tractable with a wide range of mobility and levels of endemism, and occur across a wide geographical area (Samways et al., 2011). They are valuable focal organisms for studying and investigating many ideologies in contemporary ecological and evolutionary theory (Cordoba-Aguilar, 2008). Studies on aspects of dragonfly ecology posed quite a challenge because of their great mobility capacity (Kiyoshi & Sota, 2006). Reports of species diversity and taxonomic novelty have been dynamic which is evident from the many articles published up to date.

Kalkman et al. (2008) reported a total of 5680 species of Odonata known to exist worldwide which comprised of 2739 species belonging to the suborder Zygoptera and 2941 species to the suborder Anisoptera. A speculative estimation by Tennessen (1997) indicated that there are less than 10000 extant species of Odonata. However in Malaysia, according to Orr et al. (2004), the fauna comprised of 342 named species, in which 239 species were recorded from Sabah, Sarawak and Brunei, and 226 species from the Peninsular Malaysia including Singapore. Among this order, 161 species belonged to Zygoptera with 88 families and 5 family groups of Anisoptera comprised of 181 species.

Odonates are known to exploit a wide range of aquatic habitats and they are characterized as excellent habitat indicators due to their complex habitat requirements in specific species (Corbet, 1999). Identifying the habitat types based on species presence has potential applications both in terms of choosing and assessing the species as indicators (Sato & Riddiford, 2007). Orr (2003) and Watanabe et al. (2004) stated that many species of Odonata are restricted to specific habitats both during larval and adult life stages especially the stenotopic species (limited to a single habitat). They are highly sensitive to factors such as the amount of sunlight and water movements. A study by Hawking and New (2002) indicated that observing and monitoring the abundant resident species of odonates may be important for identifying the early decline of a habitat, whereas observing and monitoring the rare species of odonates can be suggestive of relict or undisturbed surroundings and this can be used to rate the importance of a site (Eyre et al., 1986).

Thus changes within the habitat structures as for example forest clearing or human structural development would affect the presence of odonate diversity or distribution. It is the aim of this study to investigate the composition and abundance of odonate community in the Selangor state where development is at a fast phase, especially when here is where the Capital City of Malaysia, Kuala Lumpur is strategically located. The outcome of the work can assist for example policy makers, environmentalist or conservationists in their continuous effort to maintain the integrity of the environment.

## 2. Materials & Methods

### *2.1 Sampling sites*

The collections were carried out in targeted areas of Selangor state to reflect representative samples from Selangor, including the federal territories of Kuala Lumpur (3$^{o}$ 8' 8.52" N 101$^{o}$ 41' 16.8" E) and Putrajaya (2$^{o}$ 55' 00" N 101$^{o}$ 40' 00" E). The sampling sites were categorized into two main types:

(1) open areas (OA) - these covered distinctive habitats utilized by dragonflies such as at the stagnant waters which included ponds, swampy areas, marshy areas, paddy field or drains

(2) tropical lowland rainforest (TLR) – these covered typical habitats for odonates for instance flowing waters which included streams, rivers and tributaries.

The specific locations and the descriptions for each site are shown in the Table 1, while Figure 1 shows the mapping sites.

### *2.2 Sampling methods*

Methods for sampling of Odonata were based on Orr (2004) and Borror & White (1970). Specimens were caught with a light but strong insect net on hot sunny days between the time periods 10:00 to 15:00. Sufficient prior practice was done by the collector to acquire the skill of netting the dragonflies using suitable swing speed and angles. The specimens caught were placed in the triangle envelope with the wings folded together above the body and relevant information was written on the outside of the envelope.

For preservation purpose, the dragonflies were soaked in the acetone for about 8-12 hours, depending on size and damselflies for 4 hours (Mark, 1999). Then the specimens were pinned on pinning board for best results, all the legs were arranged so as not to obscure the genitalia located on the second abdominal segment of males. All the specimens were then thoroughly dried in the oven at 35$^{o}$ C overnight before storage, which were later deposited and catalogued in the collection, Museum of Zoology, University of Malaya and given specific catalogue numbers.

*2.3 Data analysis*

Shannon Wiener Index was used to measure the diversity of dragonflies and damselflies that have been collected in all the sampling sites.

Species Diversity: H'

This index indicates the degree of species composition per unit area. The higher value of H', the greater diversity and reflecting a better habitat quality (Ludwig & Reynolds, 1988; Metcalfe, 1989).

Where; $H' = - \sum [( ni / N) \ln (ni / N)]$

H'= Shannon Wiener Index
N = Total individuals of population sampled
ni = Total individuals belonging to the species i

Richness Index: R

This richness index used was Margalef's Index (R). The index indicates the number of species in a sample or the abundance of the species per unit area. . (Ludwig & Reynolds, 1988; Metcalfe, 1989).

Where; $R = S – 1 / \ln (N)$

R1 = Margalef richness Index
S = Total of species
N = Total of individuals sampled

Evenness Index: E

This index indicates the homogeneity or pattern of the distribution of species in relation to the other species per unit area. (Ludwig & Reynolds, 1988; Metcalfe, 1989).

Where; $E = H' / H'$ max

E = Evenness Index
H' = Shannon-Wiener diversity Index
H' max = Diversity Index observed to a maximum diversity

The statistical analyses that were used to analyze the data were ANOVA for multi-variate analysis and T-test for paired comparisons using the software SPSS 20.0 (Statistical Package for Social Science version 20.0). All p-values less than 0.05 were considered significant and above that not significant (NS).

## 3. Results & Discussion

*3.1 Diversity and Distribution of Odonata in Selangor*

Fifty-four known odonate species were found in twenty-two localities within the state of Selangor from this work. A total of 1298 individuals were collected from nine families of suborder Anisoptera and Zygoptera (Figure 2).

Table 2 shows the composition of family groups in descending percentages were in the order of: Libellulidae (49.11%), Chlorocyphidae (14.96%), Calopterigidae (11.64%), Euphaeidae (11.38%), Calopterygidae (10.71%), Coenagrionidae (2.90%), Platycnemididae (2.68%), Aeshnidae (2.23%) Protoneuridae (0.67%) and Amphiterygidae (0.22%). Not surprising, Libellulidae was the largest family comprised of 29 species in contrast to Protoneuridae which was represented with only 2 species. Based on the one way Analysis of Variance (ANOVA), there was no significant difference in the total abundance of the odonates community in all the study sites [$F(1,76) = 0.12$, $p = 0.73$; NS].

Previous work had reported the common occurance of Libellulidae, for example a study recently in presenting a new records of dragonflies in the southern lowland of New Guinea, which was done by Keize and Kalkman (2011) at Papua, Indonesia, reported that the two largest families were Libellulidae and Coenagrionidae. These two families were dominating the unshaded habitats of stagnant waters which included a species with the greatest migratory capacity, *Pantala flavescens*. Another study conducted by Norma-Rashid (2010) at the coastal and surrounding areas, in Peninsular Malaysia, found that Libellulidae was the highest number of species that made up 75% of the samplings while family Coenagrionidae was the second largest representative. Libellulidae had frequently been reported to be the predominant family in odonate diversity studies (Lim & Furtado, 1975; Asahina, 1993; Hamalainen, 1994; Gupta et al., 1995; Norma-Rashid, 1995a, 1995b, 1998, 1999; Norma-Rashid et al., 2001; Subramanian et al., 2008). . The abundance of Libellulidae and Coenagrionidae in the present study might be also due to their shorter life cycles and tolerant to the wide range of habitats (Gentry et al., 1975; Norma-Rashid et al., 2001; Samways, 1989).

Table 3 represented the assessment of the species status categorized as: very abundant to very rare as described in the ascending order of total numbers for such groupings. Majority of the collections comprised of the species, *Neurobasis chinensis* and *Euphaea ochracea*, while the subsequent 5 species which were considered as abundant were *Zygonyx iris, Trithemis festiva, Aristocypha fenestrella, Trithemis aurora* and *Neurothemis fluctuans*. Other species caught were considered as very rare, rare, scarce and common species in the study sites.

*Euphaea ochracea* had been known to exist in forest streams, rivers or near waterfall, and they mostly breed in running water (Lok & Orr, 2009). On the other hand, *Neurobasis chinensis* were found in moderate to swift flowing clear forest streams (Orr & Hamalainen, 2007) with a wide distribution pattern in South-East Asia (Hamalainen, 1994). However, *Neurothemis fluctuans*, had been reported by Norma-Rashid (2010) to be more widespread commonly found in the open ponds and also reported to be one of the most common species found in Malaysia (Lieftinck, 1954; Norma-Rashid et al., 1996). Shelton & Edward (1983) explained that the common species had more individuals compared to the rare species due to their ability to survive in the existing environmental conditions.

In terms of number of individuals, the suborder Anisoptera recorded was 701, while Zygoptera, 597. This would not be unusual as anisopterans were noted for their high dispersal ability (Batzer & Wissinger, 1996; Williams, 1997; Lawler, 2001; Kadoya et al., 2004; Arulprakash & Gunathilagaraj, 2010) and their adaptability to the wide range of habitats (Hodgkin & Watson, 1958; Suhling et al., 2004, 2005). Likewise, the less abundant zygopterans was probably due to their limited dispersal patterns (Weir, 1974) and intolerant to the variable micro-environmental factrs provided by the temporary water bodies (Williams, 1997; Kadoya et al., 2004).

### *3.2 Habitat Distribution of Odonata in Selangor*

This study revealed that the highest number and species recorded across all the site localities were for site locality SS7 in which contained 12 species with 159 total numbers of individuals. In contrast, SS22 had the lowest count. The high species diversity in SS7 areas could be due to the presence of rivers and forest streams (Figure 3) and may also be attributed to the availability of many different microhabitats for the species to thrive and divide themselves spatially, this was supported by the studies done by MacArthor (1965) who stated that high species abundance was related to diversification in ecosystems.

In addition, Table 2 shows the species composition of Odonata in the tropical lowland rainforest (TLR) with a higher number of species compared to the open area (OA) due to the complexity of landscape provided by the TLR areas not only in terms of vegetation structure but also bottom substrate, water flow, canopy cover and other variable physical parameters. Hawking & New (1999) reported that the habitat structures affected the odonate community within an area and other factors such as physical-chemical parameters of the rivers, or availability of the food sources had impacts on the distribution of the odonates (Furse et al., 1984; Askew, 1988). TLR was found to be higher in species abundance in contrast to OP (t-test: T (50) = -2.004, p=0.051).

The biological indices indicated that the richness of the species between the two categories of the study sites supported the findings (Figure 4). TLR demonstrated the highest value of richness index (R) with 7.26 compared to OA with only 4.46. This R index refers to the different species of Odonata in that certain area representing the observed species richness in an ecosystem, it is usually referred to as species density. However, this R index was a measure on its own, and it took no account of the number of individuals of each species present. It gave as much weight to those species represented with few individuals as to those with higher individuals. The diversity index, H index was higher for TLR areas in contrast to the OP areas which was 3.22 and 2.83 respectively. This index offered information on community composition and structure rather than simply species richness which also take into account the relative abundances of different species. The evenness index (E) values at TLR: 0.81 and OP: 0.71 which is a measure of the relative abundance or proportion of individuals among the species.

Many authors (Gaufin, 1973; Hawkes, 1979; Teles, 1994) believed that the indices of diversity could give better information implications about the environmental conditions under which the organism live than by considering individual sole taxon. The results from the current work found higher richness index (R) value in the tropical lowland rainforest compared to the open areas. Similarly, diversity indices (H') showed higher value in the tropical lowland rainforest than in the open areas.

## 4. Conclusion

The results of diversity and distribution of odonates reported here would be useful to various agencies in their monitoring services and conservation efforts. This is because the possible disappearance of certain species in the area may implicate habitat destruction of which some of the causal factors as listed in the Malaysian Wetland Directory (1987) were: shifting cultivation, possible pollution, destruction of watershed, logging operations, errosional and siltation that could have occurred. The understanding of ecology, habitat use and diversity of odonate communities in different land use types is very important in developing a bio monitoring technique.

Moreover, the presence of the odonates is generally perceived to indicate a healthy ecosystem (Corbet, 1999, Carle, 1979; Moore, 1984; Schmidt, 1985; Castella, 1987; Clark & Samways, 1996) and this group had already been identified to be 'flagships' within the field of conservation biology (Sahlén & Katarina, 2001).

Global changes and principally climate warming are likely to have various impacts on Odonata and this may lead to many of the species extending their geographical range.. Thus, the presence or absence of certain species would mirror

human activities surrounding the water habitats whether as positive or negative impacts (Rith-Najarian, 1998; Sahlén, 1999).

## 5. Acknowledgements

This research was financed by IPPP, University of Malaya and supported by the research grants PS 286/2010A PPP from University of Malaya. The first author acknowledges National Science Fellowship (NSF) under the Ministry of Science, Technology and Innovation, Malaysia for financial support.

## References

Asahina S. (1993). A list of the Odonata from Thailand: Parts I – XXI. Editor. A. Pinratana. Bangkok: Bosco Offset.

Askew R. R. (1998). The Dragonflies of Europe: Harley Books. 291p.

Borror D. J., & White R. E. (1970). A field guide to insects: America North of Mexico. Boston, MA: Houghton Mifflin Company.

Carle F. L. (1979). Environmental monitoring potential of the Odonata, with a list of rare and endangered Anisoptera of Virginia, USA. *Odonatologica*, 8, 319 – 323

Castella E. (1987). Larval Odonata distribution as a describer of fluvial ecosystems: the Rhône and Ain Rivers, France. *Advances in Odonatology,* 3, 23 – 40

Clark T. E., & Samways M. J. (1996). Dragonflies (Odonata) as indicators of biotope quality in the Krüger National Park, South Africa. *Journal of Applied Ecology*, 33(1), 1001- 1012

Corbet P. S. (1999). Dragonflies: Behaviour and Ecology of Odonata. Colchester, UK : Harley Books

Córdoba-Aguilar A. (2008). Dragonflies: Model organisms for ecological and evolutionary research. Editor. Oxford University Press. UK: Oxford

Eyre M. D., Ball S. G., & Foster G. N. (1986). An initial classification of the habits of aquatic Coleoptera in North-east England. *Journal Applied Ecology*, 23, 841 – 852

Furse M. T., Morse D., Wright J. F., & Armitage P. D. (1984). The influence of seasonal and taxonomic factors on the prediction to their macro-invertebrate communities. *Freshwater Biology,* 14, 257 – 280

Gaufin A. R. (1973). Use of aquatic invertebrates in the assessment or water quality. In: Cairns JJ, Dickson KL, editors. Biological methods for the assessment of waters quality. Philadelphia: American Society for Testing and Materials. p 96 – 116

Gupta I. J., De M. L., & Mitra T. R. (1995). Conspectus of Odonata fauna of Calcutta, India. *Rec Zoological Survey of India*, 95, 107 – 121

Hamalainen M. (1994). Dragonflies of Mount Kinabalu (the highest mountain in Borneo). *Malangpo*, 11, 77 – 81

Hawkes H. A. (1979). Invertebrates as indicators of river quality. In: James A, Evison L, editors. Biological Indicators of Water Quality. (Chichester: John Wiley and Sons)

Hawking J. H., & New T. R. (1999). The distribution patterns of dragonflies (Insecta: Odonata) along the Kiewa River, Australia, and their relevance in conservation assessment. *Hydrobiologia*, 392, 249 – 260

Hawking J. H., & New T. R. (2002). Interpreting dragonfly diversity to aid in conservation assessment: lessons from the Odonata assemblage at Middle Creek, north eastern Victoria, Australia. *Journal Insect Conservation*, 6, 171 – 178

Kaize J., & Kalkman V. J. (2011). Records of dragonflies (Odonata) from Kabupateb Asmat and Kabupaten Mappi (Papua, Indonesia). *Suara Serangga Papua*, 5, 99 – 107

Kalkman V. J., Clausnitzer V., Dijkstra K.- D. B., Orr A. G., Paulson D. R., & van Tol J. (2008). Global diversity of dragonflies (Odonata) in freshwater. *Hydrobiologia*, 595, 351 – 363

Kiyoshi T., & Sota T. (2006). Differentiation of the dragonfly genus *Davidus* (Odonata: Gomphidae) in Japan inferred from mitochondrial and nuclear gene genealogies. *Zoological Science*, 23, 1 – 8

Lieftinck M. A. (1954). Handlist of Malaysian Odonata. *Treubia*, 22, 1- 202

Lim R. P., & Furtado J. I. (1975). Population changes in the aquatic fauna inhabiting the bladderwort,Utricularia flexuosa VAHL., in a tropical swamp, Tasek Bera, Malaysia. *Verhandlungen International Verein Limnology*, 19, 1390-1397

Lenat D. R. (1993). A biotic index for Southestern United States: Derivation and lists of tolerance value with criteria for assigning water quality ratings. *Journal of the North American Benthological Society*, 12, 279 – 290

Ludwig J. A., & Reynolds J. F. (1988). Statistical ecology : A primer in method and computing. (John Wiley & Sons. Inc.)

Metcalfe J. L. (1989). Biological water quality assessment of running waters based on micro invertebrates communities: History and present status in Europe. *Environmental Pollution*, 60, 101 – 139

Moore N. W. (1984). Dragonflies as indicators of environmental health. IUCN Species Survival Commission Newsletter 1984: 7 – 8

Norma-Rashid Y. (1995a). Preliminary odonate survey of Perak, Peninsular Malaysia. *Notulae Odonatologicae*, 4, 80-82

Norma-Rashid Y. (1995b). A dynamic encounter with the odonates in Sungai Seliah, Kelantan, Peninsular Malaysia. *Wallaceana*, 76, 17 - 22

Norma-Rashid Y., Zakaria-Ismail M., & Hamalainen M. (1996). Odonate fauna from Kelantan, Pahang and Muar drainages, Malaysia. Paper presented at 5th Nat Biol Symp. UKM, Malaysia

Norma-Rashid Y. (1998). Animal of Malaysia: Dragonflies and damselflies. In: Encyclopedia of Malaysia. *Wildlife of Malaysia,* 3, 104-105

Norma-Rashid Y. (1999). Behavioural ecology of *Tyriobapta torrida* Kirby (Anisoptera: Libellulidae) at the breeding and resting sites. *Odonatologia*, 28**,** 139-150

Norma-Rashid Y., Mohd-Sofian A., & Zakaria-Ismail M. (2001). Diversity and distribution of Odonata (dragonflies and damselflies) in the fresh water swamp lake Tasek Bera, Malaysia. *Hydrobiologia*, 459 (12). 135-146

Norma-Rashid Y. (2010). Dragonflies (Odonata) of Bachok Coast, Kelantan and promoting common names. *Malaysian Journal of Science*, 29, 73-79

Orr A. G. (2003). A guide to the Dragonfly of Borneo: Their identification & biology. Kota Kinabalu (Sabah: Natural History Publication (Borneo) Sdn. Bhd.)

Orr A. G., Butler G. G., Hamalainen M., & Kemp R. G. (2004). Insecta: Odonata. In: Catherine MY, Yong HS, editors. Freshwater invertebrates of the Malaysian region, Academy of Science. pp.409-442

Orr A. G., & Hamalainen M. (2007). The metalwing Demoiselles (Neurobasis and Matronoides) of the Eastern Tropics: Their identification and biology. Natural History Publications, Borneo

Rith-Najarian J. C. (1998). The influence of forest vegetation variables on the distribution and diversity of dragonflies in a northen Minnesota forest landscape: A preliminary study (Anisoptera). *Odonatologica*, 27, 335 – 351

Rehn A. C. (2003). Phylogenetic analysis of higher-level relationships of Odonata. *Systematic Entomology*, 28, 181 – 239

Sahlén G. (1999). The impact of forestry on dragonfly diversity in Central Sweden. *The International Journal of Odonatology*, 2, 177 – 186

Sahlén G., & Katarina E. (2001). Identification of dragonflies (Odonata) as indicators of general species richness in boreal forest lakes. *Biodiversity and Conservation*, 10, 673 – 690

Sarot E. E. E. (1958). Folklore of the Dragonfly: A linguistic approach. Rome: Storia e Letteratura

Samways M. J., Pryke J. S., & Simaika J. P. (2011). Threats to dragonflies on land islands can be as great as those on oceanic islands. *Biological Conservation*, 144, 1145 – 1151

Sato M., & Riddiford N. (2007). A preliminary study of the Odonata of S'Albufera Natural Park, Mallorca:status, conservation priorities and bioindicator potential. *Journal Insect Conservation*, 12(5), 539 – 548

Schmidt E. (1985). Habitat inventarization, characterization and bioindication by a representative spectrum of Odonata species (RSO). *Odonatologica*, 14, 127 – 133

Subramanian K. A., Samir Ali, & Ramachandra T. V. (2008). Odonata as indicators of riparian ecosystem health: A case study from South Western Karnataka, India. *Fraseria (N. S)*, 7, 83 – 95

Teles L. F. O. (1994). A new methodology for biological water quality assessment. *International Association of Theoretical and Applied Limnology*, 25, 1942 – 1944

Tennessen K. J. (1997). The rate of species descriptions in odonata. *Entomological News*, 108, 122 – 126

Ware J., May M., & Kjer K. (2007). Phylogeny of the higher Libelluloidea (Anisoptera: Odonata): An exploration of the most speciose super family of dragonflies. *Molecular Phylogenetic Evolution*, 45(1), 289 – 310

Watanabe M., Matsuoka., & Taguchi M. (2004). Habitat selection and population parameters of *Sympetrum infuscatum* (Selys) during sexual mature stages in a cool temperature zone of Japan (Anisoptera: Libellulidae). *Odonatologica*, 33: 169 – 179

**Tables**

Table 1: Sampling sites descriptions with a global positioning system (GPS).

| | LOCALITIES | DESCRIPTION OF HABITATS | TYPE OF HABITATS | GPS READING |
|---|---|---|---|---|
| **SS1** | **Templer Park Forest Reserve, Rawang, Selangor** | Provided varieties of substrates which consist of stones, rocky, cobbles and sandy. Water surface was covered by canopies of trees and shrubs. Slow and fast flowing water. | Tropical lowland rainforest | 03° 29' 872" N 101° 61' 746" E |
| **SS2** | **Ulu Gombak forest area, Selangor** | An open area in the forest, pond with more sunlight, and bordered by varieties vegetation. | Open area | 03° 18' 619" N 101° 73' 230" E |
| **SS3** | **Ulu Kali, Batang Kali, Selangor** | The flow was relatively fast and has clear water. The river is largely shaded and with some sunny spot. | Tropical lowland rainforest | 03° 43' 526" N 101° 65' 917" E |
| **SS4** | **Sungai Tekali, Hulu Langat, Selangor** | The river was in forested area with fast-flowing and clear water. Rich of substrates like stone and big rocky. | Tropical lowland rainforest | 03° 10' 703" N 101° 85' 805" E |
| **SS5** | **Taman Kemensah, Ampang, Kuala Lumpur** | A small intermittent stream with varieties substrate like sandy and muddy and have more sun and vegetation. | Open area | 03° 21' 416" N 101° 75' 997" E |
| **SS6** | **Ulu Yam, Batang Kali, Selangor** | River in forested area. The flow was relatively fast and with clear water. Consist of stones, rocky and sandy. | Tropical lowland rainforest | 03° 43' 173" N 101° 65' 667" E |
| **SS7** | **Rimba Ilmu, Universiti Malaya, Kuala Lumpur** | Largely shaded area and have clear shallow water. Have some sunny spot and vegetation. | Tropical lowland rainforest | 03° 13' 131" N 101° 65' 727" E |
| **SS8** | **Taman Tasik Shah Alam, Selangor** | Pond, stagnant waters, and totally exposed to the sunlight. Open area. | Open area | 03° 07' 293" N 101° 51' 384" E |
| **SS9** | **Morib, Banting, Selangor** | Swampy habitat with stagnant to slow flowing water. Area was exposed to the sunlight. | Open area | 02° 75' 453" N 101° 44' 811" E |
| **SS10** | **Bukit Gasing, Petaling Jaya, Selangor** | River in forested area. Shallow water with sands and cobbles. The water ran slowly and passing diversified habitats along river. | Tropical lowland rainforest | 03° 09' 657" N 101° 65' 702" E |

| | | | | |
|---|---|---|---|---|
| **SS11** | **Kuala Selangor, Selangor** | Irrigation channels area around the paddy fields. Muddy areas with totally exposed to the sunlight. Open area. | Open area | 03° 33' 497" N 101° 25' 802" E |
| **SS12** | **Sekinchan, Selangor** | Irrigation channels area around the paddy fields. Muddy areas with totally exposed to the sunlight. Open area. | Open area | 03° 50' 981" N 101° 10' 398" E |
| **SS13** | **Tanjong Karang, Selangor** | Irrigation channels area around the paddy fields. Muddy areas with totally exposed to the sunlight. Open area. | Open area | 03° 42' 419" N 101° 18'454" E |
| **SS14** | **Sungai Congkak Forest Reserve, Hulu Langat, Selangor** | Provided varieties of substrates which consist of stones, rocky, cobbles and sandy. Water surface was covered by canopies of trees and shrubs. Slow and fast flowing water. | Tropical lowland rainforest | 03° 20' 925" N 101° 82' 595" E |
| **SS15** | **Sungai Gabai, Hulu Langat, Selangor** | Fast-flowing water in the forest. Have clear water and consist of stones, rocky and cobbles as well as sandy. | Tropical lowland rainforest | 03° 20' 976" N 101° 86' 523" E |
| **SS16** | **Felda Sungai Tengi, Kuala Kubu Baru, Selangor** | Swamps in forest. The water was stagnant to slow flowing and slightly shaded with some sunny spot. | Tropical lowland rainforest | 03° 34' 00" N 101° 39' 00" E |
| **SS17** | **Taman Putra Perdana, Putrajaya** | Open area. The water was stagnant, pond and totally exposed to the sunlight. | Open area | 02° 55' 00" N 101° 40' 00" E |
| **SS18** | **Kampung Baharu Sungai Pelek, Sepang, Selangor** | Small running waters in the forest. The channel was narrow and slow-flowing. | Tropical lowland rainforest | 02° 39' 00" N 101° 43' 00" E |
| **SS19** | **Kampung Sungai Burong, Sabak Bernam, Selangor** | The rivers bordered by the degraded forest, swampy habitat. Slightly exposed to the sunlight. | Tropical lowland rainforest | Data Not Available |
| **SS20** | **Pulau Tengah, Selangor** | Swamps in island and exposed to the sunlight. The water was slow flowing and muddy. | Open area | 02° 56' 283" N 101° 15' 256" E |
| **SS21** | **Pulau Pintu Gedung, Selangor** | The channel was with slow flowing water and very muddy. Exposed to sunlight bordered by vegetation. | Open area | 02° 56' 358" N 101° 15' 515" E |
| **SS22** | **Pulau Klang VGR, Selangor** | A swampy habitat with small running waters in the island. Have more sun and vegetation. | Open area | 03° 36' 558" N 101° 20' 166" E |

**Table 2**: Composition of odonates sampled for each category of study sites in Selangor.

| Family | Species | OA | TLR | Total |
|---|---|---|---|---|
| 1) Aeshnidae | *Gynacantha basiguttata* | 1 | 5 | 6 |
| | *Gynacantha subinterrupta* | 0 | 6 | 6 |
| | *Anax panybeus* | 5 | 4 | 9 |
| | *Gynacantha bayadera* | 1 | 8 | 9 |
| 2) Amphipterygidae | *Devadatta argyoides* | 0 | 3 | 3 |
| 3) Calopterygidae | *Vestalis gracilis* | 0 | 9 | 9 |
| | *Vestalis amethystina* | 5 | 7 | 12 |
| | *Neurobasis chinensis* | 32 | 91 | 123 |
| 4)Chlorocyphidae | *Rhinocypha sp.* | 0 | 6 | 6 |
| | *Rhinocypha biforata biforata* | 0 | 24 | 24 |
| | *Aristocypha fenestrella* | 52 | 38 | 90 |
| | *Heliocypha biforata* | 0 | 6 | 6 |
| | *Libellago stigmatizans* | 0 | 6 | 6 |
| | *Libellago lineata* | 8 | 61 | 69 |
| 5) Coenagrionidae | *Ischnura senegalensis* | 0 | 9 | 9 |
| | *Pseudagrion australasiae* | 9 | 3 | 12 |
| | *Pseudagrion pruinosum* | 0 | 18 | 18 |
| 6) Euphaeidae | *Dysphaea dimidiata* | 6 | 9 | 15 |
| | *Euphaea ochracea* | 36 | 102 | 138 |
| 7) Libellulidae | *Agrionoptera insignis* | 0 | 3 | 3 |
| | *Brachygonia oculata* | 1 | 2 | 3 |
| | *Brachythemis contaminata* | 0 | 3 | 3 |
| | *Lyriothemis cleis* | 0 | 3 | 3 |
| | *Onychothemis coccinea* | 0 | 3 | 3 |
| | *Orthetrum sabina* | 0 | 3 | 3 |
| | *Rhyothemis phyllis* | 0 | 3 | 3 |
| | *Tramea transmarina euryale* | 3 | 0 | 3 |
| | *Brachythemis leucosticta* | 6 | 0 | 6 |
| | *Onychothemis testacea* | 0 | 6 | 6 |
| | *Orchithemis pulcherrima* | 2 | 4 | 6 |
| | *Orthetrum testaceum* | 0 | 6 | 6 |
| | *Pseudothemis* | 0 | 6 | 6 |
| | *Crocothemis servilia* | 9 | 0 | 9 |
| | *Diplocodes nebulosa* | 0 | 9 | 9 |
| | *Orthetrum luzonicum* | 7 | 2 | 9 |

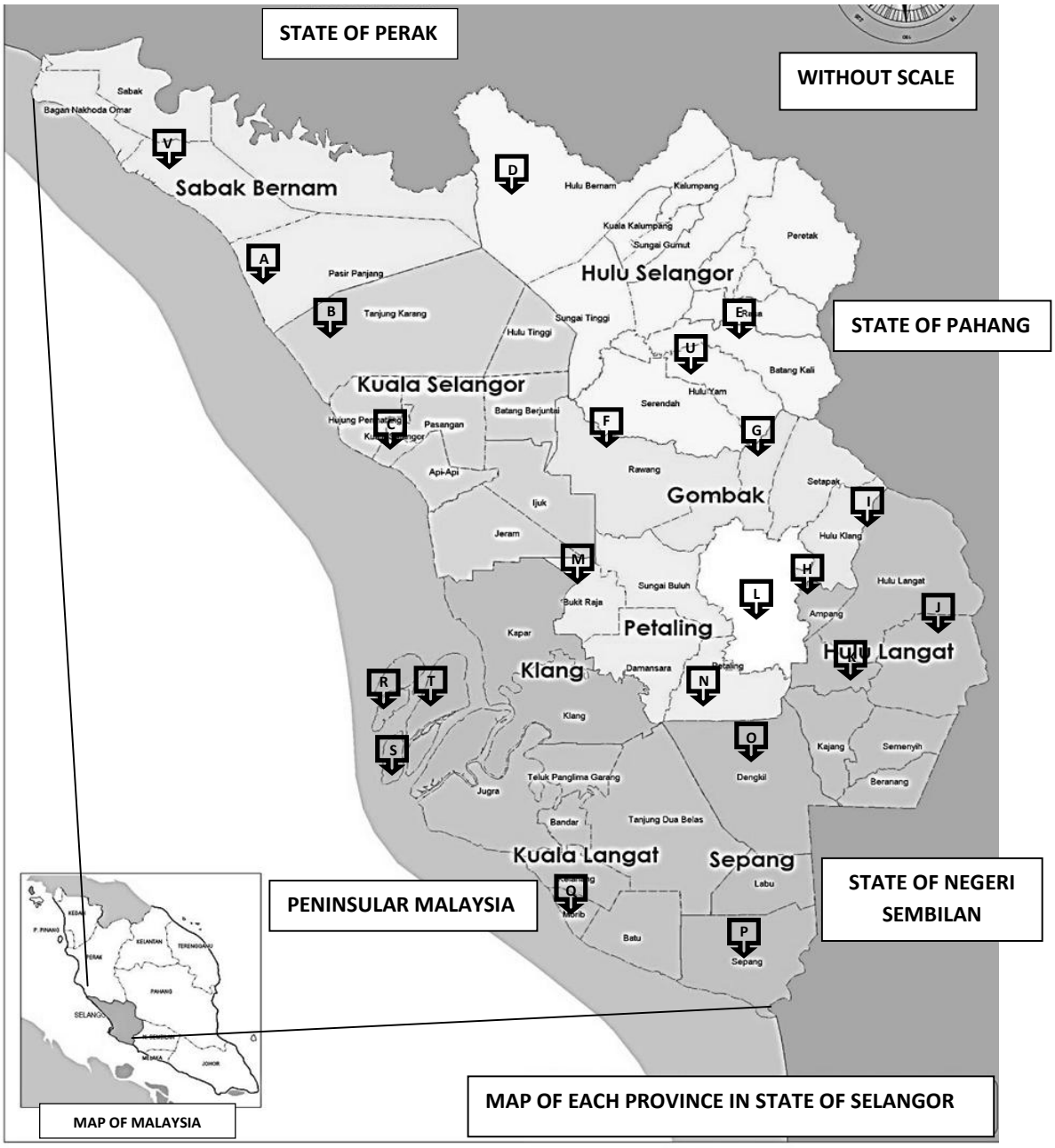
| | | | | |
|---|---|---|---|---|
| | *Rhyothemis obsolescens* | 8 | 1 | 9 |
| | *Tyriobapta laidlawi* | 0 | 9 | 9 |
| | *Diplocodes trivialis* | 3 | 9 | 12 |
| | *Neurothemis terminata* | 12 | 0 | 12 |
| | *Orthetrum glaucum* | 3 | 12 | 15 |
| | *Tyriobapta torrida* | 6 | 15 | 21 |
| | *Aethriamanta gracilis* | 18 | 6 | 24 |
| | *Pantala flavescens* | 17 | 22 | 39 |
| | *Orthetrum chrysis* | 23 | 31 | 54 |
| | *Zygonyx iris* | 15 | 63 | 78 |
| | *Trithemis festiva* | 71 | 13 | 84 |
| | *Trithemis aurora* | 36 | 72 | 108 |
| | *Neurothemis fluctuans* | 30 | 84 | 114 |
| 8) Platycnemididae | *Calicnemia chaseni* | 0 | 3 | 3 |
| | *Copera vittata* | 0 | 9 | 9 |
| | *Coeliccia albicauda* | 0 | 12 | 12 |
| | *Copera marginipes* | 0 | 12 | 12 |
| 9) Protoneuridae | *Prodasineura laidlawii* | 0 | 3 | 3 |
| | *Prodasineura humeralis* | 0 | 6 | 6 |
| | Unidentified | 8 | 15 | 23 |
| | **Total individuals** | **433** | **865** | **1298** |

**Table 3**: Assessment of species status deduced from the total number of individuals collected from Selangor.

| Status indicated | Range of individual numbers | Total species | Species names |
|---|---|---|---|
| **Very rare** | 1 – 3 | 11 | *A. insignis, B. oculata, B. contaminate, L. cleis, O. coccinea, O. Sabina, R. Phyllis, T. transmarina Euryale, C. chaseni, D. argyoides, P. laidlawii* |
| **Rare** | 4 – 10 | 21 | *G. basiguttata, G. subinterrupta, B. leucosticte, O. testacea, O. pulcherrima, O. testaceum, Pseudothemis, H. biforata, L. stigmatizans, P. humeralis, Rhinocypha sp., A. panybeus, G. bayadera, C. servilia, D. nebulosa, O. luzonicum, R. obsolescens, T. laidlawi, C. vittata, I. senegalensis, V. gracilis* |
| **Scarce** | 11 – 30 | 12 | *D. trivialis, N. terminate, C. albicauda, C. marginipes, P. australasiae, V. amethystina, O. glaucum, D. dimidiate, P. pruinosum, T. torrida, A. gracilis, R. biforata biforata* |
| **Common** | 31 – 70 | 3 | *P. flavescens, O. chrysis,L. lineata* |
| **Abundant** | 71 – 120 | 5 | *Z. iris, T. festiva, A. fenestrella, T. aurora N. fluctuans* |
| **Very abundant** | > 120 | 2 | *N. chinensis, E. ochracea* |

## Figures

**Figure 1**: Distribution Study – Sampling Sites. A map showing the locality distributions of the sampling sites.



**A:** Sekinchan, **B:** Tanjong Karang, **C:** Kuala Selangor, **D:** Felda Sungai Tengi, Kuala Kubu Baru, **E:** Ulu Kali, Batang Kali, **F:** Templer Park, Rawang, **G:** Ulu Gombak, **H:** Taman Kemensah, Ampang, **I:** Sungai Congkak, Hulu Langat, **J:** Sungai Gabai, Hulu Langat, **K:** Sungai Tekali, Hulu Langat, **L:** Rimba Ilmu, Universiti Malaya, **M:** Taman Tasik, Shah Alam, **N:** Bukit Gasing, Petaling Jaya, **O:** Taman Putra Perdana, Putrajaya, **P:** Kampung Baharu Sungai Pelek, Sepang, **Q:** Morib, Banting, **R:** Pulau Tengah, **S:** Pulau Pintu Gedung, **T:** Pulau Klang VGR, **U:** Ulu Yam, Batang Kali, **V:** Kampung Sungai Burong, Sabak Bernam.

**Figure 2**: Percentage number of families for all species sampled.

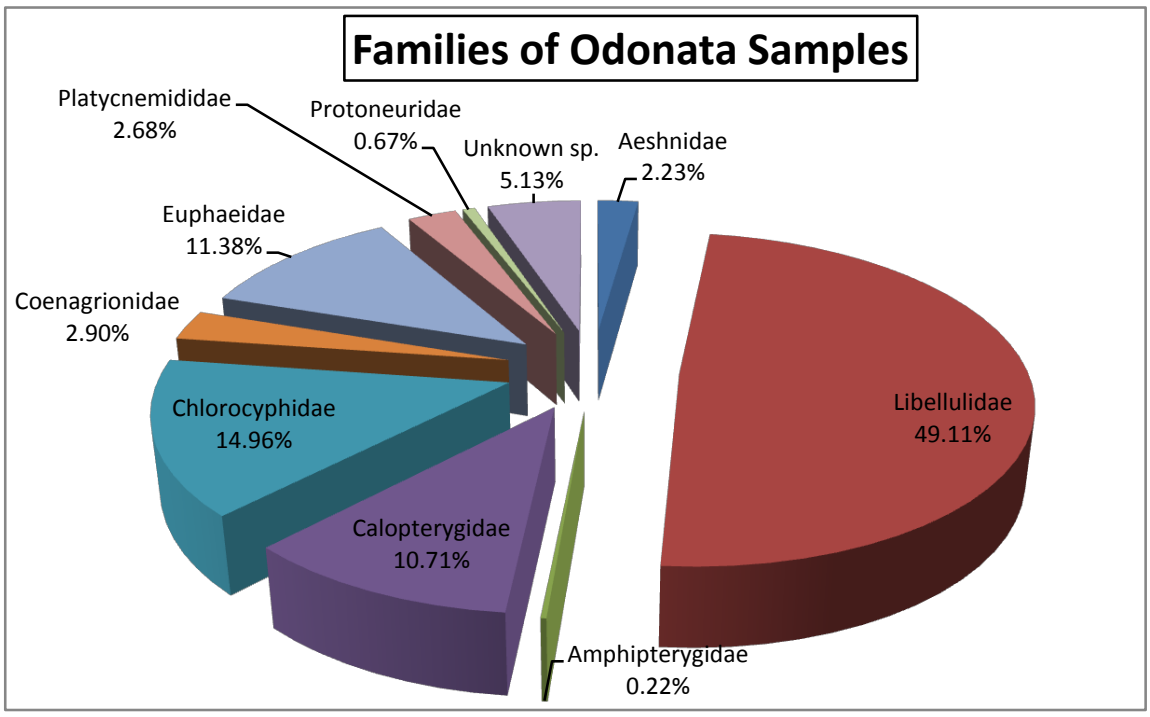


**Figure 3**: The total number of species and individuals found in every sampling locality.

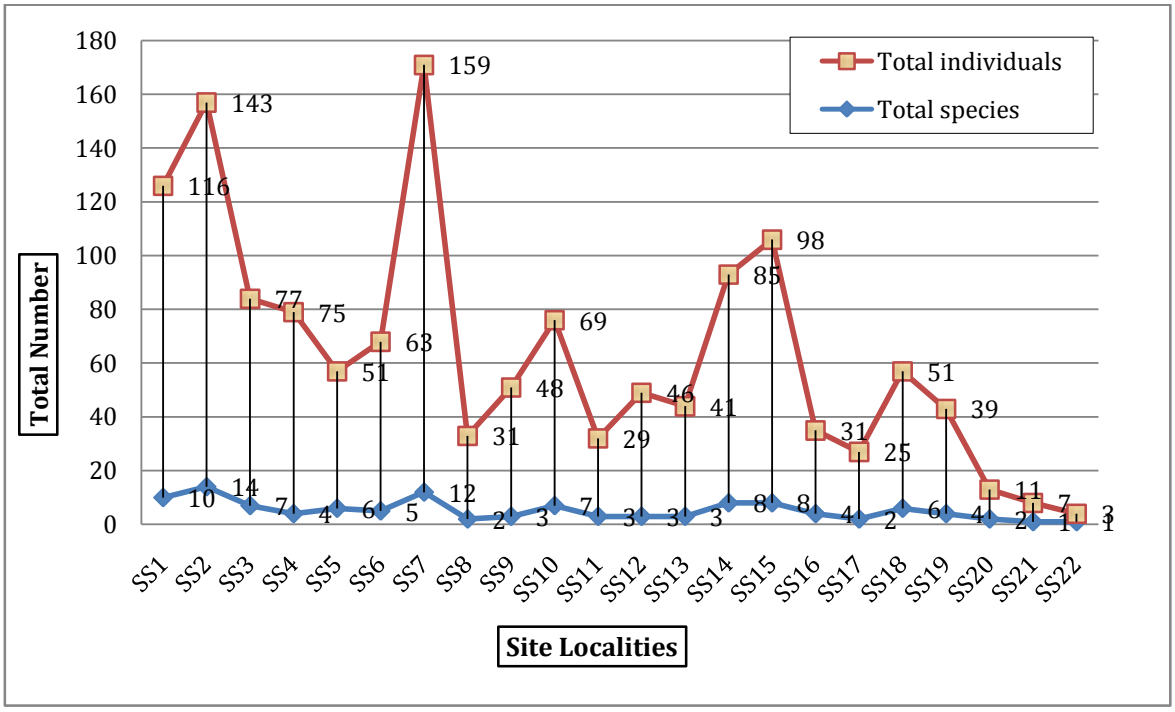


**Figure 4**: Species richness (R), diversity (H'), and evenness (E) of odonates for each category of study sites in Selangor.