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Research Article

Ichneumonid fauna associated with rice ecosystems of Tamil Nadu, India

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ABSTRACT: Surveys were conducted to explore the Ichneumonid fauna in rice ecosystems of Tamil Nadu during 2015-16 in three different rice growing zones *viz.,* western zone, Cauvery delta zone and high rainfall zone. Totally 604 Ichneumonid individuals were collected from rice ecosystem in the present study. These 604 individuals represent 14 subfamilies, 24 genera and 33 species. Alpha and beta diversity were computed for the three zones and the diversity indices (Simpson's index, Shannon-Wiener index, Pielou's index) revealed western zone as the most diverse zone, while Cauvery delta zone being the least diverse. *Leptobatopsis indica* was the dominant Ichneumonid species in the rice ecosystem with a relative abundance of 8.1 %. On comparing the species similarities using the Jaccard's index among the three zones taken in pairs, it was found that 12 per cent similarity between Western and Cauvery delta zones and no similarity between high rainfall and Cauvery delta zones and 25 per cent similarity between high rainfall and western zones.

KEY WORDS: Diversity, Ichneumonidae, parasitoids, rice ecosystem

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INTRODUCTION

Rice (*Oryza sativa* L.), is an annual grass native to Asia. Rice fields, together with the associated irrigation ponds, ditches and ridges often constitute the traditional landscape in rural environments and are a key ecosystem of Asia (Kiritani, 2009). In India, rice is not just food stuff, but a culture. Tamil Nadu, one of the leading rice growing states in India, has been cultivating rice from time immemorial as this state is endowed with all favourable climatic conditions suitable for growing rice. Rice fields harbour a rich and varied fauna than any other agricultural crop (Heckman, 1979; Fritz *et al.,* 2011). The fauna is dominated by micro, meso and macro arthropods inhabiting the soil, water and vegetation sub-habitats of the rice fields. The different communities of terrestrial arthropods in the rice field include pests, their natural enemies (predators and parasitoids) and other neutral insects that inhabit or visit the vegetation as tourists (Heong *et al*., 1991). Insect pests are reported as the major threat to its production. More than 800 species of insects are known to infest rice, of which about 20 species are of economic importance. The overall losses due to insect pest damage in rice are estimated as 25 per cent (Pathak and Dhaliwal, 1981; Dale, 1994). Farmers generally rely on insecticides to combat pest problems of rice. Indiscriminate use of insecticides resulted in the loss of biodiversity of beneficial organisms like parasitic hymenopterans (Dudley *et al.,* 2005). Reduction in the mortality of parasitic hymenopterans due to insecticides is essential for greater sustainability in rice pest management (Heong and Hardy, 2009; Gurr *et al*., 2011). They show greater stability to ecosystem than any group of natural enemies of insect pests because they are capable of living and interacting at lower host population level. To aid this means of pest control, it is essential that the diversity of Ichneumonids needs to be studied and documented (Dey *et al.,* 1999).

Ichneumonidae is one of the largest and taxonomically difficult families of Ichneumonoidea and are primary or secondary parasitoids attacking a large range of insect orders in their various stages of development, thereby playing a pivotal role in the control of insect pests in nature. Adults are often associated with moist habitats and extensive ground cover (Matthews, 1974; van Achterberg, 1984). Diversity of Ichneumonids associated with rice ecosystem is poorly studied and far from satisfaction especially in Tamil Nadu. Any additional knowledge in diversity, taxonomy and biology is of potential practical value. In this context, the present study was undertaken to explore the diversity of Ichneumonid fauna in rice ecosystems of Tamil Nadu.

MATERIALS AND METHODS

Sites of collection

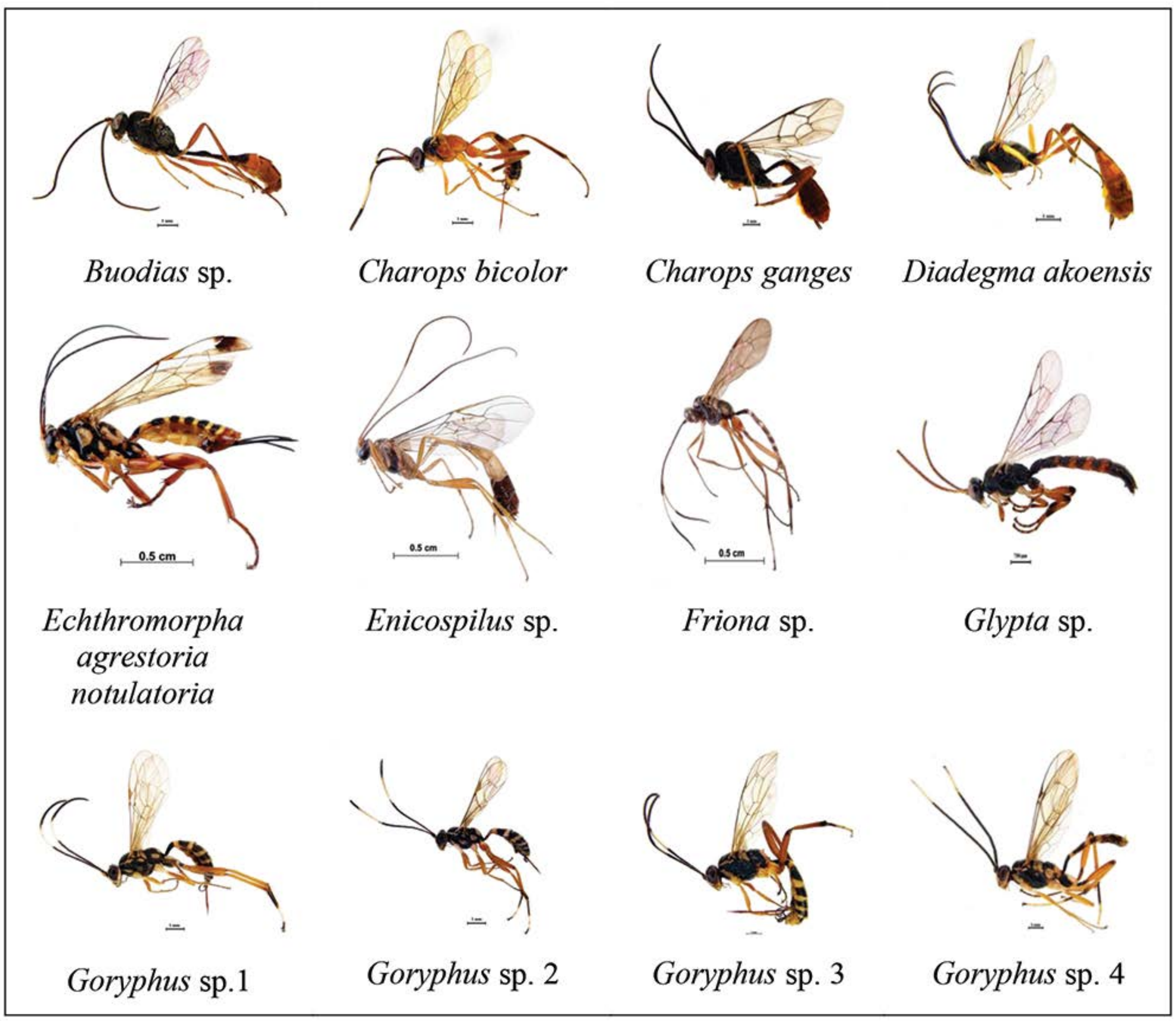
The survey was carried out in the rice fields during 2015-16 in three different agro climatic zones of Tamil Nadu State *viz.,* western zone (District representation: Coimbatore at, Paddy Breeding Station, Coimbatore, 427 m, 10° 59' 43.24" N 76° 54' 59.22" E), Cauvery delta zone (District representation: Thiruvarur at, Krishi Vigyan Kendra, Needamangalam, 26 m, 10° 46' 23.93" N 79° 25' 0.96" E) and high rainfall zone (District representation: Kanyakumari at Agricultural Research Station, Thirupathisaram, 17 m, 8° 12' 16.70" N 77° 26' 57.84" E) (Figure 1). Collections were made for 20 consecutive days in each zone to give equal weightage and to minimize chances of variations in collection. The time of sampling in each zone was decided by the rice growing season of the zone and the stage of the crop *i.e.,* 20 days during August- September, 2015 in western zone, October- November, 2015 in high rainfall zone and December, 2015 – January 2016, in Cauvery delta zone.

Methods of collection

Collections of ichneumonids were made by sweep net, yellow pan traps, one set kept at ground level and another erected at canopy levels (Daniel *et al*., 2018). All the three sampling methods were employed continuously for 20 days.

Sweep net

The net employed for collecting was essentially similar to an ordinary insect net with 673 mm mouth diameter and a 1076 mm long aluminum handle. The frame can be fitted



Habrocryptus sp.

Hypsicera sp.

Ischnojoppa luteator

Isotima sp. 1

Isotima sp. 2

Isotima sp. 3

Leptobatopsis indica

Metopius rufus

Netelia sp.

Orthocentrus sp.

Paraphylax sp.

Skeatia sp.

Temelucha biguttula

Temelucha philippinesis

Thelodon sp.

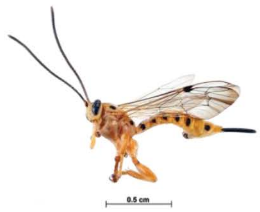
Trathala flavo orbitalis

Trichomma cnaphalocrosis

Xanthocampolex phormionis

Xanthopimpla flavolineata

Xanthopimpla punctata



Xanthopimpla stemmator

Fig. 1. **Thirty-three species of Ichneumonidae collected from three rice growing zones of Tamil Nadu**

to one end of the handle. This facilitates easy separation of the frame. The long handle allows the net to be used as far as possible making the sweeping easier and effective. The net bag was made up of thin cotton cloth. It measures about 600 mm in length and has a well-rounded bottom. The top of the bag which fits around the frame was made up of canvas. The canvas was folded over the frame and sewed in position. Sweeping of vegetation was as random as possible from ground level to the height of the crop. Sweeping was done in early morning and late evening hours for about half an hour per day which involved 30 sweeps. One to and fro motion of the sweep net was considered as one sweep.

Yellow pan traps kept at ground level

This trap was based on the principle that many insects are attracted to bright yellow colour. Yellow pan traps are shallow trays of 133 mm×195mm and 48 mm deep and was of bright yellow in colour. Altogether, twenty yellow pan traps were installed at ground level in each site on the bunds, half- filled with water containing a few drops of commercially available detergent (to break the surface tension) and a pinch of salt (to reduce the rate of evaporation and to prevent rotting of trapped insects). The spacing between traps was standardized as 1.5 m. The traps were set for a period of 24 hours (Example: traps set at 10 AM on one day were serviced at 10 AM on the following day).

Yellow pan traps erected canopy level

Erected yellow pan traps were installed at the crop canopy by means of polyvinyl chloride pipes fitted below, with a screw attachment and were installed in 10 numbers per site in the same fashion as yellow pan traps kept at ground level

Preservation and identification of the specimens up to family level

The parasitoids thus collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C, Labomed Zoom Stereo Luxeo 4D and Photographed under Leica M 205-A stereo zoom microscopes. The insects were identified through conventional taxonomic techniques by following standard keys.

Measurement of diversity

Relative density

Relative density of the species was calculated by the formula, Relative Density (%) = (Number of individuals of one species/Number of individuals of all species) X 100.

Alpha diversity

Alpha diversity of the zones was quantified using Simpson's diversity Index (*SDI*) Shannon-Wiener index (*H'*), Margalef Index (d) and Pielou's Evenness Index (*E1*).

Simpson's index

Simpson's diversity index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. It is calculated using the formula, $D = \Sigma n\ (n-1)/N\ (N-1)$ where n = total number of organisms of a particular species and N = total number of organisms of all species (Simpson, 1949). Subtracting the value of Simpson's diversity index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity.

Shannon-Wiener index

Shannon-Wiener index (H') is another diversity index and is given as follows: $H' = -\Sigma\ Pi \ln (Pi)$, where $Pi = S/N$; S = number of individuals of one species, N = total number of all individuals in the sample, ln = logarithm to base e (Shannon & Wiener, 1949) the higher the value of H' the higher the diversity.

Margalef index

Species richness was calculated for the three zones using the Margalef index which is given as Margalef Index, $\alpha = (S-1)/\ln(N)$; S = total number of species, N = total number of individuals in the sample (Margalef, 1958).

Pielou's evenness index

Species evenness was calculated using the Pielou's Evenness Index ($E1$). Pielou's Evenness Index, $E1 = H'/\ln(S)$; H' = Shannon-Wiener diversity index, S = total number of species in the sample (Pielou, 1966). As species richness and evenness increase, diversity also increases (Magurran, 1988).

Beta diversity

Beta diversity is a measure of how different (or similar) ranges of habitats are in terms of the variety of species found in them. The most widely used index for assessment of Beta diversity is Jaccard Index (JI) (Jaccard, 1912), which is calculated using the equation: JI (for two sites) = $j / (a+b-j)$, where j = the number of species common to both sites A and B, a = the number of species in site A and b = the number of species in site B. We assumed the data to be normally distributed and adopted parametric statistics for comparing the sites.

Statistical analysis

The statistical test ANOVA was also used to check whether there was any significant difference in the collections from three zones. The data on population number were transformed into X+0.5 square root before statistical analysis. The mean individuals caught from three different zones were analyzed by adopting Randomized Block Design (RBD) to find Least Significant Difference (LSD). Critical Difference (CD) values were calculated at five per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

Table 1. Comparison of Ichneumonids collected from three rice growing zones of Tamil Nadu

Species	Zones						Total			
	Western		Cauvery Delta		High Rainfall					
	No.	%	No.	%	No.	%	No.	%	F	P
Buodias sp.	9	4.1	0	0.0	11	4.8	20	3.3	2.24	0.09
Charops bicolor	4	1.8	0	0.0	4	1.8	8	1.3	1.80	0.17
Charops ganges	0	0.0	27	17.0	0	0.0	27	4.5	6.10	0.00
Diadegma akoensis	12	5.5	0	0.0	22	9.7	34	5.6	2.10	0.13
Echthromorpha agrestoria notulatoria	2	0.9	9	5.7	0	0.0	11	1.8	3.39	0.04
Enicospilus sp.	9	4.1	0	0.0	0	0.0	9	1.5	3.67	0.03
Friona sp.	0	0.0	42	26.4	0	0.0	42	7.0	7.76	0.00
Glypta sp.	19	8.7	0	0.0	0	0.0	19	3.1	4.45	0.01
Goryphus sp. 1	0	0.0	0	0.0	31	13.7	31	5.1	5.80	0.00
Goryphus sp. 2	33	15.1	3	1.9	0	0.0	36	6.0	3.60	0.03
Goryphus sp. 3	0	0.0	17	10.7	0	0.0	17	2.8	5.22	0.00
Goryphus sp. 4	0	0.0	0	0.0	9	4.0	9	1.5	2.08	0.13
Habrocryptus sp.	17	7.8	0	0.0	0	0.0	17	2.8	4.12	0.02
Hypsicera sp.	0	0.0	32	20.1	0	0.0	32	5.3	5.32	0.00
Ischnojoppa luteator	1	0.5	0	0.0	7	3.1	8	1.3	3.55	0.03
Isotima sp. 1	16	7.3	4	2.5	0	0.0	20	3.3	3.38	0.04
Isotima sp. 2	1	0.5	0	0.0	8	3.5	9	1.5	2.48	0.09
Isotima sp. 3	24	11.0	0	0.0	0	0.0	24	4.0	5.74	0.00
Leptobatopsis indica	0	0.0	0	0.0	49	21.6	49	8.1	5.63	0.00
Metopius rufus	5	2.3	0	0.0	0	0.0	5	0.8	2.43	0.09
Netelia sp.	8	3.7	0	0.0	0	0.0	8	1.3	3.23	0.04
Orthocentrus sp.	0	0.0	12	7.5	0	0.0	12	2.0	3.52	0.03
Paraphylax sp.	0	0.0	0	0.0	34	15.0	34	5.6	7.21	0.00

Skeatia sp.	7	3.2	0	0.0	0	0.0	7	1.2	3.70	0.03
Temelucha biguttula	0	0.0	0	0.0	6	2.6	6	1.0	2.80	0.06
Temelucha philippinesis	11	5.0	0	0.0	0	0.0	11	1.8	3.97	0.02
Thelodon sp.	0	0.0	13	8.2	0	0.0	13	2.2	1.99	0.14
Trathala flavo orbitalis	14	6.4	0	0.0	0	0.0	14	2.3	5.44	0.00
Trichomma cnaphalocrosis	0	0.0	0	0.0	12	5.3	12	2.0	3.52	0.03
Xanthocampolex phormionis	0	0.0	0	0.0	9	4.0	9	1.5	3.67	0.03
Xanthopimpla flavolineata	23	10.6	0	0.0	14	6.2	37	6.1	2.26	0.11
Xanthopimpla punctata	0	0.0	0	0.0	3	1.3	3	0.5	1.00	0.37
Xanthopimpla stemmator	3	1.4	0	0.0	8	3.5	11	1.8	1.31	0.27
Total No. collected	218	-	159	-	227	-	604	-	-	
Species Number	19	-	09	-	15	-	33	-	-	

%- Relative Density, No. Total number of individuals collected, F-Value, P-Value

Table 2. Diversity indices of Ichneumonidae from three rice growing zones of Tamil Nadu

Zones	Mean No. of Ichneumonidae collected/day	Std. Error	SID	*H’*	α	*E1*	β %
Western	10.90 (3.21)	± 1.60	0.92	1.15	3.34	0.39	W and C – 12
Cauvery Delta	7.95 (2.46)	± 2.47	0.83	0.89	1.57	0.40	C and H – 0
High Rainfall	11.35 (3.03)	± 2.55	0.89	1.04	2.58	0.38	H and W -25
S.ED	0.42	-	-	-	-	-	-
CD (p=0.05)	0.86	-	-	-	-	-	-

Figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by LSD (p=0.05).
SID- Simpson’s Index of Diversity, *H’*- Shannon-Wiener Index, -Margalef index,
E1- Pielou’s index, β-Beta diversity (Jaccard Index) W- Western Zone, C- Cauvery Delta Zone, H- High Rainfall Zone

Table 3. Ichneumonidae collected in the study with their host

Parasitoid	**Host**	**Reference**
Buodias sp.	Lepidoptera	Rao *et al*., 1970
Charops bicolor	*Chilo* sp.	Rao *et al*., 1970
Charops ganges	*Pelopidas* sp.	Rao *et al*., 1970
Diadegma akoensis	*Scirphophaga* sp.	Nandakumar and Pramod, 1998
Echthromorpha agrestoria notulatoria	*Parnara guttata*	Rao *et al*., 1970
Enicospilus sp.	*Sesamia inferens*	Rao *et al*., 1970
Friona sp.	Crambidae	Rao *et al*., 1970
Glypta sp.	Spiders	Jonathan, 2006
Goryphus sp. 1	Crambidae	Nath and Indrani, 1979
Goryphus sp. 2	Crambidae	Nath and Indrani, 1979
Goryphus sp. 3	Crambidae	Nath and Indrani, 1979
Goryphus sp. 4	Crambidae	Nath and Indrani, 1979
Habrocryptus sp.	Unknown	-
Hypsicera sp.	Tineidae	Jonathan, 2006
Ischnojoppa luteator	*Pelopidas mathias, Scirpophaga incertulas*	Jonathan, 2006
Isotima sp. 1	Crambidae	Jonathan, 2006

Isotima sp. 2	Crambidae	Jonathan, 2006
Isotima sp. 3	Crambidae	Jonathan, 2006
Leptobatopsis indica	*Cnaphalocrocis medinalis*	Jonathan, 2006
Metopius rufus	*Mythimna separata*	Katiyar and Gargav, 1971
Netelia sp.	*Spodoptera* sp	Rao *et al*., 1970
Orthocentrus sp.	Lepidoptera	Jonathan, 2006
Paraphylax sp.	Spiders	Rao *et al*., 1986
Skeatia sp.	Crambidae	Jonathan, 2006
Temelucha biguttula	*Scirpophaga incertulas*	Rao *et al*., 1970
Temelucha philippinesis	*Cnaphalocrocis medinalis*	Rao *et al*., 1970
Thelodon sp.	Lepidoptera	Jonathan, 2006
Trathala flavo orbitalis	*Scirpophaga incertulas*	Jonathan, 2006
Trichomma cnaphalocrosis	*Cnaphalocrocis medinalis*	Kaur *et al.,* 2000
Xanthocampolex phormionis	Crambidae	Jonathan, 2006
Xanthopimpla flavolineata	*Chilo* sp.	Pati and Mathur, 1982
Xanthopimpla punctata	*Chilo* sp.	Pati and Mathur, 1982
Xanthopimpla stemmator	*Chilo* sp.	Pati and Mathur, 1982

RESULTS AND DISCUSSION

Totally 604 ichneumonid individuals were collected from rice ecosystem in the present study. These 604 individuals represent 14 sub families, 24 genera and 33 species. *Trichomma cnaphalocrosis* Uchida was the only species that was collected under the subfamily Anomaloninae. Two species *viz*., *Glypta* sp. and *Leptobatopsis indica* (Cameron) were collected under the subfamily Banchinae. Under the subfamily Campopleginae, four species *viz*., *Charops bicolor* (Szépligeti), *Charops ganges* Cushman, *Xanthocampolex phormionis* Gupta and Gupta, and *Diadegma akoensis* (Shiraki) were collected. Species such as *Temelucha biguttula* (Munakata), *Temelucha philippinensis* (Ashmed) and *Trathala flavo orbitalis* (Cameron) were collected under the sub-family Cremastinae. Thirteen species from subfamily Cryptinae, viz., four species of *Goryphus* Holmgren and three species of *Isotima* Foerster, one species each of the six genera, *Buodias* sp., *Friona* sp., *Habrocryptus* sp., *Skeatia* sp., *Thelodon* sp. and *Paraphylax* sp. were also identified in the collections. Under Ichneumoninae, *Ischnojoppa luteator* (Fabricius) was the only species found. *Hypsicera* sp. and *Metopius rufus* (Ashmead) were collected under Metopiinae subfamily. *Enicospilus* sp. was the only species that was collected under the subfamily Ophioninae and *Orthocentrus* sp. was the only species that was collected under the subfamily Orthocentrinae. Under Pimplinae subfamily, four species *viz., Echthromorpha agrestoria notulatoria* (Fabricius), *Xanthopimpla flavolineata* Cameron, *Xanthopimpla punctata* (Fabricius), and *Xanthopimpla stemmator* (Thunberg) were collected. Among the 33 species that were collected in the present study, *L. indica* was found to be the most dominant species in rice ecosystem with a relative density of 8.1 per cent. Totally 19 species were collected from western zone, 9 species from Cauvery delta zone and 15 species from high rainfall zone (Table 1). In the present study, 9 species were collected from the western zone alone *viz*., *Enicospilus* sp*.*, *Glypta* sp., *Habrocryptus* sp., *Isotima* sp. 3, *M. rufus*, *Netelia* sp., *Skeatia* sp., *T. philippinensis* and *T. flavo orbitalis*. From Cauvery delta zone alone, six species were collected *viz*., *C. ganges*, *Friona* sp., *Goryphus* sp. 3, *Hypsicera* sp., *Orthocentrus* sp. and *Thelodon* sp. From high rainfall zone alone, 8 species were collected *viz*., *Goryphus* sp. 1*, Goryphus* sp. 4*, L. indica, Paraphylax* sp., *T. biguttula, T. cnaphalocrosis, X. phormionis* and *X. punctata*. Species such as *Buodias* sp., *C. bicolor*, D. *akoensis, I. luteator, Isotima* sp. 2*, X. flavolineata and X. stemmator were* collected from both high rainfall and western zones. Interestingly, no species was found common to both western zone and high rainfall zone. Three species *viz*., *E. agrestoria notulatoria, Enicospilus* sp. *Goryphus* sp 2. and *Isotima* sp. 1 were found common to western and Cauvery delta zones. The ANOVA test results clearly indicated that, the P-value of 22 species such as *D. akoensis, E. agrestoria notulatoria, Friona* sp, *Glypta* sp., *Goryphus* sp. 1, *Goryphus* sp. 2, *Goryphus* sp. 3, *Habrocryptus* sp., *Hypsicera* sp., *I. luteator*, *Isotima* sp. 1, *Isotima* sp. 3, *L. indica*, *Netelia* sp., *Orthocentrus* sp., *Paraphylax* sp., *Skeatia* sp., *T. philippinesis*, *T. flavo orbitalis*, *T. cnaphalocrosis* and *X. phormionis* was lesser than 0.05 and so it is evident that there was significant difference between the zones for these 22 species.

Mean number of ichneumonids collected per day from western zone was 10.90 ± 1.60, while it was 7.95 ± 2.47 from Cauvery delta zone and 11.35 ± 2.55 from high rainfall zone. From the present study, it was found out that western zone was the most diverse zone with a Simpson's index of 0.92, followed by high rainfall zone (0.89) and Cauvery delta zone (0.83). The Shannon- Wiener index for western, Cauvery delta and high rainfall zones was 1.15, 0.89 and 1.04, respectively. Margalef index also indicated that western zone was the species rich zone (3.34) followed by high rainfall zone (2.28) and Cauvery delta zone (1.57). As far as species evenness was concerned, Cauvery delta zone is high in evenness (0.40), followed by western zone (0.39) and high rainfall zone (0.38) (Table 2).

On comparing the species similarities using the Jaccard's index among the three zones taken in pairs, it was found that 12 per cent similarity was observed between Western and Cauvery delta zones and no similarity between high rainfall and Cauvery delta zones and 25 per cent similarity between high rainfall and western zones. Host insects of the parasitoid that were collected in the present study were provided in Table 3.

The difference in indices among the zones may be due to the factor that the enhancement of biodiversity in rice would depend on the biodiversity of the surrounding environment; after transplanting rice, many organisms including pests, natural enemies and neutral species immigrate to colonize rice paddies from the surrounding environment (Buchs 2003). Daniel *et al.* (2017) obtained similar results by conducting experiments to assess the diversity of Pteromalidae of rice ecosystems in Tamil Nadu. The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida and Wilson, 1985; Condit *et al.* 2002). Studies on the effect of elevation on species diversity of taxa such as spiders (Sebastian *et al.* 2005), moths (Axmacher and Fiedler, 2008), paper wasps (Kumar *et al.* 2008) and ants (Smith *et al.* 2014) reported that species diversity decreased with increase in altitude. However, according to Janzen (1976), diversity of parasitic Hymenoptera is not as proportionately reduced by elevation as in other insect groups, a fact that is in support of our results. A similar study conducted by Shweta and Rajmohana (2016) to assess the diversity of members belonging to the subfamily Scelioninae also declared that the elevation did not have any major effect on the overall all diversity patterns. Daniel and Ramaraju (2019) conducted experiments in Tamil Nadu to understand the diversity patterns of 28 different families under Hymenoptera and found out that High rainfall zone is the most diverse zone in the state. Diversity also depends on the varietal preference of the natural enemies (Daniel *et al*., 2019a). The Elevational Diversity Gradient (EDG) in ecology proposes that species richness tends to increase as elevation increases, up to a certain point creating "diversity bulge" at moderate elevations (McCain & Grytnes, 2010). The elevation dealt with in this work ranged from 17-427 m which was not very high. So taking into account the scale and extent of elevational gradients, it can be said that species diversity and richness have not showed any correlation i.e. species diversity and richness were not proportional with that of elevation. Daniel and Ramaraju (2017) assessed the diversity of chalcididae among three rice growing tracts of Tamil Nadu and concluded that there was no correlation between elevation and species richness. This fact supports our present study. Daniel *et al.* (2019b) conducted research to find out the diversity patterns of Braconidae in Tamil Nadu and concluded that High rainfall zone and Western zone were rich in the diversity of Cauvery delta zone. Studies on the altitudinal variation of parasitic Hymenoptera assemblages in an Australian sub-tropical rainforest by Hall *et al.* (2015) did not record any distinct assemblage at each altitude, at the morphospecies level, even though there was a clear separation between 'upland' and 'lowland' assemblages. To detect minute changes in species assemblages, species level sorting is found to give the best result (Grimbacher *et al.* 2008). The area under cultivation turns out to be a very important factor with respect to abundance and species density in rice fields (Wilby *et al.* (2019b) 2006). Diversity of parasitoids also depends on weather factor prevailing in the area of the study (Daniel *et al.,* 2019c). Diversity of Mymaridae in Tamil Nadu state were assessed by Daniel *et al*. (2019d) and concluded that High rainfall zone and Western zones were more diverse. All these findings matched with our present findings.

CONCLUSION

This study reveals the diversity of ichneumonids of three different rice ecosystems of Tamil Nadu, where the western zone is the most diverse and the Cauvery delta zone being the least. The reasons for the significant changes in diversity of parasitoids and their host insects are to be further studied. Influence of weather factors on the diversity patterns of parasitoids, varietal preferences of parasitods and elevational influence on the abundance of parasitods are to be further studied. There is much scope for research to be taken on these aspects.

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