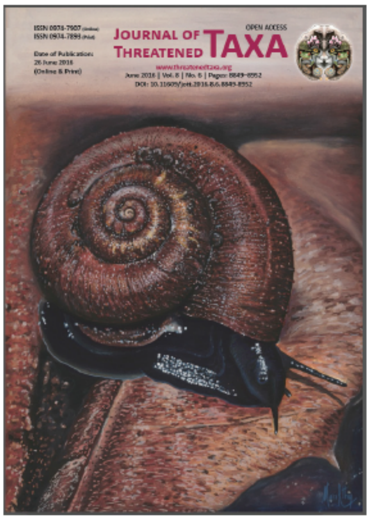

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COMMNUNICATION

EGG PARASITOIDS FROM THE SUBFAMILY SCELIONINAE (HYMENOPTERA: PLATYGASTRIDAE) IN IRRIGATED RICE ECOSYSTEMS ACROSS VARIED ELEVATIONAL RANGES IN SOUTHERN INDIA

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Egg parasitoids from the subfamily Scelioninae (Hymenoptera: Platygastridae) in irrigated rice ecosystems across varied elevational ranges in southern India

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Abstract: Platygastridae (Hymenoptera) is the most abundant family of parasitic Hymenoptera in rice ecosystems in southern India. Members belonging to the subfamily Scelioninae were assessed in rice ecosystems along three elevation ranges, a highland (737m), midland (54m) and lowland (1.5m) in northcentral Kerala (southern India) during the pre-flowering to the milky-grain stage of paddy. Malaise traps were employed as the standard specimen collection methodology with collections made for four weeks, using two malaise traps per field, from August 2008 to January 2009, serviced once a week. The study recorded a total of 198 individuals belonging to 38 species in 21 genera. The species diversity, richness, evenness as well as beta diversity were computed for the three sites along with ANOVA and it was concluded that, contrary to other studies on different taxa, elevation did not have any major effect on the overall diversity patterns in Platygastridae even though there was a difference in species assemblages.

Keywords: Diversity, elevation, north central Kerala, Platygastridae, richness, Scelioninae, species assemblage.

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Author Contribution: MS compiled and analyzed the data. KR collected and identified the Scelionids upto species.

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INTRODUCTION

Paddy cultivation is considered to be the oldest form of intensive agriculture by man (Fernando 1977) and paddy is home to a rich assemblage of arthropod communities (Bambaradeniya & Edirisinghe 2008). Members of parasitic Hymenoptera are known to parasitize insects and spiders and are effective biocontrol agents since they can control the population of their hosts in a density dependent manner (LaSalle & Gauld 1993). They occupy a high trophic position and are sensitive to environmental changes (Siemann 1998; Tscharntke et al. 1998).

Platygastridae is the sole family under Platygastroidea (Johnson 2015), the third largest superfamily of parasitic Hymenoptera (Austin et al. 2005) and has five subfamilies (Telenominae, Teleasinae, Scelioninae, Sceliotrachelinae and Platygastrinae) out of which the first three, are exclusive egg parasitoids (Austin et al. 2005). It is the most abundant family of parasitic Hymenoptera in rice ecosystems in southern India (Rajmohana 2014; Johnson 2015; Shweta & Rajmohana 2015).

Based on several studies of parasitic Hymenoptera from different habitats including paddy ecosystems, it has been observed that the most abundant subfamily under Platygastridae is Scelioninae (Rajmohana 2014; Johnson 2015). The taxonomy of the group is well worked out despite its small size. Members of Scelioninae are known to parasitize mainly arthropod groups like Orthoptera, Hemiptera and spiders (Galloway & Austin 1984; Austin et al. 2005). More than 75 percent of them have orthopterans as their hosts.

Studies on the effect of elevational gradients on species diversity gives an idea of how species and communities respond to changes in climate through changes in their distributions (Fielding et al. 1999; Hodkinson 2005). Among the limited studies on altitudinal variation of parasitoid species diversity, Kaufman & Wright (2011) found a significant amount of variation in the assemblage structure of *Udea stellata* (Lepidoptera) parasitoids. However, Maunsell (2014) found no relationship between altitude and the assemblage structure of leaf miner parasitoids. Hall et al. (2015) studied the altitudinal variation of parasitic Hymenoptera in an Australian sub-tropical rainforest and found that there was not much difference in the parasitoid assemblages. Even though important components of rice ecosystems, there are very few studies on parasitoid assemblages due to their small size and limited taxonomic expertise (Heraty 1998). In order to examine if diversity of parasitoids varies with altitude, we assessed Scelioninae in irrigated rice ecosystem in northcentral Kerala at different elevations. The present work is the first of its kind attempted from India, designed to test whether elevation was a parameter affecting the diversity of parasitic Hymenoptera.

MATERIALS AND METHODS

Study area and field sites

Three rice fields at different elevations, belonging to three districts of northcentral Kerala, were chosen as the study area (Fig. 1). They were a highland site: Madakkimala, Kalpetta, Wyanad, 737m at 11^{0}39.651N & 76^{0}05.318E; a lowland site: Peruvayal, Mavoor, Kozhikode, 1.5m at 11^{0}15.178N & 75^{0}54.238E; and a midland site: Kavalamukkatta, Nilambur, Malappuram, 54m at 11^{0}15.132N & 76^{0}21.174E. The area under cultivation was approximately 2000m^2 in the highland site and 1000m^2 in the lowland site where as in the midland site the total area under cultivation was approximately 500m^2.

Parasitoid sampling

Malaise traps were employed for the parasitoid sampling and serviced once a week. The entire study lasted for a period of six months from August 2008 to January 2009. Collections were made for four weeks continuously from each site, using two malaise traps per field generating a total of eight sets of samples of parasitic Hymenoptera from each site (in two months). The collections from the pair of malaise traps set at the same time were combined and taken as a single effort. The collections were made in such a way that there was synchronization in the growth stage between the sites. It was ensured that the cultural practices involved irrigation farming with double cropping along with a moderate input of nitrogen fertilizers and insecticides. The rice varieties at the three sites were indigenous varieties such as 'Gandhakasala' in the highland site, ASD in the midland site and 'Aishwarya' in the lowland site.

The total number of samples from each site was very low. Malaise traps are widely used for catching flying insects (Ganho & Marinoni 2003), especially dipteran and hymenopteran insects (Selfa et al. 2003). Since Malaise trap collections are essentially standardized (Mazon & Bordera 2008), the data could be used for assessing diversity.

According to Wilby et al. (2006) insect species diversity and density in a rice ecosystem increases from

Figure 1. Map of Kerala showing the field sites at three different districts of Kerala. A - highland site, 737m; B - lowland site, 1.5m; C - midland site, 54m.

seedling stage and reaches a maximum at the milky/ripening stage of paddy. Accordingly, the rice fields for this study were monitored for parasitoid assemblages during the pre-flowering to the milky-grain stage.

The parasitoids collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under an Olympus SZ 61 and Leica M 205-A stereomicroscopes, at a magnification of 60 to 160X. The specimens studied are deposited at the National Zoological Collection at Zoological Survey of India, Kozhikode.

Identification of the specimens

Taxonomic identification of the genera followed mainly Masner (1976) and Mani & Sharma (1982) and that for species followed Rajmohana (2014). The species taxonomy in Platygastridae, mostly relies on the taxonomic characters of female wasps.

Measurement of diversity

Species or alpha diversity of the sites was quantified using Simpson's diversity Index (SDI), (Simpson 1949) and Shannon-Wiener index (Shannon & Wiener 1949). SDI is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. SDI 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. Subtracting the value of Simpson's index from 1, gives Simpson's Index of Diversity. The value of the index ranges from 0 to 1, with 1 representing infinite diversity and 0 representing no diversity.

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. The higher the value of H', the higher the diversity.

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

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

Beta diversity is a measure of how different (or similar) ranges of habitats are in terms of the variety of species found in them (Magurran 1988). 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. The statistical test ANOVA was used to check whether there was any significant difference in the collections from the three sites. All the analyses were done using Microsoft Excel (2010).

RESULTS AND DISCUSSION

Studies have been conducted on latitudinal gradients in insect species richness but elevational gradients of diversity have received increasing attention lately (Rahbek 2005). A total of 198 individuals (females) belonging to 38 species in 21 genera were recorded (Table 1). The gryllid egg parasitoid *Duta* Nixon with six species was the most dominant and species rich, among the orthopteran egg parasitoids, whereas among the spider parasitoids, *Idris* Förster was the most dominant.

The highland site (Madakkimala, Wyanad) and lowland site (Peruvayal, Kozhikode) were rich in orthopteran egg parasitoids with 24 species under 15 genera and

Table 1. Species abundance represented as Mean±SD for the members of subfamily Scelionidae recorded during the study (*parasitoids of spider eggs)

	Species	Malapuram	Kozhikode	Wyanad
		Mean±SD	Mean±SD	Mean±SD
1	*Baeus primitus* Rajmohana*	0.17±0.102	0	0
2	*Baryconus keralensis* Narendran	0.5±0.305	0	0.5±0.305
3	*Calliscelio agaliensis* Narendran & Ramesh Babu	0	0	0.17±0.102
4	*Calliscelio glabratus* Rajmohana	0	0	0.5±0.305
5	*Calliscelio indicus* Narendran & Ramesh Babu	0	0	1.17±0.51
6	*Ceratobaeus dunensis* Mukerjee*	0	0	0.5±0.305
7	*Ceratobaeus granulosus* Rajmohana*	0.33±0.205	0	0
8	*Ceratobaeus longituberculatus* Mukerjee*	0.5±0.55	0	0
9	*Cremastobaeus indicus* Mukerjee	0	0	0.33±0.205
10	*Cremastobaeus unicolor* Rajmohana	0	0.67±0.41	1.5±0.59
11	*Dicroscelio malabaricus* (Narendran)	0	0.5±0.305	0
12	*Doddiella nigricephala* Mukerjee	0	0	0.33±0.205
13	*Duta bicolour* Rajmohana	0.17±0.102	0	0.33±0.13
14	*Duta dissimilis* Rajmohana	0	0	0.33±0.205
15	*Duta elongata* Rajmohana	0	0	0.17±0.102
16	*Duta indica* Mukerjee	0.17± 0.102	0	0.17±0.102
17	*Duta polita* Rajmohana	0.17±0.0.102	0	0
18	*Duta serraticeps* (Priesner)	0	0.17±0.102	0.67±0.30
19	*Elgonia alpha* Rajmohana	1.67±0.8	0	0
20	*Elgonia chitrae* Rajmohana	0	0	0.17±0.102
21	*Fusicornia indica* Mani & Sharma	0.17±0.102	0	0
22	*Fusicornia tehrii* Mukerjee	0	0.17±0.102	1.0±0.5
23	*Idris keethami* Mukerjee*	0.17±0.102	0	0
24	*Idris nuperus* Rajmohana*	0	2.5±1.115	0.33±0.13
25	*Leptoteleia rustica* Rajmohana	0	0.17±0.102	0
26	*Macroteleia indica* Sharma	0	0	0.17±0.102
27	*Macroteleia lamba* Saraswat	0	0.33±0.205	1.17±0.46
28	*Neoceratobaeus gibbus* Rajmohana*	0.17±0.102	0	0
29	*Opisthacantha dunensis* Mukerjee	0	0.17±0.102	0.67±0.41
30	*Opisthacantha keralensis* Sharma	0	0.17±0.102	0.33±0.205
31	*Palpoteleia indica* Mukerjee	0.33±0.205	0.5±0.305	2.83±1.1
32	*Paridris coorgensis* Sharma	0.33±0.205	0.33±0.205	0.33±0.205
33	*Platyscelio pulchricornis* Kieffer	0	0.67±0.41	1±0.42
34	*Probaryconus cauverycus* Saraswat	0	0.5±0.21	1.5±0.59
35	*Probaryconus punctatus* Rajmohana	0	0.17±0.102	0
36	*Psilanteris coriacea* Rajmohana	0.33±0.205	0.33±0.205	1.5±0.625
37	*Scelio nilamburensis* Mukerjee	0.67±0.26	0.5±0.305	0.83±0.33
38	*Scelio spinifera* Mukerjee	0.17±0.102	0	0

15 species under 13 genera respectively, whereas, the midland site (Kavalamukkatta, Malappuram) was the richest in spider egg parasitoids with five species under four genera (Table 1). Since habitat heterogeneity increases crop-associated diversity of arthropods (Altieri 1999), the landscape surrounding the midland site could

Table 2. Diversity indices for the three sites

Diversity index	highland site (Wyanad)	midland site (Malappuram)	lowland site (Kozhikode)
Simpson's Index	0.94	0.92	0.88
Shannon-Wiener index (*H*')	2.97	2.55	2.48
Margalef index (α)	5.48	4.34	4.32
Pielou's index (*E1*)	0.90	0.90	0.86

be a factor influencing the presence of an increased richness of spider egg parasitoids.

The genera *Duta* Nixon, *Fusicornia* Risbec, *Idris* Förster, *Palpotelia* Kieffer, *Paridris* Kieffer, *Psilanteris* Kieffer and *Scelio* Latreille and species *Palpotelia indica* Mukerjee, *Paridris coorgensis* Sharma, *Psilanteris coriacea* Rajmohana and *Scelio nilamburensis* Mukerjee reported from all the sites can be considered as generalists (Table 1).

From Table 2, the Simpson's index of diversity values were near to one for all the sites even though there was a difference in the assemblages of the parasitoids. The highland site (Madakkimala, Wyanad) showed highest Simpson's index of diversity (0.94), followed by midland site (Kavalamukkatta, Malappuram) and lowland site (Peruvayal, Kozhikode) with values of 0.92 and 0.88 respectively.

A similar trend was observed for the Shannon-Wiener index (*H'*) and Margalef index (α) (Table 2).

The *H'* values for the sites revealed that it was more or less similar, with maximum diversity (2.97) accounted for the highland site (Madakkimala, Wyanad).

From the values of the Margalef index, (α) for the three sites, it was observed that the highland site (Madakkimala, Wyanad) was very rich in species with a richness value of 5.48, followed by midland site (Kavalamukkatta, Malappuram) and lowland site (Peruvayal, Kozhikode), with closely similar values of α (4.34 and 4.32 respectively). Hence, from Table 2, it is clear that species diversity and richness did not vary greatly between the sites since there was only minimal differences in the final values for Simpson's index of diversity, *H'* and *α*. The mean and Standard Deviation (SD) values for each species was calculated and given in Table 1. Further, it was decided to apply ANOVA to test if there was a significant difference between the three sites based on the collections. All species had a P-value >0.05, showing that there was no significant difference between the sites (Table 3).

The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida & 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 & 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.

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 1.5–760 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 increases with increasing altitude, within limits, a trend, though minute, which was observed from the values of Simpson's Index of diversity, *H*' and α.

The species evenness is a measure of the even distribution of the species. The Pielou's evenness value (*E1*) for the sites clearly indicate that the highland site (Madakkimala, Wyanad) and the midland site (Kavalamukkatta, Malappuram) show a similar evenness patterns with evenness index values which was the same for both the sites (0.90) and that for the lowland site (Peruvayal, Kozhikode) varied only slightly (0.86).

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). In the present work, identity of the specimens were worked out up to the species level, which generated the best possible results. The ANOVA test results (Table 3) clearly indicate that statistically there is no significant difference in the collections from the sites. Since the P-value for 37 species was >0.05, we could easily conclude that the sites were similar based on the species collected, without applying further tests.

The overall Jaccard's index between the three sites, viz., Madakkimala (Wyanad), Kavalamukkatta (Malappuram) and Peruvayal (Kozhikode), was found to be 0.105 (10.5% similarity between the sites). On comparing the species similarities between the three sites, taken in pairs it was found that 50% similarity was between lowland site (Peruvayal, Kozhikode)

Table 3. ANOVA test results for each species (+ Statistical interpretation impossible)

	Species	F-value	P-value
1	*Baeus primitus* Rajmohana	1	0.391
2	*Baryconus keralensis* Narendran	1	0.397
3	*Calliscelio agaliensis* Narendran & Ramesh Babu	1	0.397
4	*Calliscelio glabratus* Rajmohana	1	0.397
5	*Calliscelio indicus* Narendran & Ramesh Babu	2.042	0.173
6	*Ceratobaeus dunensis* Mukerjee	1	0.397
7	*Ceratobaeus granulosus* Rajmohana	1	0.397
8	*Ceratobaeus longituberculatus* Mukerjee	1	0.391
9	*Cremastobaeus indicus* Mukerjee	1	0.391
10	*Cremastobaeus unicolor* Rajmohana	1.245	0.316
11	*Dicroscelio malabaricus* (Narendran)	1	0.397
12	*Doddiella nigricephala* Mukerjee	1	0.391
13	*Duta bicolour* Rajmohana	1.154	0.392
14	*Duta dissimilis* Rajmohana	1	0.391
15	*Duta elongata* Rajmohana	1	0.391
16	*Duta indica* Mukerjee	0.5	0.616
17	*Duta polita* Rajmohana	1	0.391
18	*Duta serraticeps* (Priesner)	1.327	0.295
19	*Elgonia alpha* Rajmohana	1.623	0.23
20	*Elgonia chitrae* Rajmohana	1	0.391
21	*Fusicornia indica* Mani & Sharma	1	0.391
22	*Fusicornia tehrii* Mukerjee	1.24	0.317
23	*Idris keethami* Mukerjee	0.7	0.512
24	*Idris nuperus* Rajmohana	1.645	0.226
25	*Leptoteleia rustica* Rajmohana	1	0.391
26	*Macroteleia indica* Sharma	1	0.391
27	*Macroteleia lamba* Saraswat	1.612	0.232
28	*Neoceratobaeus gibbus* Rajmohana	0.765	0.483
29	*Opisthacantha dunensis* Mukerjee	0.765	0.483
30	*Opisthacantha keralensis* Sharma	0.6	0.561
31	*Palpoteleia indica* Mukerjee	1.633	0.228
32	*Paridris coorgensis* Sharma	+	+
33	*Platyscelio pulchricornis* Kieffer	0.854	0.446
34	*Probaryconus cauverycus* Saraswat	1.694	0.217
35	*Probaryconus punctatus* Rajmohana	1	0.391
36	*Psilanteris coriacea* Rajmohana	1.07	0.368
37	*Scelio nilamburensis* Mukerjee	0.115	0.892
38	*Scelio spinifera* Mukerjee	1	0.391

and highland site (Madakkimala, Wyanad) and 22% similarity between midland site (Kavalamukkatta, Malappuram) and highland site (Madakkimala, Wyanad) and least similarity (16%) was between midland site (Kavalamukkatta, Malappuram) and lowland site (Peruvayal, Kozhikode). A possible explanation for the 50% similarity between the assemblages at the sites at Peruvayal (Kozhikode) and Madakkimala (Wyanad) could be due to the similarity in the total area of the two plots. 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. 2006). The number of species in a habitat increases with increase in area (Gotelli & Graves 1996). The site at Kavalamukkatta, Malappuram having lesser area under cultivation compared to the other two sites, housed lesser number of species, but with a distinct assemblage.

CONCLUSION

Studies on species diversity along elevational ranges give inputs on the ecology of taxa assessed. Our study indicates that the elevational gradient of parasitic Hymenoptera, Platygastridae in particular, is not sharply defined which has been proved statistically. In the light of the special ecological role performed by parasitic Hymenoptera, coupled with its tertiary feeding level, it is clear that parasitic Hymenoptera diversity patterns are different, compared to other arthropod taxa.

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