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SPECIES RICHNESS AND COMPOSITION OF ODONATA IN FOUR SWAMP FORESTS OF TERENGGANU, PENINSULAR MALAYSIA

Muhammad Adam-Ibrahim[1] & Amirrudin B. Ahmad[1, 2,*]
[1]Faculty of Science and Marine Environment,
Universiti Malaysia Terengganu,
21030 Kuala Nerus. Terengganu Malaysia
[2]Institute of Tropical Biodiversity and Sustainable Development,
Universiti Malaysia Terengganu,
21030 Kuala Nerus, Terengganu, Malaysia.
*Corresponding author: *amirrudin@umt.edu.my*

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ABSTRACT

Odonata is an insect order that includes dragonflies and damselflies. These cunning and swift-flying insects are known to be habitat specialists and are often sensitive to environmental changes. Studies on Odonata diversity in tropical areas are still limited, especially in swampy areas that are often subject to anthropogenic disturbances. A study was conducted in four different swampy areas in Terengganu, Malaysia, to assess the Odonata diversity in these areas. Four sampling days were spent at each study site between February and June 2023. A total of 1,843 individuals were collected, representing 63 species from ten families. Ten of these were new records for Terengganu. The family Libellulidae was the most well-represented family, with *Neurothemis fluctuans* being the most abundant species. Some notable findings from the study include the occurrence of the uncommon *Heliaeschna simplicia*, *Pornothemis* cf. *serrata*, *Risiophlebia dohrni,* and *Teinobasis ruficollis.* Species richness was highest in Tasik Bungkus (36 species), followed by Jambu Bongkok, Sungai Ular, and Bandar Kuala Nerus. These findings provide new insights into the Odonata diversity of swampy areas in Terengganu. The discovery of stenotopic species (species restricted to specific habitats) is particularly important, as these species are often vulnerable to changes in environmental quality. The study also highlights the need for further research on Odonata diversity in tropical areas, especially in swampy areas that are under threat of urbanisation.

Keywords: Odonata, checklist, swamp forest, stenotopic, species composition, Terengganu

ABSTRAK

Odonata merupakan order serangga yang merangkumi pepatung dan pepatung jarum. Serangga terbang yang pantas dan licik ini diketahui mempunyai pengkhususan habitat dan selalunya amat sensitif dengan perubahan persekitaran. Kajian mengenai Odonata di kawasan tropika adalah masih terhad, terutamanya di kawasan yang berpaya, di mana kawasan ini selalunya

menjadi tumpuan untuk aktiviti gangguan manusia. Satu kajian telah dijalankan di empat kawasan berpaya yang berbeza di Terengganu, Malaysia, untuk mengenal pasti kepelbagaian Odonata di kawasan ini. Empat hari persampelan telah diperuntukkan di setiap kawasan kajian antara Februari dan Jun 2023. Sebanyak 1,843 individu berjaya ditangkap, diwakili oleh 63 spesies daripada sepuluh famili. Sepuluh spesies merupakan rekod baru bagi Terengganu. Famili Libellulidae adalah famili dengan wakil yang paling banyak, dengan *Neurothemis fluctuans* menjadi spesies yang paling tinggi. Antara penemuan penting daripada kajian ini ialah kehadiran langka *Heliaeschna simpilcia, Pornothemis* cf. *serrata, Risiophlebia dorhni* dan *Teinobasis ruficollis*. Kekayaan spesies adalah paling tinggi di Tasik Bungkus (36 spesies), diikuti oleh Jambu Bongkok, Sungai Ular, dan Bandar Kuala Nerus. Dapatan kajian ini membuka pandangan kepada kepelbagaian Odonata di kawasan berpaya di Terengganu. Penemuan spesies stenotopik (spesies yang tertakluk kepada habitat yang spesifik) adalah penting, kerana spesies ini kebiasaannya terdedah kepada perubahan kualiti alam sekitar. Kajian ini juga menzahirkan kepada keperluan untuk meneruskan kajian mengenai kepelbagaian Odonata di kawasan tropika, terutamanya di kawasan berpaya yang kini menjadi ancaman kepada pembangunan bandar.

Kata Kunci: Odonata, senarai semak, hutan paya, stenotopik, komposisi spesies, Terengganu

INTRODUCTION

Odonata is an order of insects that includes dragonflies and damselflies. These ancient-winged insects are believed to have existed on Earth as far back as 250 million years ago in the Permian period (Bybee et al. 2016). This is evidenced by the fossil of *Meganeuropsis permiana*, a dragonfly that was much larger than any living species today (Beckemeyer 2020). Members of the order Odonata have elongated bodies, small antennae, four wings with pterostigma, and large globular eyes (Choong et al. 2017b).

Swamp forest formations are edaphic or influenced by substrate, and Orr (2003) reductively classified the habitats into several categories. Firstly, mangrove swamp grows on saltwater, usually harboring typical eurytopic Libellulilds and aeshnids. Secondly, peat swamp forest, which detains dissolved tannins resulting in low pH blackish water. There are plenty of Odonata species that can be found exclusively restricted to peat swamp forests, such as *Brachygonia oculata* and *Brachygonia ophelia* (Hendriks et al. 2023). Next, freshwater swamp forest is formed on soil, which can contain little to no tannins. Lastly, tropical heath or Melaleuca forest, which grows on pure white sand often called as Beach Ridges Interspersed with Swales (BRIS), proximate to the sea and inundated during raining periods. It is common to see other configurations of swamp forests in tropical heath forests.

Climatic climax forests, such as mixed-dipterocarp and montane forests are given a higher precedency for conservation as they consist of a higher habitat association and provide substantial revenue through ecotourism (Sabri et al. 2014). In Borneo, almost half forest Odonata species are confined in mixed dipterocarp forest alone (Orr 2006). Meanwhile, the existence of swamp areas is often neglected and undervalued, casually subjected to new land uses including palm oil plantations, agriculture, and housing (Muhammed Idris et al. 2014).

There are almost 400 species from 17 families that can be found in Malaysia (Choong et al. 2017a), with 253 species (103 Zygoptera, 150 Anisoptera) present in Peninsular Malaysia

(Dow et al. 2024). Odonata in Terengganu is relatively well documented, but there is a need for an extensive study on the taxa itself, particularly in ecosystems other than lowland dipterocarp forests. Choong et al. (2020) listed a total of 132 species from several localities in the Terengganu state. Some of the areas covered by previous works of literature were Sekayu Recreational Forest (Choong et al. 2012; Wahizatul-Afzan et al. 2006), Bukit Bauk (Choong et al. 2008), Jambu Bongkok (Amirrudin et al. 2011) Bukit Kesing, Tasik Kenyir (Choong et al. 2012), Gunung Tebu (Choong & Ng 2014), Lata Belatan and Lata Tembakah (Choong et al. 2020). Out of all these studies, only Bukit Bauk and Jambu Bongkok were localities that fall into the swamp forest category.

Odonata communities have high ecological fidelity, are relatively sedentary, easy to find in the field, and respond rapidly and predictably to disturbances. These characteristics makes them among the best indicators of biodiversity within the insect group (Speight et al. 1999). Many species of Odonata are stenotopic or habitat specialists (Suhonen et al. 2010). The diversity and distribution of Odonata are highly influenced by the presence of microhabitat associations with high heterogeneity of vegetation (Watanabe et al. 2004).

Since Odonata's life history revolves around aquatic habitats (Corbet 1999), assessing the ecology and richness of Odonata species in the swamp areas might be a good alternative to evaluate the health of the microhabitat. Furthermore, dedicating Odonata community monitoring primarily in swamp areas could help in discovering species that depend solely on the microhabitat formations within the ecosystem. In this study, Odonata samples were collected in four different swamp areas with various types of disturbances, and the checklist from previous studies conducted in Terengganu was updated and revised. The species composition was presented, and the species richness of Odanata in all study areas was estimated.

MATERIALS AND METHODS

Sampling Areas

Sampling areas prioritized any form of lowland swamp habitats, namely Sungai Ular in Setiu, Bandar Kuala Nerus in Kuala Nerus district, Jambu Bongkok (extended to Sungai Merchang) in Marang and Tasik Bungkus in Kemaman, Terengganu, Malaysia (Figure 1). Four days of sampling occasions were allocated in each study area, which lasted from February to June 2023. Description and details regarding all the study areas were summarised in Table 1.

Table1. Description of selected sampling sites

No	Site	Coordinates	Dates	District	Conditions	Microhabitats
1	Sungai Ular	5.666944N, 102.706389E	19-22 Feb 2023	Setiu, Northern Terengganu	Agriculture- Oil Palm	Unshaded tannin-stained river, small patch of forested peat swamp, open freshwater swamp, small tributary
2	Bandar Kuala Nerus	5.397778N, 103.059167E	16-20 Mar 2023	Kuala Nerus, Northeast Terengganu	Undergoing development	Melaleuca swamp with Lepironia, freshwater swamp
3	Tasik Bungkus	4.287222N, 103.35E	28 Apr- 1 May 2023	Kemaman, South Terengganu	Rural area	Open freshwater swamp, peat swamp, stagnant and sluggish rivulet, alluvial forest with small pools
4	Jambu Bongkok	4.880556N, 103.376389E	23-25 May, 24 Jun 2023	Marang, Middleast Terengganu	Protected area	Open freshwater swamp, forested muddy swamp, stagnant and sluggish rivulet

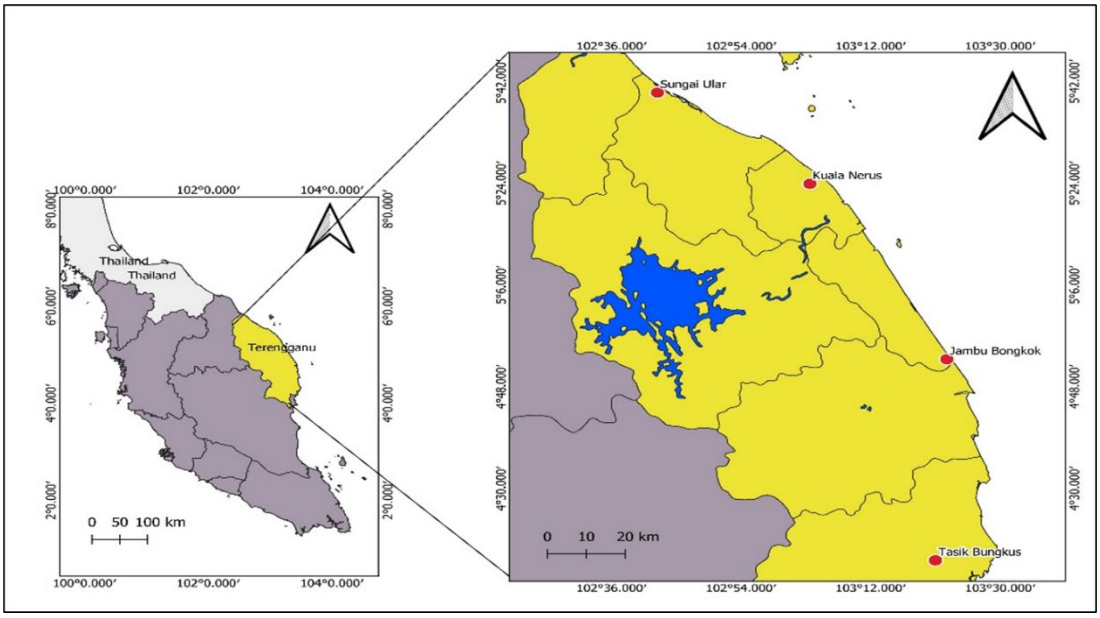

Figure 1. Map showing selected study sites, which consists of four swamp forests (red circle), located in the state of Terengganu (yellow), Peninsular Malaysia

Sampling Methods

Sample collection procedures mostly follow guidelines as per Orr (2003). Odonates were caught on hot sunny days, ranging from 0900 to 1600 hrs. An aerial net was used to aid sample collection, with the mesh made out of a various nylon mosquito net to prevent water retention. Each sample was kept separately in a triangular paper envelope to prevent cannibalism amongst the specimens. After that, the specimen was euthanised either by pinching its thorax or by direct immersion into acetone. Then, the specimens in the envelope were labeled and stored in a hermetic container with naphthalene balls, silica gel, and mold-proof agent to eradicate possible damage to the specimens.

All specimens collected were identified to the species level using the guide of Orr (2003; 2005), Bun et al. (2010), Choong et al. (2017b), and Ngiam and Ng (2022). In addition, photographs of specimens that were hard to identify were sent to Dr. C.Y. Choong of Universiti Kebangsaan Malaysia (UKM) for clarification and confirmation. Familial arrangements for Odonata species were made by referring to the most recent taxonomic list, available at World-Odonata-List (Paulson et al. 2023). Specimens were deposited to the Ecology Laboratory of Universiti Malaysia Terengganu (MEKO UMT).

Data Analysis

A pie chart was used to visualise the family composition of the Odonata community. Rank Abundance Curve (RAC) or Whittaker plot is a curve of ranked species from the highest to the lowest, and it was also generated to show the most dominant and rare species. RAC visualises both dominance and species richness of species in the study. Microsoft Excel 365 was used to plot the RAC.

Species Accumulation Curve (SAC) is a graph used to determine the completeness of sampling or sampling effort in each study area. Sampling was considered complete when the SAC curve was flat or constant after all samples were used in the analysis. Sample-size-based

RAC was used to show the completeness of sampling using the iNEXT package, which can be generated online (Chao et al. 2016).

Additional species for Terengganu were refined to its ecology and conservation status. The ecology of species, distribution based on regional or localities, and conservation status (based on the IUCN Red List of Threatened Species), and threats were elucidated in detail to provide comprehensive information for further works on conservation.

RESULTS AND DISCUSSION

Species Composition of Odonata in Swamp Forest of Terengganu

Overall, a total of 1,844 individuals of Odonata from various localities in Terengganu (Table 2) collected. Suborder Anisoptera presented higher yields of 69% (1273 individuals) as compared to suborder Zygoptera with only 571 individuals. Several records in other states conducted prior to this study also reported similar findings. For example, a study by Aziz et al. (2018) from nine different localities in Johor collected 1368 individuals from the suborder Anisoptera and 854 individuals from the suborder Zygoptera. Mamat et al. (2012) also reported a higher abundance of Anisopteran (701 individuals) as compared to Zygopteran (597 individuals) in various locations in Selangor. The reason behind the dominance of Anisoptera might be due to their adaptability to disturbances, thus making most of the species more widespread (Orr et al. 2004). In contrast, the small and slender-bodied damselflies (Zygoptera) seem more vulnerable to overheating and desiccation, thus making them ecophysiologically restricted (Corbet & May 2008).

Table 2. Species composition of Odonata in all study areas

No	Family	Species	SU	BKN	TB	JB	Total
1	Calopterygidae	*Vestalis gracilis*	0	0	0	1	1
2	Chlorocyphidae	*Libellago lineata*	21	0	0	0	21
3	Coenagrionidae	*Aciagrion hisopa*	0	1	0	0	1
4		*Agriocnemis femina*	0	34	0	2	36
5		*Agriocnemis pygmaea*	1	23	1	5	30
6		*Amphicnemis gracilis*	0	0	28	0	28
7		*Archibasis incisura**	0	0	5	0	5
8		*Archibasis viola*	1	0	23	4	28
9		*Argiocnemis rubsecens*	0	0	6	12	18
10		*Ceriagrion cerinorubellum*	20	22	21	56	119
11		*Ceriagrion auranticum**	28	0	0	0	28
12		*Ischnura senegalensis*	0	23	0	6	29
13		*Pseudagrion microcephalum*	0	28	2	26	56
14		*Pseudagrion williamsoni*	56	0	0	21	77
15		*Teinobasis ruficollis**	2	0	3	0	5
16	Lestidae	*Lestes praemorsus*	0	2	0	0	2
17	Platycnemididae	*Copera ciliata*	4	0	2	11	17
18		*Copera marginipes*	0	0	42	0	42
19		*Onychargia atrocyana*	0	0	7	0	7
20		*Prodasineura laidlawii*	4	0	0	0	4

21		*Prodasineura humeralis*	10	0	0	0	10
22	Argiolestidae	*Podolestes orientalis*	0	0	7	0	7
23	Aeshnidae	*Anax guttatus**	0	1	0	1	2
24		*Gynacantha bayadera*	0	0	0	3	3
25		*Gynacantha subinterrupta**	1	1	0	0	2
26		*Heliaeschna crassa*	0	2	1	0	3
27		*Heliaeschna simplicia**	0	0	1	0	1
28	Macromiidae	*Epophthalmia vittigera**	1	0	1	2	4
29		*Macromia cincta**	0	0	0	1	1
30	Gomphidae	*Ictinogomphus decoratus*	14	7	5	14	40
31	Libellulidae	*Acisoma panorpoides*	0	4	6	2	12
32		*Aethriamanta brevipennis*	1	0	0	0	1
33		*Brachydiplax chalybea*	40	16	34	63	153
34		*Brachygonia oculata*	1	0	60	0	61
35		*Brachythemis contaminata*	0	17	0	0	17
36		*Chalybeothemis fluviatilis*	2	0	0	2	4
37		*Cratilla lineata*	0	0	0	1	1
38		*Diplacodes nebulosa*	7	5	0	8	20
39		*Diplacodes trivialis*	0	7	0	0	7
40		*Hydrobasileus croceus*	3	5	2	14	24
41		*Lathrecista asiatica*	19	0	0	10	29
42		*Nannophya pygmaea*	30	2	3	5	40
43		*Nesoxenia lineata*	0	0	2	0	2
44		*Neurothemis fluctuans*	72	18	52	64	206
45		*Neurothemis fulvia*	0	0	1	0	1
46		*Neurothemis tullia**	0	10	0	0	10
47		*Orchithemis pulcherrima*	0	0	53	0	53
48		*Orthetrum chrysis*	10	1	3	14	28
49		*Orthetrum sabina*	42	67	2	39	150
50		*Pantala flavescens*	0	8	5	0	13
51		*Pornothemis* cf. *serrata**	0	0	15	0	15
52		*Potamarcha congener*	0	3	0	0	3
53		*Pseudothemis jorina*	0	0	0	4	4
54		*Rhodothemis rufa*	0	11	3	23	37
55		*Rhyothemis atterima*	0	0	27	53	80
56		*Rhyothemis obsolescens*	1	0	12	0	13
57		*Rhyothemis phyllis*	30	44	19	18	111
58		*Rhyothemis triangularis*	0	0	0	8	8
59		*Risiophlebia dohrni*	0	0	9	0	9
60		*Tholymis tillarga*	11	11	0	0	22
61		*Tramea transmarina*	0	18	0	4	22
62		*Urothemis signata*	22	7	0	4	33
63		*Zyxomma petiolatum*	10	0	9	9	28
		Total	464	398	472	509	1844

SU: Sungai Ular; BKN: Bandar Kuala Nerus; JB: Jambu Bongkok, TB: Tasik Bungkus; asterisk (*): new records for Terengganu

Family composition based on individuals was depicted as a pie chart in Figure 2. Libellulidae (suborder Anisoptera) was the most dominant family in this study, comprising 66% of the total individuals recorded. Family Coenagrionidae (suborder Zygoptera) was the runner-up, with relative abundance of 24.95%. Family Platycnemididae, Gomphidae, and Chlorocyphidae contributed to 4.34%, 2.17%, and 1.14% of the collected individuals, respectively. On the other hand, family Aeshnidae, Argiolestidae, Macromiidae, Lestidae, and Calopterygidae were among the families in the study, whose relatively were less than 1% (0.6%, 0.38%, 0.27%, 0.11%, and 0.05% respectively).

Family Libellulidae was the most widely represented family in the study. This was also complimented by many other studies conducted before (Amirrudin et al. 2011; Aziz et al. 2018; Che Salmah & Wahizatul Afzan 2004; Choong & Cheah 2013; Farizawati et al. 2014; Izzat-Husna & Amirrudin 2014; Norma-Rashid et al. 2001; Norma-Rashid 2009; Wahizatul Afzan et al. 2006). Libellulid's exceptional distribution throughout the continent might be the main reason for its dominance (Kalkman et al. 2008). Besides, most species from this family are heliothermic (sun-loving) and able to tolerate disturbances, hence enabling them to preside over open and lentic aquatic habitats (Remsburg et al. 2008; Mamat et al. 2012).

A total of 63 species from 10 families in four different localities within five months have been collected from this study. Choong et al. (2012) conducted a study in three different localities in central Terengganu, namely Tasik Kenyir, Bukit Kesing, and Sekayu Recreational Park. During the six sampling days, Choong et al. (2012) managed to collect an astonishing record of 90 species from 13 families. The differences in richness between these two studies might be due to the preference of habitat within the localities. The localities in the study by Choong et al. (2012) comprise protected and more pristine habitats of mixed dipterocarp forest, which is known to have a wider type of microhabitat associations and harbor a greater number of species (α diversity) and variability between sites (β diversity) (Orr 2006).

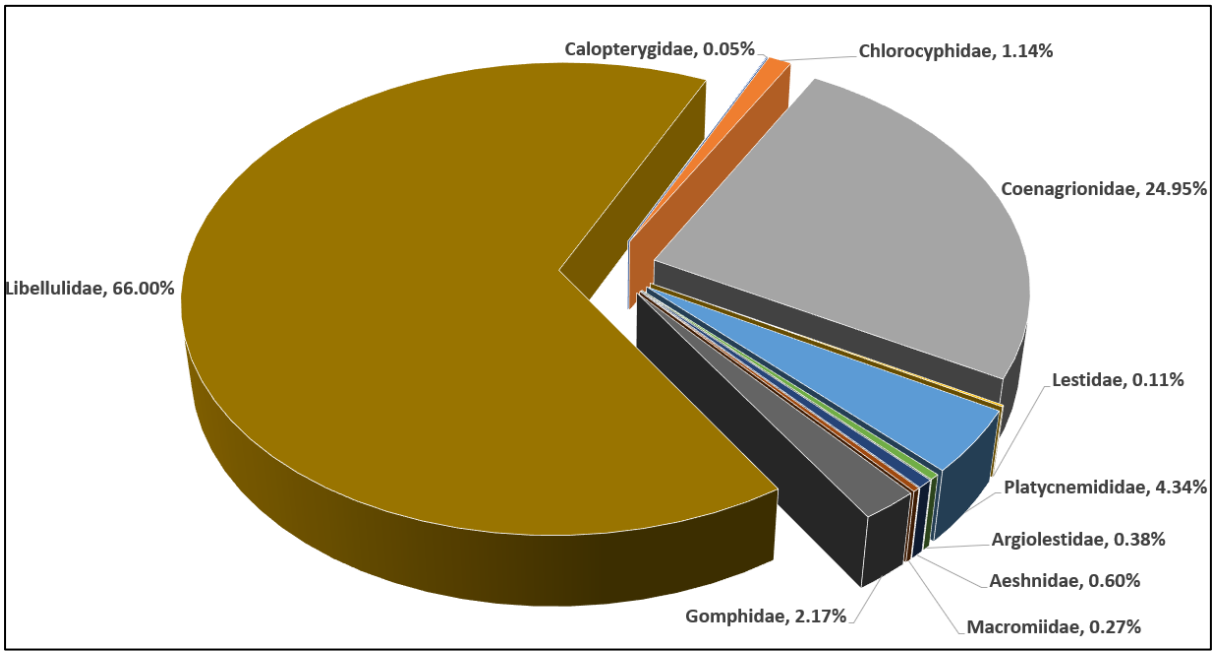

Figure 2. Family composition of all Odonata represented in swamp areas of Terengganu

Figure 3 visualised the dominance of each species through Rank Abundance Curve (RAC). The most abundant species in this study is *Neurothemis fluctuans* (11.17%, 206 individuals), followed by *Brachydiplax chalybea* (8.3%, 153 individuals) and *Orthetrum sabina* (8.13%, 150 individuals). All three species were from the family Libellulidae. All these species were described as generalist species and well-adapted to a wide range of open and degraded habitats (Ngiam & Ng 2022; Orr 2005). Nine species were found consistently in all study sites, namely *Ceriagrion cerinorubellum, Ictinogomphus decoratus, Brachydiplax chalybea, Hydrobasileus croceus, Nannophya pygmaea, Neurothemis fluctuans, Orthetrum chrysis, Orthetrum sabina* and *Rhyothemis phyllis.*

There were several singleton species (species with one specimen) in this study. Family Calopterygidae was represented only by one individual, *Vestalis gracilis* which was found in a sluggish stream in Jambu Bongkok. *Aciagrion hisopa* was found in a small puddle near a pond in Bandar Kuala Nerus. *Neurotemis fulvia* and *Heliaeschna simplicia* were both found in Tasik Bungkus, but in different plots. *Macromia cincta* and *Cratilla lineata* were found in Sungai Merchang, not far from Jambu Bongkok Forest Reserve. *Aethriamanta brevipennis* was captured in an open freshwater swamp in Sungai Ular Setiu.

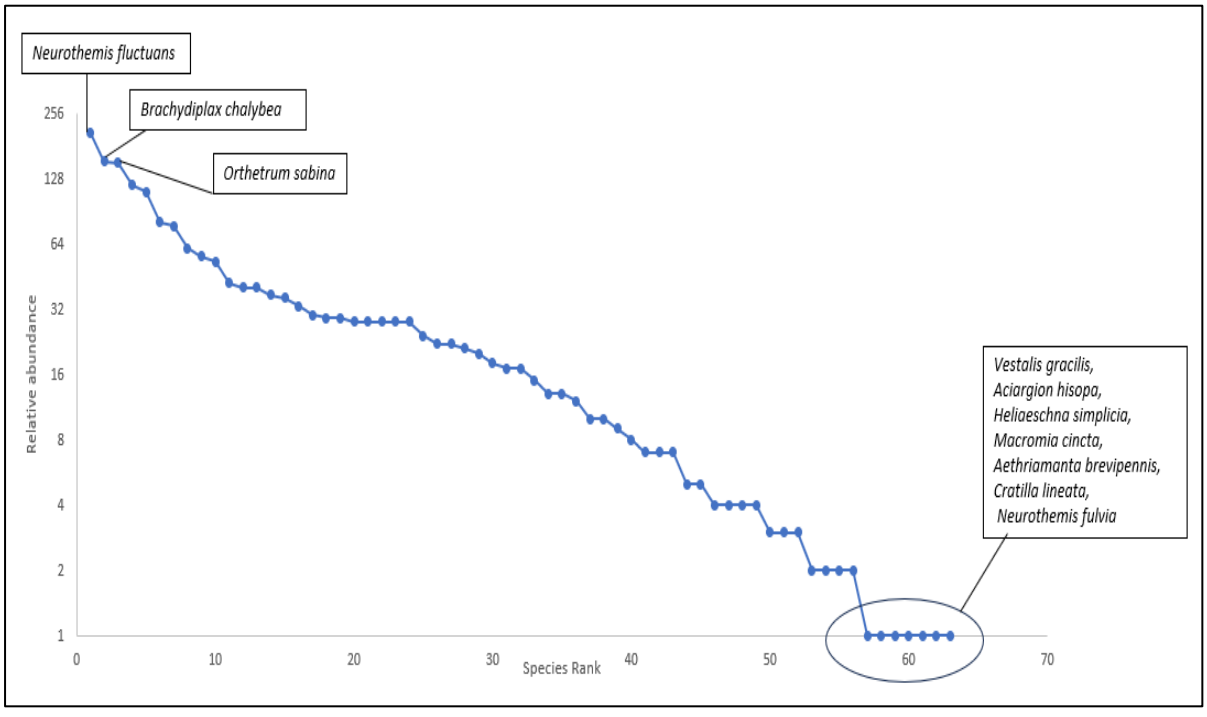

Figure 3. Rank Abundance curve for total Odonata community in this study

Species Richness Estimation and Comparison

The Species accumulation curve is a conventional approach of displaying the the sampling completeness by plotting the increase of species as the sampling effort progresses (Staudhammer et al. 2018). Besides the standard method of individual abundance, the species accumulation curve can also be plotted based on time and locality. Many species will be found at first, making the curve rise steeply, but then slowed as more rare species are found (Ugland et al. 2003). True richness can only be determined if the species accumulation curve reaches

asymptote (the trend started to plateau) (Gotelli & Colwell 2001). However, the trend of the uncompleted species accumulation curve can now be predicted through the extrapolation based on Chao-1 estimator provided by the iNEXT package (Hsieh et al. 2016).

Figure 4 shows the sample-sized-based species accumulation curve of all Odonata sampled in this study. The dot in the solid line is the total species observed in this study, stacked at 1,844 individuals. The line persisted with a dotted line, which is the extrapolation of Chao-1 estimator generated through iNEXT. The trend plateaued at 67.17 which means that 67 species are predicted to exist in the area, suggesting that perhaps at least four more species can be discovered if the sampling effort increases.

The species that has not yet been discovered were predicted to be the other members of the family Aeshnidae, due to their abnormal behavior. Most species from this family, especially genus *Gynacantha* and *Heliaeschna* prefer to be active at dawn and dusk while remaining inconspicuously hanging on low vegetation by day. As we allocated our sampling time only on hot sunny days, it is hard to notice their presence amid the forests. Besides, the tenaciously strong flyers, such as members of Macromiids, Gomphids, and some Aeshnids might be present in the fields but were hard to catch, photograph, or guess through the naked eye.

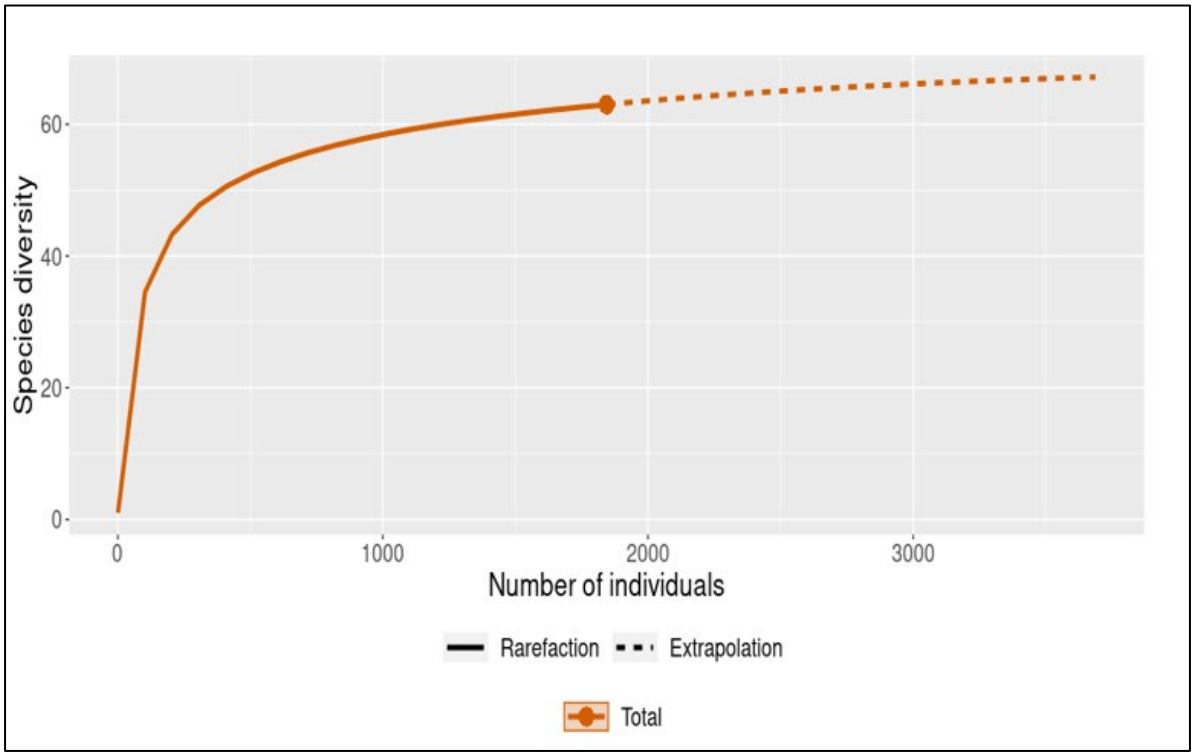

Figure 4. Sample-size-based species accumulation curves (solid line segment) and extrapolation (dotted line segments) of total Odonata sampled in this study. The Graph was generated using iNEXT, and R package for extrapolation of species diversity

The species richness in each study area is shown in Figure 5. Tasik Bungkus and Jambu Bongkok hold the highest species richness, with 35 and 34 species respectively. We already

expected this outcome, as both areas were observed to be the least disturbed in all study areas. Tasik Bungkus is located in rural areas of Ibok, with the least intense urban development, producing an intact, non-degraded peat swamp habitat. Jambu Bongkok is part of the protected areas of Terengganu under the jurisdiction of the Forestry Department of Malaysia.

Whereas, Sungai Ular, which holds 29 species, and Bandar Kuala Nerus with 28 species indicated quite a lower species richness. Sungai Ular consists of freshwater swamps, peat swamps, and Melaleuca-associated forests that have intergraded with each other but are highly patched and degraded due to a huge oil palm conversion. Land use for urbanisation in Bandar Kuala Nerus is currently undergoing, and it costs a huge area of Melaleuca swamp. Rith-Najarian (1998) suggested that the richness of Odonata was higher in a pristine primary forest as compared to a degraded one. Habitat specialist can disappear from their natural habitat if severe disturbances are made (Suhonen et al. 2014).

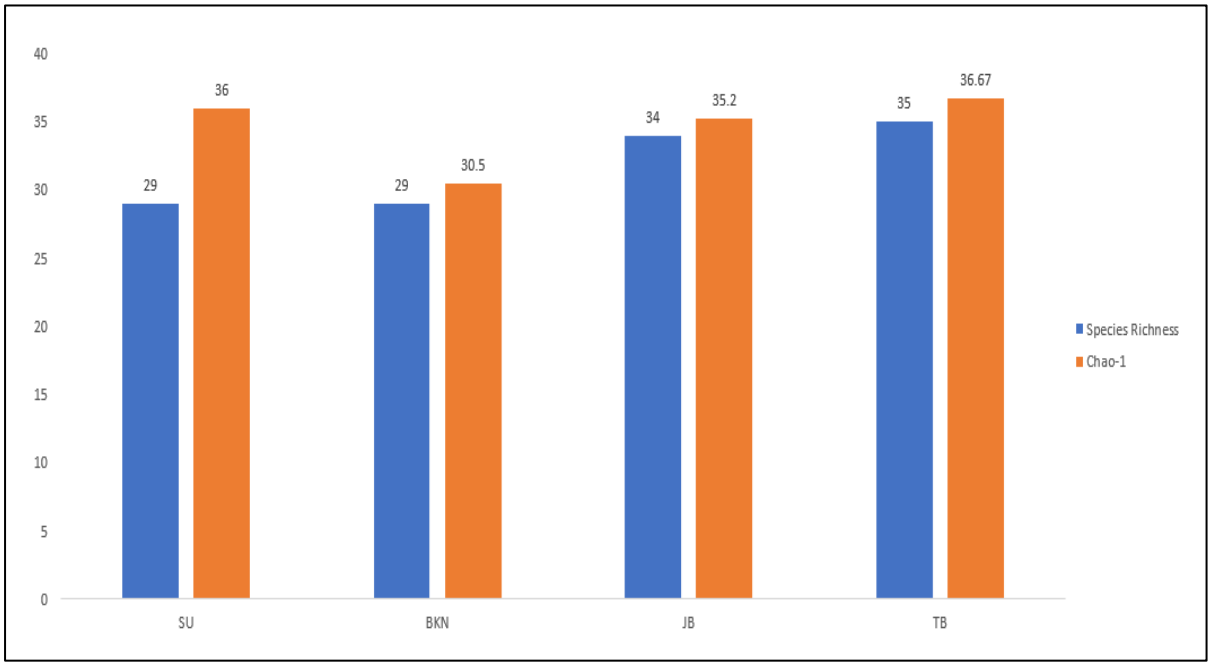

Figure 5. Species richness of Odonata, with an estimation of predicted total species represented in each site (SU: Sungai Ular; BKN: Bandar Kuala Nerus; JB: Jambu Bongkok; TB: Tasik Bungkus)

Notes: Additional Records and Interesting Species of Swamp Forest in Terengganu

Out of 63 species recorded, ten were listed as new records for the Terengganu state; three species from families Coenagrionidae (*Archibasis incisura*, *Ceriagrion auranticum* and *Teinobasis ruficollis*) and Gomphidae (*Anax guttatus*, *Gynacantha subinterrupta*, and *Heliaeschna simplicia*), and two species from families Macromiidae (*Epophthalmia vittigera* and *Macromia cincta*) and Libellulidae (*Neurothemis tullia* and *Pornothemis* cf. *serrata*). We included some available photographs of new records and interesting species in Figure 6. Here we provide notes on all additional records and rediscoveries of swamp-dwelling species in this study.

Family Coenagrionidae

A few specimens of *Archibasis incisura* in small alluvial pools of Tasik Bungkus, coexisting with members of its genus *A. viola* collected. Its morphology is almost identical to *A. viola*, except for having a lighter blue colouration on its marking rather than violet and more definitive on terminal appendages (Orr 2005). This species can be found in Peninsular Malaysia and Borneo. The population of *Archibasis incisura* is now decreasing but still classified as Least Concern (LC) in the IUCN Red List of Threatened Species (Dow 2019b). This species has previously been recorded in some other lowland swamp forests in Peninsular Malaysia, such as Sungai Bebar (Dow et al. 2012) and Tasik Bera (Choong et al. 2016).

Ceriagrion auranticum was found profusely (28 individuals) in Sungai Ular, Setiu, confined in a small patch of peat swamp that is surrounded by an oil palm plantation. Despite being widespread in Peninsular Malaysia and mainland Tropical Asia, while also described to prefer still water habitats in disturbed areas (Orr 2005), this species was seen to be more reserved. Only a few studies reported the occurrence of this species, namely in Kedah (Asahina 1967), Kelantan (Choong et al. 2017c), and it is also recently a new record for Selangor, found in Batu Caves (Choong 2023).

Teinobasis ruficollis was recorded five times, two in a small patch of peat swamp in Sungai Ular and three in a peat swamp forest in Tasik Bungkus. *Teinobasis ruficollis* is known to be widespread, and recorded in Malaysia, Indonesia, and Singapore. However, this species is considered rare and listed as a Near Threatened (NT) in the IUCN Red List of Threatened Species (Dow 2019c). In Peninsular Malaysia, it is known to be found only in Tasik Bera (Choong et al. 2016) and Krau Wildlife Reserve (Dow 2010; Choong 2014).

Family Aeshnidae

Anax guttatus was caught in Bandar Kuala Nerus, then observed in Jambu Bongkok, flying rapidly from a high and dense canopy to a widely open freshwater swamp, patrolling and foraging for a short period before returning to the canopy. This species is widespread and was previously recorded in many areas elsewhere outside Terengganu, such as Kelantan (Choong et al. 2017c), Taman Negara National Park (Choong et al. 2018), Tasik Bera (Choong et al. 2016), Tioman Island (Choong et al. 2017a), and Kedah (Tsuda & Kitagawa 1987).

Only one specimen of *Heliaeschna simplicia* was discovered in a sluggish swamp of Tasik Bungkus. *Heliaeschna simplicia* was not included in Orr (2005) because its discovery in Peninsular Malaysia is recent. This species is newly recorded in Singapore (Ngiam et al. 2022), and found in some places in Peninsular Malaysia such as Batu Pahat (iNaturalist 2023). This species is crepuscular (attracted to light), which is typical for its genus, and distributed in Sundaland, Philipines to South Cambodia (Ngiam & Ng 2022).

Gynacantha subinterrupta was found unintentionally on a food stall close to our main sampling sites in Bandar Kuala Nerus. Ngiam & Ng (2022) described this species to be in swampy and forested areas. But since this species is crepuscular, they often strayed to urban areas, especially at night due to the presence of artificial light. Although known to be widespread in tropical Asia, this species is quite uncommon and not frequently reported around Peninsular Malaysia. Some available records for this species were in Endau Rompin (Wilson & Gibert 2006), Taman Negara National Park, Jerantut (Choong et al. 2018), and some

protected areas in Johor such as Hutan Lipur Sungai Bantang and Hutan Lipur Soga Perdana (Aziz et al. 2018).

Family Macromiidae

Members from the family Macromiidae were poorly recorded in Terengganu. The only record available for this state is *Macromia cupricinta* which was found in Gunung Tebu Forest Reserve (Choong & Ng 2014) Here two more species were added to the record, the first one is *Epophthalmia vittigera*. This species is quite common in lakes and marshes and is distributed widely from India to Southeast Asia (Ngiam & Ng 2022). This species was recorded in various areas in Peninsular Malaysia outside Terengganu (Butler & Kohler 2013; Choong et al. 2016; Choong et al. 2017a; Choong & Cheah 2013, Dow et al. 2012; Farizawati et al. 2014; Wilson & Gibert 2006). The probable reason for this species not being recorded by previous studies might be due to its continuous flight behavior. This species seldom perch and can be seen patrolling the edges of very wide reservoirs, making them hard to catch or photograph (Ngiam & Ng 2022; Orr 2005).

Macromia cincta was only encountered once in Sungai Merchang, near Jambu Bongkok Forest Reserve. It was caught by our colleague, Syimir Nurazim, after watching it patrolling a small swampy rivulet. However, the specimen was lost after capturing its photograph. This species can be found across Sundaland and Cambodia, and the population is believed to have decreased over the years, but still enlisted as Least Concern (LC) in the IUCN Red List of Threatened Species (Dow 2021). There are several previous workers reported the presence of this species in Peninsular Malaysia, such as Tasik Bera (Norma-Rashid et al. 2001), Penang Island (Farizawati et al. 2014), Kedah (Novelo- Gutiérrez & Che Salmah 2006), and Sungai Bebar (Dow et al. 2012). It was also found several times in Sarawak (Dow & Reels 2009; Dow & Reels 2011; Dow 2016).

Family Libellulidae

Neurothemis tullia, also known as 'Paddy Skimmer' or 'Cloudy Velvetwing' was recorded occasionally (10 individuals) in Bandar Kuala Nerus. This species was observed dwelling in open grassland and was sometimes associated with *Lepironia articulata* or 'Kercut' which can be found growing adjacent to the *Melaleuca* swamp. Befitting its common name, this species was recorded in other states with prominent paddy fields, such as Kelantan (Norma-Rashid 2010; Choong et al. 2017c), Perlis (Che Salmah et al. 2005; Dow et al. 2016), and Kedah (Dow et al. 2017). Since this species is widespread in Tropical Asia, it may be present in other states, particularly in swampy grassland-associated areas.

A total of 15 individuals of *Pornothemis* cf. *serrata* were recorded, which were quite locally common in peat swamps and sluggish rivulets in Tasik Bungkus. However, we found several morphological differences in the specimen as compared to the description and illustration of *P. serrata* Krüger 1902 in Orr (2005). Some of the discernable differences are hindwing size (specimen 25 cm, *P. serrata* Krüger 1902, 27 cm), venation markings, and shape of paired green spots on synthorax. Based on Dow (2022), there is an unresolved taxonomic issue in the description of *P. serrata* that made it fall under Data Deficient (DD) in the IUCN Red List of Threatened Species. *P. serrata* was first described from a specimen retrieved from Sukaranda, North Sumatra. This species was then discovered in other localities in Southeast Asia. However, it is now known that at least three superficially very similar species were treated under the same name. For assessment purposes, the records of these similar species

were agglomerated under the name *serrata*. Estimation of the area of occupancy (AOO) and extent of occurrence (EOO) was only certain for the type specimen in Sukaranda. However, it should be noted that whichever taxa eventually proves to be the true *P. serrata* it is unlikely that it will be possible to assess it as Least Concern (LC).

Rediscovery of Swamp Dwelling Species in Terengganu

Amphicnemis gracilis is a species that favours a very dense shaded swampy forest, inconspicuously foraging in the darker corners of swampy, small, and sluggish streams, or still, pools filled with debris and fallen leaves (Ngiam & Ng 2022). This species was discovered previously in Bukit Bauk, herein Terengganu (Choong et al. 2008). *A. Gracilis* was locally common (28 individuals) in the microhabitat exactly as per the description herein Tasik Bungkus. The population of this species was calculated to drop in the past years but still listed as Least Concern (LC) in the IUCN Red List of Threatened Species (Dow 2019a). This species is distributed in Singapore, Sumatra, Southern Thailand, and Peninsular Malaysia as reported in some studies such as in Tasik Bera (Choong et al. 2016), Ayer Hitam Forest Reserve (Choong & Cheah 2013), Sungai Bebar (Choong et al. 2012), and Kenaboi (Norma-Rashid 2009)

Brachygonia oculata is an uncommon species, that can be found guarding territories in a shaded or semi-shaded pool of swampy areas (Ngiam & Ng 2022; Orr 2005). This species was encountered in Bukit Bauk (Choong et al. 2008), and this species was discovered in two different areas, Sungai Ular with only one individual, found perching in a small patch of peat swamp, and 60 individuals in Tasik Bungkus, which is quite common due to large area coverage of forested peat swamp and sluggish rivulets. This species is reported in some other studies in Peninsular Malaysia such as Tasik Bera (Choong et al. 2016), Kedah (Dow et al. 2017), and Sungai Bebar (Choong et al. 2012).

Nesoxenia lineata is a rare species occurring in swampy and marshy areas with shaded, leafy-bottomed pools (Ngiam & Ng 2022; Orr 2005). Choong et al. (2012) reported this species to be present in Sekayu Recreational Park. A doubleton of this species were found in Tasik Bungkus. This species is known to be widespread in Sundaland, Sulawesi, and Sundaland but is seldom reported in other places of Peninsular Malaysia (Choong et al. 2012; Choong et al. 2016; Wilson & Gibert 2006). Deforestation is the main threat to this species (Dow 2009).

Risiophlebia dohrni is a species restricted to a dense swampy forest, including peat swamps and small pools under a dense canopy (Orr 2005; Ngiam & Ng 2022). A total of nine individuals of this species are in Tasik Bungkus. This species was preliminarily only recorded in Singapore but not in Peninsular Malaysia (Orr, 2005), but then further studies reported this species occurred in the east of Malaysia with intact swamp formations, such as Bukit Bauk (Choong et al. 2008), Sungai Bebar (Choong et al. 2012), and Ayer Hitam Forest Reserve (Choong & Cheah 2013).

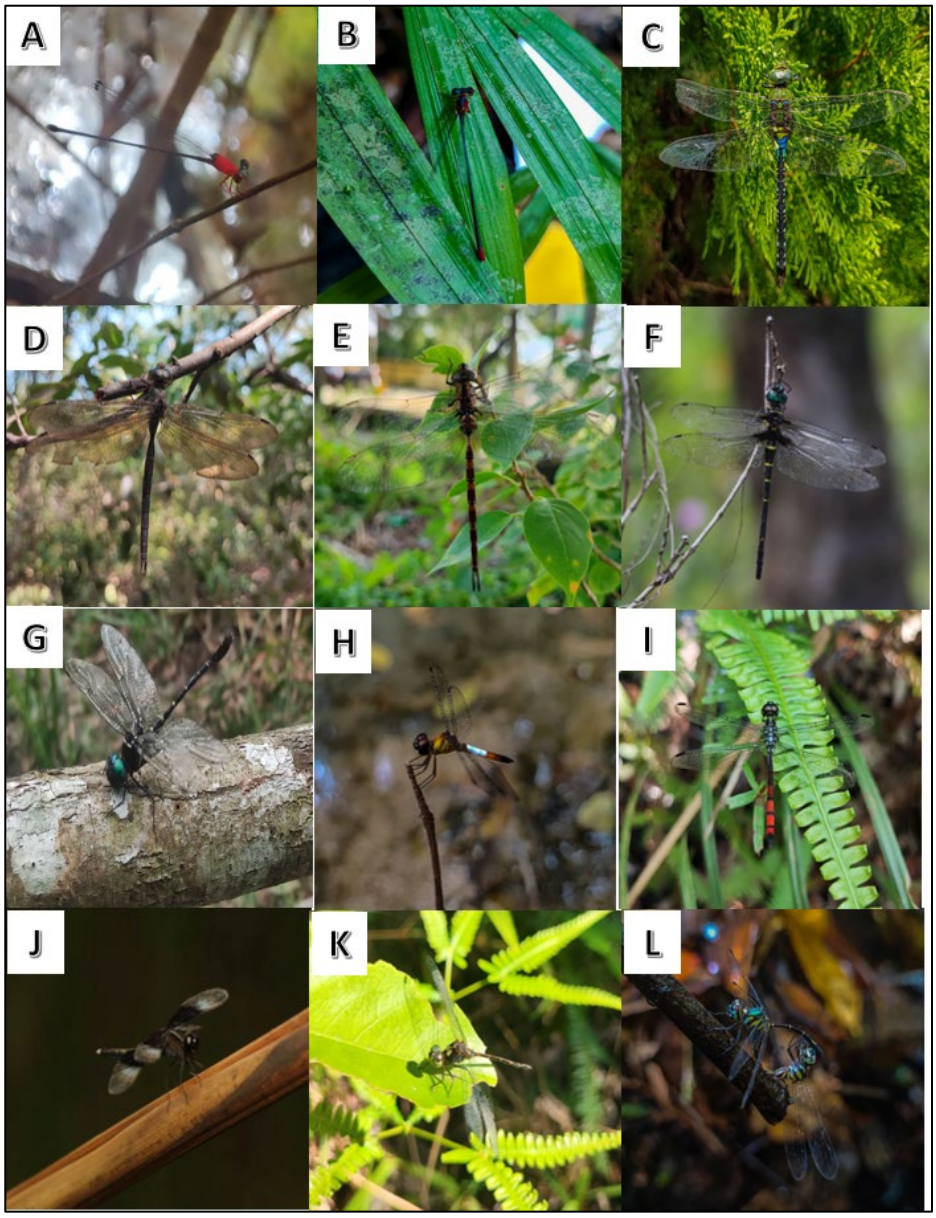

Figure 6. Some interesting species and new records for Terengganu (A: *Amphicnemis gracilis,* B: *Teinobasis ruficollis*, C: *Anax guttatus,* D: *Heliaeschna simplicia,* E: *Gynacantha subinterrupta,* F: *Epophthalmia vittigera*, G: *Macromia cincta*, H: *Brachygonia oculata,* I: *Nesoxenia lineata,* J: *Neurothemis tullia,* K: *Pornothemis* cf. *serrata,* L: *Risiophlebia dohrni)*

CONCLUSION

Swamp forests are home to many stenotopic Odonata species with great species richness in the area, as evidenced by the many new records of Odonata in Terengganu with a considerable occurrence of species from this study. As many Odonata members are well-known habitat specialists, this study can help to fill the gaps in our knowledge of Odonata diversity by discovering new areas that may potentially harbour undiscovered species. Further research on Odonata community, particularly in terms of habitat associations should be conducted. This

will allow to get a better understanding of Odonata habitat preferences, allowing important areas to be accounted for conservation priorities.

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The authors declare that they have no conflict of interest.

Ethics Declarations
No ethical issue was required for this research.

Data Availability Statement
All data in this study are openly available and presented in the article. Additional data is available upon request from both authors.

Authors' Contributions
Muhammad Adam-Ibrahim (MAI) conceived and designed the study, conducted fieldwork, collected and analysed data, and wrote the manuscript. Amirrudin Ahmad (AA) assisted in study design and data analysis, supervised fieldwork activities, wrote the manuscript, and finalised the manuscript. Both authors read and approved the final manuscript.

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