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Species composition, abundance and seasonality of dermatitis causing *Paederus* rove beetles in paddy fields of Malabar region, Kerala, India

P.M. Kavyamol, P.J. Vineesh* and V.P. Vineetha

PG and Research Department of Zoology, St. Joseph's College (Autonomous), Devagiri, Kozhikode, Kerala, India.
Email: kavyamohan5540@gmail.com; vineeshpj@gmail.com, vineethavpnambiar@gmail.com

ABSRACT: Species composition, abundance, and seasonality of *Paederus* in the paddy fields of the Malabar region, Kerala, India, are analysed. Among the five species of *Paederus* beetles collected from Malabar, four are known to cause dermatitis. *Paederus sondaicus* Fauvel 1895 was the dominant species in the paddy fields of the Malabar region. Regional variation in the species composition, abundance, and seasonality of species was observed. *P. sondaicus* was dominant in Wayanad and Palakkad, *P. fuscipes* Curtis, 1826 in Malappuram and Kozhikode and *P. extraneus* Wiedemann, 1823 in Kannur. A modified taxonomic key for identification of *Paederus* beetles in Kerala is provided.

KEY WORDS: Rove beetles, regional variation, rice ecosystem, pederin, linear dermatitis

INTRODUCTION

Paederus Fabricius, 1775 is a genus of Rove beetle belonging to the subfamily Paederinae of the family Staphylinidae, with more than 622 species distributed in all continents except Antarctica (Zargari *et al.,* 2003; Mammino, 2011). In general, species of *Paederus* inhabit moist environments such as marshes, edges of freshwater lakes, river banks, and crop fields (Frank and Kanamitsu, 1987). *Paederus* species are nocturnal in habit, remain under bark, stones, soil, litter during day time (Frank and Kanamitsu, 1987; Nasir *et al*., 2012; Bong *et al.,* 2012). There are predators on soft bodied insects; soil nematodes and hence act as biological control agents (Frank and Kanamitsu, 1987, Bong *et al*., 2015, Maruthadurai *et al*., 2022). Large populations of *Paederus* have been recorded from agricultural habitats which make them beneficial due to their feeding on insect pests of major crops and fodders (Devi *et al*., 2003), particularly insect pests like *Heliothis armigera* Hübner, 1808; *Aphis gossypii* Glover, 1877; *Earias vittella* Fabricius, 1794; *Spodoptera litura* Fabricius, 1775; *Marasmia patnalis* Bradley, 1981; *Aphis glycines* Matsumura, 1917 and many dipterous and other arthropods (Berglind *et al*., 1997; Krakerb *et al*., 2000; Devi *et al*., 2003). However, the benefits provided by species of *Paederus* are annulled by the problems they cause for humans (Bong *et al*., 2015). When a beetle is brushed vigorously over the skin or crushed, a toxic haemolymph containing Pederin is released those leads to localized blistering (Kitisin and Sukphopetch, 2021) and inflammation

* Author for correspondence

referred as *Paederus* mediated dermatitis also called linear dermatitis, dermatitis linearis, Nairobi fly dermatitis, spider-lick, whiplash, Blister beetle dermatitis (Zargari *et al*., 2003; Mullen and Durden, 2009). *P. fuscipes* is reported to cause Paederus dermatitis in Kerala (Ramakrishnan *et al.,* 2019). Eleven species of *Paederus* are recorded till now from Kerala including three species recorded by Cameron (1931) and Kavyamol *et al*. (2023), and there is no recent taxonomic analysis of the *Paederus* beetles in the paddy fields of the Malabar region. Present study was undertaken to identify the species of *Paederus* beetles in Malabar region and to generate baseline ecological data of *Paederus* beetles in Malabar region.

MATERIALS AND METHODS

Sampling for ecological studies: During 2018–2019 light traps (SAFS ltrap 01 B) were used to sample *Paederus* beetles. Ten light traps were placed at a distance of 100 meters within a paddy field and monthly collections were made from Palakkad (10.6726° N, 76.7531° E), Malappuram (10.9015° N, 76.1904° E), Wayanad (11.6165°N, 76.2140°E), Kozhikode (11.4146°N, 75.9363°E) and Kannur (11.7481°N, 75.4929°E). Thus, thirty samples were collected from each site during Pre-summer (December, January, February/Pre-harvesting), Summer (March, April, May/ Harvesting) and Monsoon (September, October, November/ Post-harvesting) seasons. Traps were operated from 6pm to 7am the next day. Trapped beetles were collected and transferred into vials containing 70% alcohol. Beetles collected were examined under a Stereo Zoom Trinocular Microscope (LABOMED – 200 MAR, CODE:-ZM 45 TM). Specimens were identified with the help of keys provided by Cameron (1931). Photographs were taken with a Leica MC170HD camera attached to a Leica M205C stereomicroscope.

Species abundance data was tested for normality with Anderson-Darling test and opted parametric tests for further analysis. Shannon diversity index was calculated to analyse the diversity of *Paederus* beetles in different seasons at different collection sites. Two- way ANOVA followed by Tukey's test was done to compare the species abundance between habitats and seasons. All statistical analyses were done using PAST software version 3.15 (Hammer *et al.,* 2001). For all analyses, significance was determined at $P<0.05$.

RESULTS AND DISCUSSION

Overall Species composition, abundance and distribution: Five species of *Paederus* were recorded in the paddy fields of Malabar region (Plate 1). Among these, *P. sondaicus* Fauvel 1895 was the dominant ($F= 97.72$; $P< 0.0001$) (Fig. 1). Tukey's comparison examined whether there is any possible difference between the mean of all possible pairs and found that, *P. sondaicus* showed difference in abundance with that of *P. alternans* Walker, 1858, *P. extraneus* Wiedemann, 1823, *P. nigricornis* Bernhauer, 1911 and *P. fuscipes* Curtis, 1826 (Table 1).

Site wise Species composition, abundance and distribution: Variation in species composition and abundance in different localities was recorded. Highest diversity was recorded in Wayanad. Five species were recorded from Wayanad and *P. sondaicus* as the dominant there ($F= 89.07$; $P< 0.0001$). Comparison of the abundance of species collected from Wayanad found that *P. fuscipes* showed difference in abundance with that of *P. sondaicus* ($P< 0.05$), *P. alternans* ($P< 0.0001$), *P. extraneus* ($P< 0.0001$), *P. nigricornis* ($P< 0.0001$); *P. sondaicus* showed difference in abundance with that of *P. alternans* ($P<0.0001$), *P. extraneus* ($P<0.0001$), *P. nigricornis* ($P< 0.0001$) (Table 2, 3).

Three species of *Paederus* were recorded from Malappuram and *P. fuscipes* was dominant here ($F= 125.8$; $P< 0.0001$). Tukey's comparision indicates that in Malappuram, *P. fuscipes* showed difference in abundance with *P. sondaicus* ($P< 0.0001$) and *P. alternans* ($P< 0.0001$); *P. sondaicus* showed difference in abundance with that of *P. alternans* ($P< 0.0001$). Two species of *Paederus* were recorded from Palakkad and *P. sondaicus* was the dominant species ($F=691.9$; $P< 0.0001$). Tukey's test compared the abundance of that species and found that in this site, there is a difference in abundance of *P. fuscipes* with that of

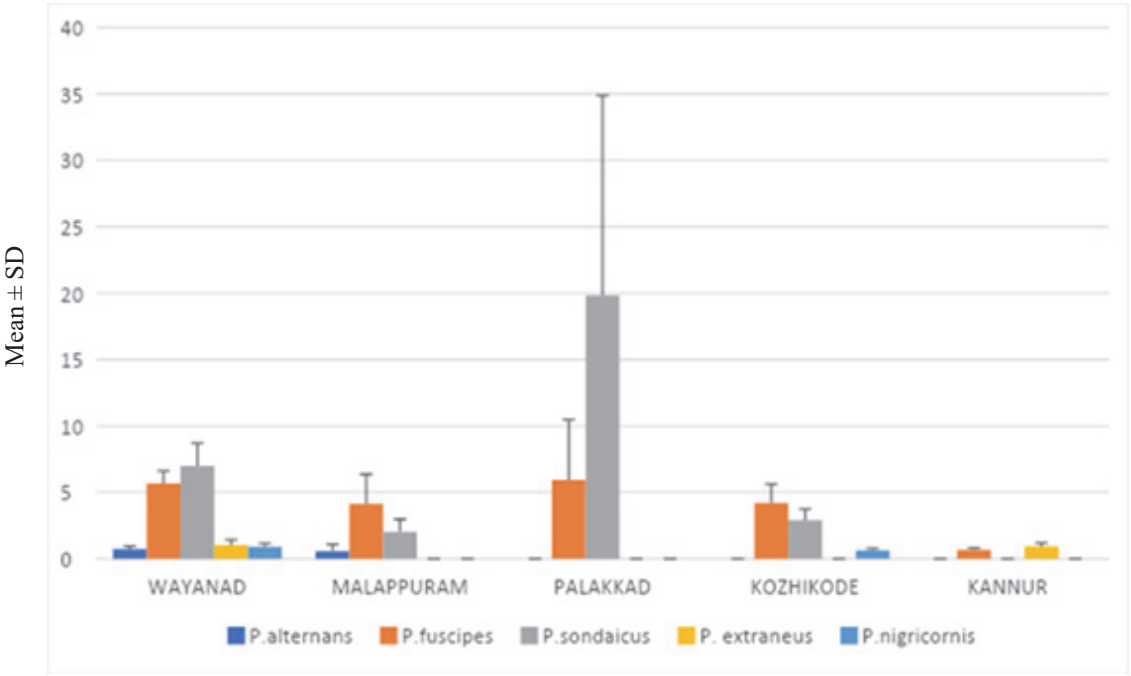

Fig. 1 Abundance of *Paederus* beetles collected from Malabar region

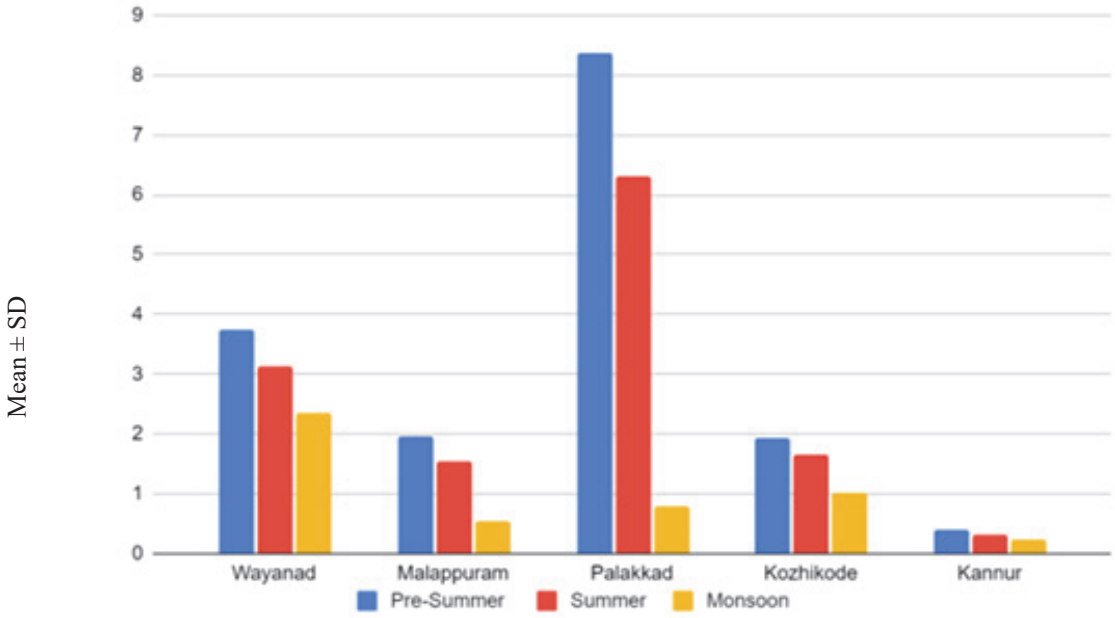

Fig. 2 Seasonality of *Paederus* beetles collected from Malabar region Pre-summer (December, January, February); Summer (March, April, May); Monsoon (September, October, November)

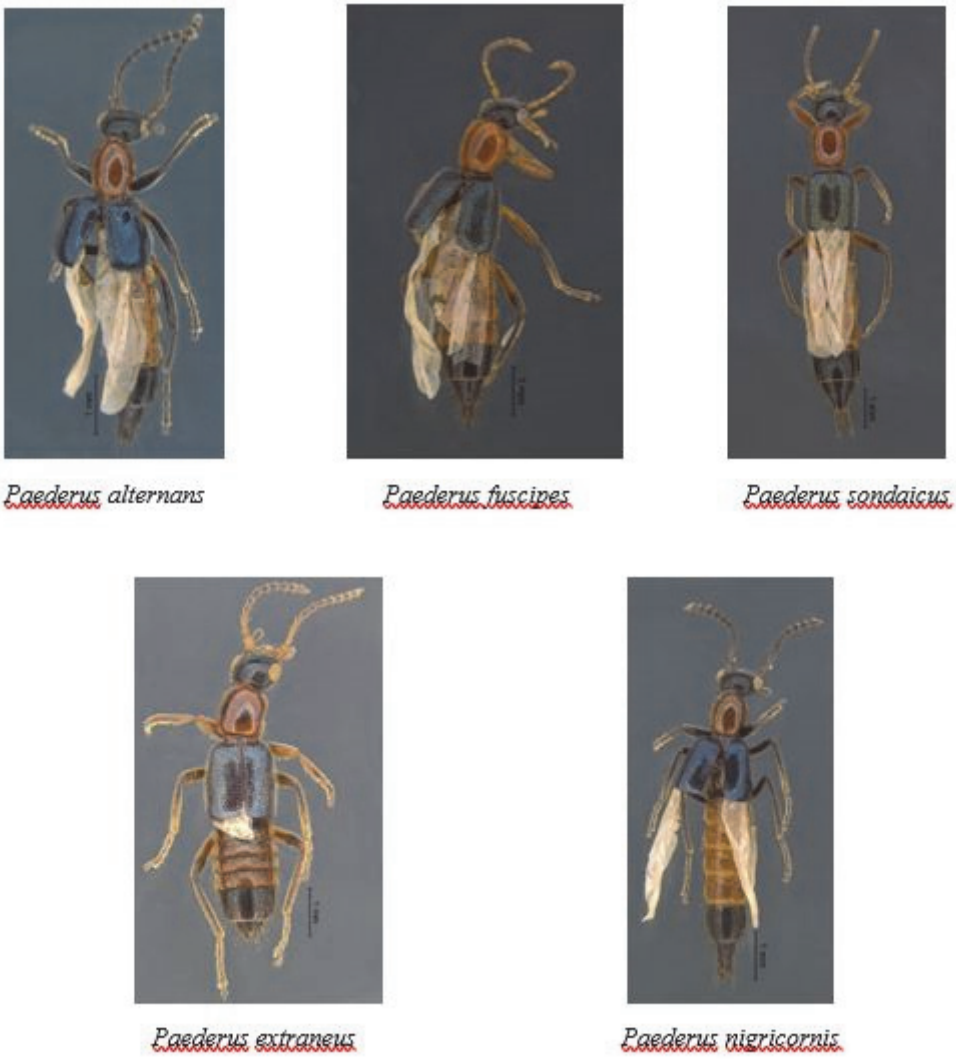

Plate 1. Spicies recorded in paddy fieds of Malabar region

P. sondaicus (P< 0.0001). Three species of *Paederus* were recorded from Kozhikode and *P. fuscipes* was the dominant species (F=167.8; P<0.0001). Tukey's comparision results that, *P. fuscipes* has shown a difference in abundance with *P. sondaicus* (P< 0.0001), *P. nigricornis* (P< 0.0001); *P. sondaicus* has shown a difference in abundance with *P. nigricornis* (P< 0.0001). Two species of *Paederus* were recorded from Kannur with *P. extraneus* as the dominant one (F= 5.987; P< 0.05). Comparison of abundance of species collected from Kannur indicated that there is a difference in abundance between *P. extraneus* and *P. fuscipes* (P< 0.05).

All species were not recorded from all collection sites. *P. alternans* was recorded only from Wayanad and Malappuram; *P. fuscipes* were captured from all the five collection sites *i.e.*, Palakkad, Malappuram, Kozhikode, Kannur and Wayanad; *P. sondaicus* from all the collection sites except Kannur region; *P. extraneus* from Wayanad and Kannur; *P. nigricornis* from Kozhikode and Wayanad. The highest overall abundance (Mean±SD) of the total *Paederus* beetles was recorded at Palakkad followed by Wayanad.

Overall Seasonality: *P. fuscipes* (P< 0.0001), *P. sondaicus* (P< 0.0001), and *P. alternans* (P<

0.001) showed high dominance during pre- summer (December, January and February) in Malabar region. Tukey's test for seasonal comparison of the dominant *Paederus* species indicated that, there was a significant variation of the abundance of *P. fuscipes* between all the three seasons (Table 4).

Site-wise Seasonality: *Paederus* beetles showed seasonality in abundance with high dominance during pre- summer season in all the collection sites (Fig. 2). *P. sondaicus* (P< 0.05), *P. extraneus* (P< 0.001) and *P. nigricornis* (P< 0.01) showed seasonality with high abundance during the pre-summer in Wayanad. Likewise, among the three species recorded from Malappuram, *P. fuscipes* (P< 0.0001) and *P. sondaicus* (P< 0.001) showed seasonality in abundance. The average number of all species collected from Palakkad has shown significant seasonal variation *i. e., P. fuscipes* (P<0.0001) and *P. sondaicus* (P<0.0001) have shown seasonality in abundance. Similarly, in Kozhikode *P. fuscipes* (P< 0.0001) and *P. sondaicus* (P< 0.0001) showed seasonality in abundance. From Kannur, *P. extraneus* showed seasonality in abundance (P< 0.05). Two-way ANOVA was done to compare the abundance of *Paederus* beetles irrespective of species, between different habitat (collection sites) and seasons. There was a significant variation in *Paederus* beetle abundance between different habitats (F=4.41; P<0.05) but there was no significant variation between the seasons (F=2.87; P>0.05).

As per literature references, a total of 11 species of *Paederus* are reported till now from Kerala (Table 5). A toxonomic key for the identification of these species is prepared.

Key to the *Paederus* species of Kerala (modified from Cameron, 1931)

1 Unicolorous species with reddish yellow colour……..…….....….*P. pallidus*

Species multicolored.....2

2 Elytra reddish.....*P. mussardi*

Elytra bluish or blackish.....3

3 Elytra vertically impressed near lateral margins……..…...……*P. loebli*

Elytra without vertical impression.....4

4 Apterous, head red.....*P. hingstoni*
Winged, head black, blue or blueblack.....5

5 Head black.....7

Head blueblack.....6

6 Legs including the coxae entirely black.....*P. kuluensis*

Legs with at least the coxae reddish brown.....*P. variicornis*

7 Legs wholly dark brownish black including the coxae.....8

Legs in part at least testaceous.....9

8 Post- ocular region almost rounded.....*P. extraneus*

Post-ocular region straightly converging to the neck.....*P. nigricornis*

9 Legs black, the coxae and extreme base of the femora reddish yellow.....*P. alternans*

Legs almost yellowish and anterior femora entirely testaceous.....10

10 Larger (>9mm). Last joint of antennae testaceous..... *P. sondaicus*

Table 1. Tukey's table (Studentized range statistic) the comparison of total *Paederus* species collected from Malabar region

Species name	Q value	P value
P. fuscipes/P. sondaicus	7.87	<0.0001
P. fuscipes /P. alternans	13.56	<0.0001
P. fuscipes /P.extraneus	13.15	<0.0001
P. fuscipes /P. nigricornis	13.44	<0.0001
P. sondaicus /P. alternans	21.43	<0.0001
P.sondaicus /P. extraneus	21.02	<0.0001
P. sondaicus/P. nigricornis	21.31	<0.0001
P. alternans/P.extraneus	0.42	>0.05
P. alternans/P. nigricornis	0.12	>00.5
P. extraneus/P. nigricornis	0.29	>0.05

Smaller (<7.5mm). Last joint of antennae concolorous.....*P. fuscipes*

The high abundance of *Paederus* beetles, in paddy fields, is closely linked to their role as natural predators that coexist with numerous agricultural pests (Bong *et al*., 2015). Specifically, proximity to paddy fields is a pivotal factor in the outbreak of *Paederus* beetle dermatitis (Coondoo and Nandy, 2013). The current study further revealed that paddy fields serve as the optimal habitat for *Paederus* beetles (Frank and Kanamitsu, 1987; Bong *et al*., 2015), indicating their preference for this particular ecological niche.

Among the five species of *Paederus* collected from paddy fields of Malabar region, the following species are known to cause dermatitis in different parts of the world: *P. fuscipes* (Frank and Kanamistu 1987; Verma and Agarwal 2006; Toppo *et al*., 2013; Ramakrishnan *et al* 2019); *P. alternans* (Frank and Kanamistu, 1987), *P. extraneus* (Taneja *et al*., 2013; Gopal 2014) and *P. nigricornis* (Nikbakhtzadeh and Tirgari, 2008).

Of the five different study areas of Malabar, the highest abundance was recorded in Palakkad and the highest diversity was recorded in Wayanad, as these two places have the largest area under paddy cultivation as compared to other collection sites (Agricultural Statistics, 2020; Jankielsohn, 2023). According to the Kerala Water Resource Information System (KWRIS 2018-2019), the annual rainfall of Palakkad and Wayanad is less compared to Kannur, Kozhikode and Malappuram, which is the second possible reason for the high abundance of *Paederus* beetles in Palakkad and high diversity in Wayanad since heavy rainfall adversely affect the survival of *Paederus* beetles (Nasir *et al*., 2012).

During the pre-summer season with mild and moderate weather, there was a noticeable rise in the number of *Paederus* beetles (personal observation). The amount of rainfall significantly affects the *Paederus* beetle population. There is a noticeable decrease in *Paederus* beetles in summer and monsoon with extreme climatic conditions. Intense heat and dryness were noticed during the summer season, which lead to low abundance of *Paederus* beetles in this period of collection. Previous study results from Pakistan, recorded that, heavy rainfall in the monsoon season causes suffocation of larvae and pupae in the soil, and it reduces the population of *Paederus* beetles during the months of heavy rain (Nasir *et al*., 2012). This study results also substantiate the negative influence of heavy rainfall on abundance of *Paederus* beetles.

The abundance of *Paederus* beetles was strongly influenced by the various stages of Paddy cultivation (Maryam *et al*., 2017). Similarly, this study reaffirmed that the different paddy cultivation stages significantly impact the number of *Paederus* beetles, as they were prevalent during the milky grain stage of rice crop (pre-summer season), when insect pests like planthoppers and leafhoppers pose a significant threat to rice plant. *Paederus* beetles are predators of these insect pests (Frank and Kanamistu 1987; Kartohardjono,1988) and the availability of their food sources increased their population density at this

Table 2. Seasonal Abundance data (mean ± SD) of *Paederus* species from the study sites

Species name	WAYANAD			MALAPPURAM			PALAKKAD			KOZHIKODE			KANNUR		
	PS	S	M	PS	S	M	PS	S	M	PS	S	M	PS	S	M
P. alternans	0.9±0.7	0.8±0.7	0.5±0.6	1±0.9	0.7±0.6	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0
P. fuscipes	6.7±4.0	5.5±3.7	4.8±3.2	5.8±2.8	5±2.2	1.6±0.9	10.1±3.4	6.6±2.3	1.1±1.1	5.3±1.9	4.7±1.5	2.6±1.3	0.8±0.5	0.7±0.5	0.5±0.5
P. sondaicus	8.6±5.1	7.2±4.2	5.2±3.7	3±2.21	2±1.4	1.1±0.7	31.7±3.4	24.9±4.3	2.9±1.7	3.7±1.2	3±1.4	2±1.1	0±0	0±0	0±0
P. extraneus	1.4±0.9	1.1±0.6	0.6±0.5	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	1.2±0.7	0.9±0.7	0.7±0.5
P. nigricornis	1.1±0.6	1±0.5	0.6±0.5	0±0	0±0	0±0	0±0	0±0	0±0	0.8±06	0.6±0.5	0.5±0.5	0±0	0±0	0±0

PS= Pre- summer, S= Summer and M=Monsoon

Table 3. Shannon Diversity Index of different sites in different seasons

Seasons	Wayanad	Malappuram	Palakkad	Kozhikode	Kannur
Overall	1.219	0.8709	0.5403	0.9071	0.6809
Pre-summer	1.229	0.9044	0.5529	0.9013	0.6768
Summer	1.239	0.8551	0.5141	0.8854	0.6829
Monsoon	1.167	0.673	0.5939	0.947	0.684

stage (Bong *et al*., 2013). The lowest number of *Paederus* beetles during the monsoon season may be due to the aftermath of the Kerala flood in August 2018. *P. fuscipes* was the only species found in each of the five collection sites. According to Frank and Kanamistu 1987, *P. fuscipes* is a widely distributed species, and from central Asia its range extends west to the British Isles, east to Japan, and southeast to Australia. Its habitats range from cultivated, irrigated fields to marshes and riverbanks. The results of this study are consistent with the especially wide distribution of *P. fuscipes* and its adaptability to nearly every environment. *P. fuscipes, P. sondaicus and P. alternans* have shown seasonality in abundance in Malabar region, however, *P. nigricornis* and *P. extraneus* showed no seasonality. It might be because of the fewer number of *P. nigricornis* and *P. extraneus* in the collection.

Table 4. Tukey's table showing the seasonal comparison of species collected from Malabar

Species	[1]Seasons	Q value	P value
P. fuscipes	Pre-Summer/Summer	4.677	<0.01
	Pre-Summer/Monsoon	13.75	<0.0001
	Summer/Monsoon	9.07	<0.0001
P. sondaicus	Pre-Summer/Summer	2.69	>0.05
	Pre-Summer/Monsoon	9.77	<0.0001
	Summer/Monsoon	7.08	<0.0001
P. alternans	Pre-Summer/Summer	1.51	>0.05
	Pre-Summer/Monsoon	5.76	<0.001
	Summer/Monsoon	4.26	<0.01

Pre-summer (December, January, February); Summer (March, April, May); Monsoon (September, October, November)

According to reports (Singh and Ali, 2007; Kumaraguru *et al*., 2022) *P. melampus* is the most common species found in India. Contrary to the former report, *P. sondaicus* was found to be the predominant species in the Malabar region. Although *P. sondaicus* was already reported from Silent Valley, Kerala (Biswas, 1986), additional research on the abundance and seasonality of *Paederus* species need to be conducted in Kerala.

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Table 5. Table showing the distribution of *Paederus* species in Kerala, India.

No	Species name	Distribution	Reference	Authors' observation
1	*P. alternans* Walker, 1858	Tamil nadu: Nilgiri Hills; Karnataka: Kanara; Himalayas	Cameron, 1931; Biswas & Sengupta, 1982	Kerala: Malappuram, Wayanad
2	*P. fuscipes* Curtis, 1826	Central Kerala; Tamil Nadu: Annamalainagar, Chidambaram; Karnataka; Uttar Pradesh: Rampur, Ballia, Mirzapur, Allahabad; Gujarat; Uttarakhand; Himachal Pradesh; Bihar; Kashmir, Madhya Pradesh; West Bengal: Sikkim, Darjeeling District; Meghalaya and Tripura	Cameron, 1931; Kamaladasa *et al*.,1997; Varma and Agarwal, 2006; Toppo *et al*., 2013; Sar and Hedge, 2015; Ramakrishnan *et al*., 2019; Vineesh *et al*., 2023	Kerala: Palakkad, Malappuram, Kozhikode, Kannur, Wayanad
3	*P. sondaicus* Fauvel, 1895	Kerala: Silent Valley (Palakkad); Tamil nadu: Nilgiri Hills; Karnataka: Belgaum, Nagargali, Khanapur, Sampgaon; Meghalaya: Khasia Hills, Maharashtra	Cameron, 1931; Biswas, 1986	Kerala: Palakkad, Malappuram, Kozhikode, Wayanad
4	*P. extraneus* Wiedemann, 1825	Karnataka: Manipal; Andra Pradesh; Bengal	Cameron, 1931; Taneja *et al*., 2013;Gopal, 2014	Kerala: Wayanad, Kannur
5	*P. nigricornis* Bernhauer, 1911	Uttar Pradesh: Allahabad- Ramghat; Mizoram; Uttaranchal; Uttarakhand: Chakrata district Garhwal hills; West Bengal: Darjeeling, Nurbong and Mahanadi Valleys; Sikkim; Himachal Pradesh: Simla Hills	Cameron, 1931; Sar and Hedge, 2015; Sar and Ilango, 2016	Kerala: Kozhikode, Wayanad
6	*P. mussardi* Biswas and Gupta, 1982	Kerala: Silent Valley (Palakkad); Peermade, Munnar	Biswas & Sengupta, 1982; Biswas, 1986	-
7	*P. pallidus* Scheerpeltz, 1933	Kerala: Munnar; Tamil nadu: Madura, Palani Hills, Kodaicanal, Madras	Cameron, 1931; Biswas & Sengupta, 1982	-
8	*P. loebli* Biswas and Gupta, 1982	Kerala: Munnar	Biswas & Sengupta, 1982	-
9	*P. variicornis* Fauvel, 1903	Kerala: Silent valley (Palakkad); Tamil nadu: Nilgiris: Coonoor. Ghozeh. Madura; Karnataka: Kanara).	Cameron, 1931; Biswas and Sengupta, 1982; Biswas, 1986	-
10	*P. kuluensis* Bernhauer, 1911	Kerala: Silent Valley; Himachal Pradesh	Cameron, 1931; Biswas, 1986	-
11	*P. hingstoni* Cameron, 1928	Kerala: Calicut; Sikkim: Darjeeling	Cameron, 1931; Sreevidhya and Sebastian, 2020	-

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