ODONATES (INSECTA: ODONATA) ASSOCIATED WITH RICE ECOSYSTEMS IN SUNWAL MUNICIPALITY, CENTRAL NEPAL

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ABSTRACT

This paper aims to list the odonates fauna associated with rice fields and to study their behaviour in Sunwal, Central Nepal. Research was conducted from June to November 2019 in a rice field by establishing three study plots of (50×50) m^2 each. A total of 33 odonata species (11damselflies and 22 dragonflies) from six families were recorded. Six of them were sporadic, while the rest were common. Territorial behaviour of Odonates was observed and the reproductive behavior of 11 species was thoroughly investigated. The copulatory period varied between species, ranging from two seconds to 49 minutes. Females attempted to mate up to three times. The second and third mating were both brief. Homing behaviour was observed in single species - *Orthetrum sabina*. In this research, we noticed odonates to be predatory as well as prey species.

Keywords: Dragonfly, damselfly, behaviour, territory, diversity, oviposition.

INTRODUCTION

Rice field provides a host for aquatic fauna, adult fliers (Hemiptera, Coleoptera, Orthoptera, Odonata) and also pest species of rice plant (Pires *et al*., 2015). Short seasonal rice plant cultivation practices helps to regulate their diversity and abundances (Mogi, 2007).

Odonates (dragonflies and damselflies) are amphibious insects i.e. larvae are aquatic while adults are terrestrial. Rice field is one of the best habitats to study odonate diversity as it provides best foraging area and prey species for them (Plot *et al*., 2005). Odonates abundance is high in tiller and mature phases of rice (Che Salmah & Abu Hassan, 2002) and they (both larvae and adult odonates) are important predators of pests in rice fields (Heinrichs, 1995).

Odonates are comparatively large insects in all life stages so their behaviors can be studied readily in wild (Bybee *et al*., 2016). Odonates perform rapid flight during foraging, migration, courtship, copulation, oviposition and guarding of mates by close petrol (Bomphery *et al*., 2016). Male odonates establish a territory of about 1-2 m^2 in size, the size depends on the density of individuals, whereas majority of them are found wandering (Hassan, 1978). Territorial males defend their area by perching in particular submerged plants, darting to the intruder and driving him away (Ueda, 1979). Male dragonflies seized their mates in their territory, copulate with female and usually perform post-copulatory guarding during oviposition by hovering near the ovipositing female and repelling other males from the area (Sakagami *et al*., 1974). The guarding of male keeps the female within the territory and prevents post-copulatory mate with other males (Rathod *et al*., 2019). The post copulatory guarding enhances the survival rate of newly hatched nymphs (Tsubaki *et al*., 1994). Most of the dragonfly species show high degree of localization known as 'residentility' behaviour. Residential males try to monopolize the area of his selection (Rathod *et al*., 2019).

Globally, 6329 species of odonates are known (Schorr & Paulson, 2021); of this, 180 species in 18 families exist in Nepal (Kalkman *et al.*, 2020). However, information about diversity of odonates in rice ecosystem and their behavioral study in Nepal is scanty. So this paper deals with the diversity and behavioral study of Odonates at the rice field in Parasi, central Nepal.

Study area

Swathi (27.65028 N, 83.6575 E, 132 m) lies in Sunwal municipality, Parasi of Lumbini province in central Nepal. The average temperature ranges from 25 - 37°C, 259 mm rainfall and 66.5 % humidity during study period. During rainy season paddy are cultivated in all agricultural fields. In cultivated land irrigation canal and artificial ponds are present.

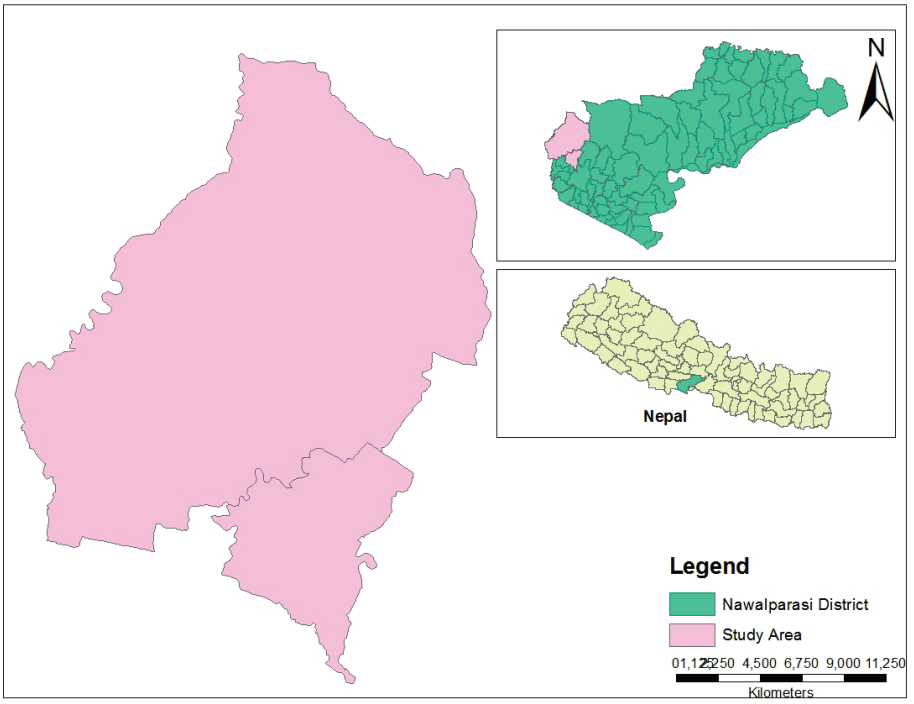

Fig. 1. Map of study area.

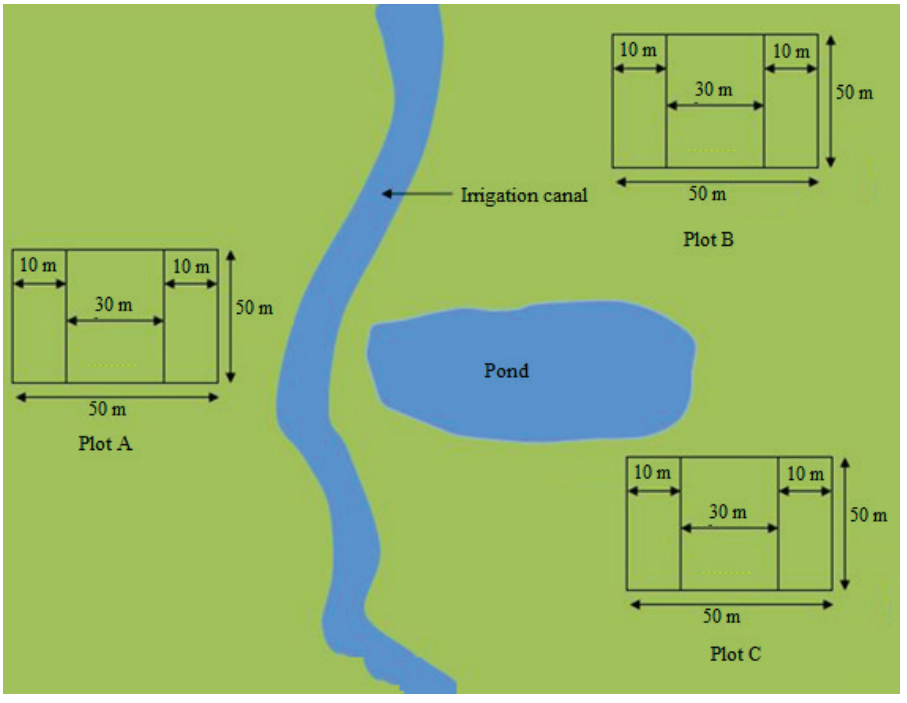

Fig. 2. Field design showing study plots.

MATERIALS AND METHODS

Species diversity

Sampling was carried out during June to November, 2019. In field, altogether three observation plots (Plot-A, Plot-B, Plot-C) were established each having (50×50) m^2 area. In each plot, two line transects of 10×50 m were created separating 30 m from each other for odonata sampling (fig. 2). Specimen were scanned in line transects from each plot at a week interval starting from 10 days after transplanting paddy crops till harvesting by adopting fixed transect protocol (Pollard, 1977). A sweeping net was used to capture adult odonates and released them after *in situ* identification. Specimen collection was strictly avoided and photographic documentation was carried out. Species were identified with the help of keys (Fraser 1933, 1934 and 1936), field guides (Subramanian, 2009; Nair, 2011) and online resources (www.allodonata.com; http://asia-dragonfly.net).

Behavioral study

Odonate activity and behaviour were observed in rice field adopting study methods (De Macro, 1998; Corbet, 1999). Observed activities were copulatory behaviour, selection of mating place, territory defense at mating place, Prey-predator relation and roosting behaviour (day to day, night survey was conducted for one week). Photographs were taken using a Nikon D5300 camera with 18-55 zoom lens by Manoj Sharma in the field (Photo Plate 1-6).

RESULTS AND DISCUSSION

Species diversity and distribution

A total of 33 species belonging to six families (11 species of damselflies and 22 species of dragonflies) were recorded from study area (Table 1). Libellulidae was the most abundant family of dragonflies (Arulprakash *et al*., 2017) with 17 species followed by family Coenagrinonidae (9 species), Gomphidae (3 species), Aeshnidae (2 species), Platycnemididae (*Copera marginipes*) and Lestidae (*Lestes* sp.) respectively.

Table 1. Dragonflies and damselflies species recorded as regular and sporadic (*) in rice ecosystems of Sunwal Municipality.

S.N.	Species	Plot-A	Plot-B	Plot-C
	Suborder: Zygoptera			
	Family: Coenagrionidae			
1.	*Aciagrion hisopa*		+	+
2.	*Aciagrion pallidum*	+	+	+
3.	*Agriocnemis femina*	+		+
4.	*Agriocnemis lacteola*	+	+	+
5.	*Agriocnemis pygmaea*	+	+	+
6.	*Ceriagrion coromandelianum*	+	+	+
7.	*Ischnura nursei* *		+	
8.	*Ischnura rubilio*	+	+	+
9.	*Pseudagrion rubriceps*		+	+
	Family: Lestidae			
10.	*Lestes* sp.	+		+
	Family: Platycnemididae			
11.	*Copera marginipes*	+		+
	Suborder: Anisoptera			
	Family: Aeshnidae			
12.	*Anax guttatus*	+	+	+
13.	*Anax immaculifrons**	+		
	Family: Gomphidae			
14.	*Ictinogomphus rapax*		+	+
15.	*Nychogomphus duaricus**			+
16.	*Paragomphus lineatus**	+		+
	Family: Libellulidae			
17.	*Acisoma panorpoides*	+	+	+
18.	*Brachydiplax sobrina*	+	+	+
19.	*Brachythemis contaminate*	+	+	+
20.	*Crocothemis servilia*	+	+	+
21.	*Diplaccodes nebulosa*	+	+	+
22.	*Diplacodes trivialis*	+	+	+
23.	*Neurothemis tullia*	+		+
24.	*Orthetrum pruinosum neglectum* *		+	+
25.	*Orthetrum sabina*	+	+	+
26.	*Palpopleura sexmaculata* *	+		
27.	*Pantala flavescens*	+	+	+
28.	*Potamarcha congener*	+	+	
29.	*Rhyothemis variegate*	+	+	
30.	*Tholymis tillargra*	+	+	+
31.	*Tramea basilaris*	+	+	+
32.	*Trithemis pallidinervis*	+	+	+
33.	*Urothemis signata signata*	+		+

Note: '+'= Present

Among recorded species, six species were sporadic (*Ischnura nursei*, *Anax immaculifrons*, *Paragomphus lineatus*, *Nychogomphus duaricus*, *Palpopleura sexmaculata*, *Orthetrum pruinosum neglectum*) which visited in search of prey occasionally and rests were common to rice ecosystem (table 1). The number of per sporadic species was less than five throughout the study period. Common species were frequently observed and found feeding, perching, gliding and mating in the rice field. In per sweep with sweeping net Damselflies capture rate was high in comparison to dragonflies (Saikia *et al*., 2016).

Prey-predator relation

Odonata were found both as predators and as prey in study area. Cannibalism is common in odonates. *Neurothemis tullia* was found feeding on *Ischnura rubilio* and *Brachythemis contaminata* was preying upon *Ceriagrion coromandellianum*. Mostly dragonflies were found predation on damselflies though *Orthetrum pruinosum* was found feeding on *Neurothemis tullia*. Sporadic species were mostly seen feeding on small dipterans and hymenopterans. *Orthetrum sabina* was recorded as prey of king fisher and garden lizard was preying upon *Orthetrum pruinosum*. *Pseudagrion rubriceps* was observed being preyed by frog while laying eggs in water. Beside these, wings of *Aciagrion pallidum* was found in web of spider which indicates that they are the prey species for the spiders too.

Reproductive behaviour

As shown in Table 2, reproductive behaviour of 11 species (two damselflies and nine dragonflies) was well recorded. Males were observed to forming territory of 1-2 m^2 for mating (Rehfeldt, 1991) and the size of territory was found to be modified according to the number of males (males density) in the habitat (Pajunen, 1962). Within territory, perched species made their perching sites and patrollers or fliers patrol in search of female. They seized passing female by chasing and started copulation (Sakagami *et al*., 1974).

Table 2. Reproductive behaviour of dragonflies and damselflies.

Species	Territory (by ♂ for mate)	Copulation		Oviposition
		Occurs in	Length(after ♂♀ contact)	
Ischnura rubilio	1-2 m diameter, Overlapping	Wheel position occurs at perch	1 -35 min $\bar{X}$= 5 min	Non-contact guarding, egg lays in submerged stem, leaf of aquatic vegetation
Acisoma panorpoides	0.5-2 m, perch on floating leaves	Wheel position occurs at perch	4-7 sec $\bar{X}$= 5 sec.	Non-contact guarding, egg laying in stem, underside of leaf of hydrophytes plants
Diplacodes trivalis	♂ male perch on grass/ paddy leaf blade and chase on passing ♀	Wheel position occurs at perch in grassland	4-8 sec $\bar{X}$= 5 sec.	♀ search water bodies and lays eggs by washing its abdomen on water surface without ♂ guarding
Psudagrion rubriceps	Overlapping, 1-2 m diameter	Wheel position occurs at perch	2-49 min $\bar{X}$= 6 min	Guarding in tandom position, ♀ lays eggs in submerged stem of aquatic vegetation, also underwater oviposition
Pantala flavescens	4-6 m circular, patroller	Wheel position occurs at aerial	1-5 min $\bar{X}$= 2 min	Male guard in tandom position, egg lays by washing its abdomen on water surface
Orthetrum sabina	4-6 m circular, perch by dropping down wings for alertness	Wheel position occurs at perch	1-10 min $\bar{X}$=2.5 min	Non-contact guarding, non guarding also seen, egg lays by washing its abdomen on water surface
Tramea basilaris	1-3 m diameter, overlap mating couple	Wheel position occurs at aerial	4-33 sec $\bar{X}$=18 sec	Non-contact guarding, rare contact guard, egg lays on water surface by abdomen washing
Urothemis signata signata	1-3 m diameter	Wheel position occurs at aerial	2-32 sec $\bar{X}$=10 sec	Non-contact guarding, egg lays on water surface by abdomen washing
Brachythemis contaminate	2-3 m diameter have 2/3 perching sites	Wheel position occurs at aerial	3-7 sec. $\bar{X}$= 4 sec.	Male guard separately, egg lays on stem, leaf of submerged vegetation

Crocothemis servilia	1-2 m diameter, percher	Wheel position occurs at aerial	4-12 sec $\bar{X}$= 6 sec.	Male guard separately, egg lays by washing its abdomen on water surface
Tholymis tillarga	10-15 m circular, both percher and flier	Wheel position occurs at aerial	10-30 sec $\bar{X}$=14 sec	Male guard separately, egg lays by dipping abdomen in water surface, also seen non-guarded ♀ laying in morning

Usually copulation was taken during flight or partially at perch (Sakagami *et al*., 1974). In six species viz. *Brachythemis contaminata, Crocothemis servilia, Pantala flavescens, Tramea basilaris, Tholymis tillarga* and *Urothemis signata signata*, the copulation process occurred entirely in flight (Sharma, 2017) and in five species viz. *Ischnura rubilio, Psudagrion rubriceps, Acisoma panorpoides, Diplacodes trivalis* and *Orthetrum sabina* it occurred partially at perch condition. The duration of copulation recorded to be varied from species to species as well as within the couples of same species (Corbet, 1962). Longest copulation length (49 min) was recorded in *Psudagrion rubriceps* while in *Urothemis signata signata* the duration of copulation was of only 2 seconds which was the shortest length of copulation recorded during the study period. Interestingly in *Psudagrion rubriceps* within 49 minutes of copulation length, without breaking tandem position couple migrates 17 times for proper settlement in aquatic plants. In each migration breaking and reformation of wheel position was observed. This study showed that entirely aerial copulation has shortest copulating length than partially perching species (Wolf *et al*., 1989) except *Pantala flavescens* (1-5 min, $\bar{X}$= 2 min).

In odonates, resting is common after copulation and before oviposition (Corbet, 1999) but in this study, it was rare. After mating, female started eggs laying in suitable water resources (Hassan, 1978). Usually, male guards ovipositing female after copulation either at tandem position or by hovering above (Rathod *et. al.*, 2019). During oviposition, male of *Psudagrion rubriceps* and *Pantala flavescens* guarded female in tandem position (contact guarding) and male of *Ischnura rubilio, Acisoma panorpoides, Brachythemis contaminata, Crocothemis servilia, Orthetrum sabina, Tholymis tillarga, Tramea basilaris, Urothemis signata signata* guarded by hovering above the ovipositing female (non contact guarding). At low light intensity, the close male guarding was observed (Miller & Miller, 1985).The rate of egg laying is more in guarded female than non guarded female. Non-guarding egg laying was also recorded

in *Diplacodes trivalis* (Hassan, 1978), *Orthetrum sabina* and *Tholymis tillarga*. In these species, copulation occurred in rice field and female visited water bodies alone for egg laying (Rathod *et al*., 2019). The unguarded oviposition by female helps to reduce the predation of eggs by aquatic fauna, especially fishes (Miller & Miller, 1985). Female laid eggs either by washing abdomen on water surface (*Crocothemis servilia, Diplacodes trivalis, Orthetrum sabina, Pantala flavescens, Tholymis tillarga, Tramea basilaris, Urothemis signata signata*) or by settle down on aquatic plants and then attaching eggs in submerged leaves and stems (*Ischnura rubilio, Psudagrion rubriceps, Acisoma panorpoides, Brachythemis contaminata*) (Martens, 1993). In *Psudagrion rubriceps*, gathering of many couples in same submerged vegetation and dipping of females underwater for oviposition was recorded. Interestingly, in *Urothemis signata signata,* after mating female laid few batches of egg, mated for second time with another male and then oviposited. We observed up to third attempt of mating in which copulation duration for 2nd and 3rd attempts were very short (<5 sec) (Jacobs, 1955).

Homing behaviour

Homing is uncommon in odonates but this behaviour was observed in *Orthetrum sabina* (Ito, 1960; Gambles, 1971). Single male homing in same place after dusk i.e. 19:00 hr for consecutive five days was observed. On fifth day, it flew away due to disturbance and never seen in the same place.

The present study revealed higher numbers of Anisoptera species than Zygoptera. Though species richness of dragonfly was higher, damselflies populations were more in rice fields. Odonates were recorded as predator which may play important role to control serious insect pests of rice crops. Odonates perform territorial behaviour and have different mating periods. Rice field serves as good habitat to odonata fauna for performing all the daily activities and complete their life cycle.

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PHOTO PLATES

Plate 1. ***Neurothemis tullia*** **feeding on damselfly**

Plate 2. ***Brachythemis contaminata*** **feeding on**

Ceriagrion coromandelianum

Plate 3. ***Orthertum sabina*** **(Roosting Habitat)**

Plate 4. ***Agriocnemis femina*** **(Mating)**

Plate 5. ***Orthetrum sabina*** **(Mating)**

Plate 6. ***Ischnura rubilio*** **(Mating)**

REFERENCES

ARULPRAKASH, R; CHITRA, N; GUNATHILAGARAJ, K (2017) Biodiversity of Odonata in rice at Pattukkottai in Tamil Nadu. *International Journal of Entomology* 79(4): 498–502.

BYBEE, S; CORDOBA-AGUILAR, A; DURYEA, M C; FUTAHASHI, R; HANSSON, B; LORENZO-CARBALLA M O *et al*. (2016) Odonata (dragonflies and damselflies) as a bridge between ecology and evolutionary genomics. *Frontiers in Zoology* 13: 46. DOI: 10.1186/s12983-016-0176-7

BOMPHERY, R J; NAKATA, K; HENNINGSSON, P; LIN, H T (2016) Flight of dragonflies and damselflies. *Phil. Trans.R. Soc. B* 371: 20150389.

CHE SALMAH, M R; ABU HASSAN (2002) Distribution of aquatic insects in relation to rice cultivation phases in a rain fed rice field. *Jurnal Biosains* 13: 87–107.

CORBET, P S (1962) A biology of dragonflies. H. F. & Witherby, London, UK; 247pp.

CORBET, P S (1999) Dragonflies. Behaviour and ecology of odonata. Harley Books, Colchester, England, UK; 829pp.

DE MACRO, P (1998) The Amazonian Campina dragonfly assemblage: Patterns in microhabitat use and behaviour in a foraging habitat. *Odonatologica* 27: 239–248.

FRASER, F C (1933) The Fauna of British India Including Ceylon and Burma. Odonata. Vol. I. Taylor and Francis Ltd; London, xiv + 424pp.

FRASER, F C (1934) The fauna of British India including Ceylon and Burma. Odonata. Vol. II. Taylor and Francis Ltd; London, xxiv + 398pp.

FRASER, F C (1936) The fauna of British India including Ceylon and Burma. Odonata. Vol. III. Taylor and Francis Ltd; London, xii + 46 pp.

GAMBLES, R M (1971) Dragonfly dormitories. *Niger Field* 36: 166–170.

HASSAN, A T (1978) Reproductive behaviour of *Acisoma panorpoides inflatum* selys (Anisoptera: Libullulidae). *Odonatologica* 7(3): 237–245.

HEINRICHS, E A (1995) (Editor) Biology and management of rice insects. John & Sons Inc, NY, USA;794pp.

ITO, Y (1960). Territorialism and residentiality in a dragonfly, *Orthretrum albistylium speciosum* (Uhler) (Odonata: Anisoptera). *Ann. Ent. Soc. Am.* 53: 851–853.

JACOBS, M E (1955) Studies on territorialism and sexual selection in dragonflies. *Ecology* 36: 566–586.

KALKMAN, V J; BABU, R; BEDJANIC, M; CONNIFF, K; GYELTSHEN, T; KHAN, M K *et al*. (2020) Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Zootaxa 4849(1): 001–084.

MARTENS, A (1993) Influence of conspecifics and plant structures on oviposition site selection in *Pyrrhosoma nymphula* (Sulzer) (Zygoptera: Coenagrionidae). *Odonatologica* 22: 487–494.

MILLER, P L; MILLER, A K (1985) Rates of oviposition and some other aspects of reproductive behaviour in *Tholymis tillarga* (fabricius) in Kenya (Anisoptera: Libellulidae). *Odonatologica* 14(4): 287–299.

MOGI, M. (2007) Insect and other invertebrate predators. *Journal of the American Mosquito Control Association* 23: 93–109.

NAIR, M V (2011) Dragonflies and Damselflies of Orissa and Eastern India, Wildlife Organisation, Forest and Environment Department, Government of Orissa, India; 252pp.

PAJUNEN, V I (1962) A description of aggressive behaviour between males of *Leucorrhinia dubia*v. d. Lind (Odonata: Libellulidae). *Ann lent. Fenn*. 28:101–118.

PIRES, M M; KONTZIAN, C B; SPIES, M R; BAPTIST V A (2015) Comparative assessment of aquatic macroinvertebrate diversity in irrigated rice fields and wetlands through different spatial scales: an additive partitioning approach. *Marine and Freshwater Research* 67: 368–379.

POLLARD E (1997) A method for assessing changes in the abundance of butterflies. *Biol Conserv* 12: 115–134.

PLOT, M J; RADHAKRISHNA, C; SONIYA, V P (2005) Odonata (Insecta) diversity of rice field habitat in Palakkad district, Kerala. *Rec. Zool. Surv. India* 104(1-2): 71–77.

RATHOD, P P; RAJA, I A; MILIND, K (2019) Contrast behaviour by female dragonfly, *Orthetrumbabina* while mating with its territorial male. *Biosc. Biotech. Res. Comm.*12(4): 927–933.

REHFELDT, G E (1991) Site-spefecific mate finding strategies and oviposition behaviour in *Crocothemis erythraea* (Brullé) (Odonata: Libellulidae). *Journal of Insect Behaviour* 4: 293–303.

SAIKIA, R; MISHRA, H; DEVI, A; SAIKIA, D K (2016) Biodiversity of odonates in rice ecosystem, Titabar, Assam. *Journal of Entomology and Zoology Studies* 4(4): 1376–1381.

SAKAGAMI, S F; UBUKATA, H; IGA, M; TODA, M J (1974) Observations on the behavior of some odonata in the Bonin Island, with considerations on the evolution of reproductive behavior in Libelludae. *Jour. Fac. Sci. Hokkaido Uni. Ser. VI, Zool* 19(3): 722–757.

SCHORR, M; PAULSON, D (2021) World odonata list. Available at: https://www.pugetsound.edu.

SHARMA, G (2017) Studies on the reproductive behaviour of dragonfly, *Pantala flavescens* (Fabricius, 1798) (Odonata: insecta) in Aravalli range and desert ecosystem of Rajasthan, India. *Bio bulletin* 3(1): 67–73.

SUBRAMANIAN, K A (2009) Dragonflies of India- A field guide. Vigyan Prasar, India; 180 pp.

TSUBAKI, Y.; SIVA-JOTHY, M.T.; ONO, T (1994) Re-copulation and post copulatory mate guarding increase immediate female reproductive output in dragonfly *Nannophya pygmaea* Rambur. *Behav Ecol Socio Biol* 35: 219 – 225.

UEDA, T (1979) Plasticity of the reproductive behaviour in a dragonfly *Sympetrum parvalum* Barteneff, with reference to the social relationships of males and densities of territories. *Res. Popul. Ecol* 21: 135–152.

WOLF, L L; WALTZ, E C; WAKELEY, K; KLOCKWSKI, D (1989) Copulation duration and sperm competition in white faced dragonflies (Leucorrhinia intact: Odonata: Libellulidae). *Behavioral Ecology and Sociobiology* 24: 63–68.