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Diversity of short-horned grasshoppers (Orthoptera: Caelifera) in selected mangrove ecosystem and Kole Wetland of central Kerala, India

Thasnim E S*, Bijoy C
Department of Zoology, Shadpada Entomology Research Lab, Christ College, Irinjalakuda, Thrissur, Kerala, India

Abstract
The Caeliferan diversity in selected Kole wetland and mangrove ecosystem of Thrissur was documented for seven months from June to December 2018. A total of 11 species belonging to seven subfamilies and two families were recorded. Species richness was higher in the Kole wetland, but they were more evenly distributed in the mangrove ecosystem. The study was interrupted by the 2018 Kerala flood, and the grasshopper distribution in relation to the flood was recorded.

Keywords: orthoptera, caelifera, grasshopper, Kole Wetland, mangrove, diversity

Introduction

Orthopterans are the primary insect group representing grassland ecosystems, [1] comprising grasshoppers, crickets and katydids. The suborder Caelifera of order Orthoptera represents grasshoppers with lesser antennal segments (short-horned grasshoppers). About 29,009 grasshoppers are known so far from the world, [2] among which only 1033 species are recorded from India,[3] 140 species from Kerala [4, 5, 6, 7, 8]. The pest status of grasshoppers in India is one reason for the lack of information on their functional role in different ecosystems [5]. Being important primary consumers and contributing to the diet of many other animals, grasshoppers play a significant role in the functioning of grassland ecosystems [9, 10]. They are good indicators of the health and quality of different habitats and respond quickly to the changing environmental conditions [11]. But they remain less explored and no grasshopper species in India has so far been considered as a biodiversity indicator [4]. Prabakar and Radhakrishnan [12] documented four new reports of grasshoppers from Kerala while studying the orthopteran specimens of the Zoological Survey of India collection. Koya *et al.* [13] recorded 35 species belonging to five families from Palakkad, Kerala. Bhaskar *et al.* [4] compiled a checklist for Orthoptera of Kerala in which they reported 130 species of Orthoptera. Bhaskar *et al.* [5] studied the impact of fire management practices on the grasshopper fauna of Eravikulam National Park and Parambikulam Tiger Reserve, Kerala. Bhaskar *et al.* [14] rediscovered *Mopla guttata* Henry, from Western Ghats, Kerala, and described the first male specimen of the genus. Bhaskar *et al.* [6] recorded a new species *Tettilobus trishula,* from the Western Ghats of Kerala. The grasshopper diversity of the Kole wetlands and mangrove ecosystems of central Kerala was never documented. The present study aims to find the grasshopper diversity in two selected wetland ecosystems; mangrove and Kole wetland of the Thrissur district of Kerala state. The Kole wetlands are one of the largest, highly productive and threatened low lying wetlands located 0.5 - 1m bmsl. The Kole wetland, including paddy field greenery spread over the Thrissur and Malappuram districts of Kerala, recognized as one of the Ramsar sites during 2002 [15]. The 'Kole' is a local term in regional language (Malayalam) that refers to the bumper yield or high yield, which is a particular cropping pattern from December to May [16]. Mangroves, globally distributed on tropical shores, consist of trees, shrubs, climbers, and ferns adapted to saline and anoxic habitats which make mangrove plants structurally and functionally unique [17, 18, 19]. In Kerala, the maximum extent of mangroves is reported from Kannur (1100 ha), followed by Ernakulam (600 ha) and Kasaragod (315 ha). Thrissur has a minimum extent of 30 ha. of mangroves [20]. Human intervention is evident in both the Kole wetland and Mangrove ecosystem as paddy and aquaculture practices respectively. Since the impact of human intervention can significantly affect these ecosystems' faunal diversity, field surveys and faunal documentation programmes are needed to know the status and distribution of species to implement conservation efforts. No work has been reported so far on grasshopper diversity from these ecosystems of this region; hence this primary step on inventorying the grasshopper fauna of these ecosystems will form a foundation for carrying out future research in this area.

Materials and Methods

Two kinds of wetland ecosystems; Mangrove ecosystem in Vallivattaom ($10^0$15'51.79'' N and $76^0$11'31.18'' E) and the Kole wetland of Muriyadu ($10^0$21'51.46" N and $76^0$15'53.54" E) in Thrissur district, Kerala, India, were selected for monitoring grasshopper diversity. The study was conducted from June to December 2018.

A systematic collection of grasshoppers was done from both fields twice a month. The collection was done by net sweeping, covering a linear distance of 10m on a band of about 1m width [21]. Being cold-blooded organisms, grasshoppers place themselves on the vegetation surface to warm up during morning hours at low-intensity sunlight.[22] Hence, the collection was carried out during the morning hours from 9:00 am to 11:00 am. The collected specimens were killed by using ethyl acetate, spread, dried and preserved by pinning. Voucher specimens were preserved and deposited in Shadpada Entomology Research Lab

Entomology collections. Unidentified and taxonomically difficult species were later identified using various taxonomic literature and by consulting experts. The taxonomy follows the latest version of the Orthoptera Species File [2]. In August 2018, Kerala experienced an extended period of torrential rainfall due to a low-pressure system near the beginning of the month, followed by a monsoon depression. Though the study was interrupted in August by the floods, the data collected before the deluge (June - July) and data collected after it (September - October) was also compared to find if any significant change may have occurred to the diversity of Caeliferan fauna of the ecosystem. Diversity indices such as Shannon's diversity index (H') and Simpson's diversity index (1-D) were calculated. Besides, Sorensen similarity index, Equitability (J) index for evenness and Fisher's alpha for richness were also calculated. Estimate S (Version 9.1.0) was used to estimate total species richness from the observed richness and to plot species accumulation curves, non-parametric estimators, namely Chao 2 and Jacknife 2, [23] were employed. The software PAleontological STatistics (PAST) Version 3.25 was used to calculate different diversity indices.

Results and Discussion

Eleven species of Caeliferans under 10 genera belonging to seven subfamilies and two families (Acrididae and Pyrgomorphidae) were recorded from both the Kole wetland and Mangrove ecosystem. Ten species under nine genera and eight species under seven genera were recorded from the Kole wetland and Mangrove ecosystems respectively (Table 1). Acrididae was the dominant family in both the ecosystems, and Pyrgomorphidae was represented by a single species, *Atractomorpha crenulata* Fabricius, 1793. The Acrididae which is recognised as the most diverse family within the Orthopteran suborder Caelifera has a wide cosmopolitan distribution [24]. The Acrididae are found to be dominant in the paddy fields of Coimbatore and Uttar Pradesh [25, 26]. Tan [27] from Singapore reported the higher Acrididae diversity from Mangrove ecosystems. The fresh lush greenery of paddy fields favoured the higher grasshopper distribution in the Kole wetlands than that of the Mangrove ecosystems.

The subfamily Catantopinae had the most significant species representation (three species), followed by Oedipodinae and Oxyinae (two species each), while other subfamilies were represented by single species (Table. 2). After the Oedipodinae, Catantopinae was the richest subfamily in both agriculture and forest ecosystems of Dharwad, Karnataka [28]. *Acrida exaltata* Walker, 1859, *Choroedocus robustus* Serville, 1838, *Stenocatantops splendens* Thunberg, 1815 were recorded only from the Kole wetland. *Acrida exaltata* was also reported from rice ecosystems of Uttar Pradesh [26] and Tamilnadu [25, 29] and paddy is found to be the most preferred food by *Acrida exaltata* [30]. *Choroedocus robustus* is also recognized as a pest, which prefer mixed vegetation and paddy fields [31]. *S. splendens* is also defined as a pest of paddy [31] and a minor pest of wheat [32]. Thus, paddy cultivation may have an impact on their distribution in the Kole wetland. *Chondracris rosea* De Geer, 1773 was recorded only from mangroves. This species is inhabited primarily on forest areas and dense mixed vegetation [31]. Thus, three species were recorded only from Kole wetland, one from mangrove and seven species, *Diabolocatantops innotabilis* Walker, 1870, *Oedaleus abruptus* Thunberg, 1815, *Trilophidia annulata* Thunberg, 1815, *Oxya hyla* Serville, 1831, *Oxya fuscovittata* Marschall, 1836, *Spathosternum prasiniferum* Walker, 1871 and *Atractomorpha crenulata* were found in both the ecosystem. Most of them were also reported from other wetland ecosystems; Roper wetland, Panjab [33] and Pong Dam wetland, Himachal Pradesh [34]. *O. fuscovittata* and *O. hyla* were the dominant species of the Kole wetland and mangrove ecosystem, respectively. Subfamily Oxyinae was described as one of the subfamilies of Acrididae that are colonized in marshy zones and water associated areas [35]. *O. fuscovittata* was recorded as the common and dominant species of irrigated rice ecosystem in Madurai, Tamil Nadu [29]. The species accumulation curve describes species richness in a local homogeneous assemblage as a function of sampling effort [36]. The species accumulation curve in the mangrove has flattened, so maybe most of the species represented in this ecosystem were documented during the study. While the species accumulation curve in the Kole wetland has started flattening, there are possibilities of getting some more species from there (Fig. 2 and 3).

The rank abundance curves of the mangrove ecosystem and Kole wetland ecosystem show that grasshoppers are more evenly distributed in mangroves than in the Kole wetland (Fig. 1).

Diversity indices are statistics used to summarize the diversity of a population in which each member belongs to a unique group [37]. The concept of species diversity generally consists of two components, namely, species richness and species evenness. Fisher's alpha for richness was higher in the Kole wetland than the mangrove ecosystem, thus species richness was higher in Kole wetland. Evenness calculated by equitability index (J) was higher for mangrove than Kole wetland ecosystem. Generally, Shannon diversity index (H) and Simpson diversity index are commonly used to evaluate the diversity of organisms present in an area. Shannon diversity index and Simpson index were higher for mangrove than Kole wetland (Table 4). Even though species richness was higher in Kole wetland, these diversity indices' value was higher for mangrove. This is because of the more even distribution of species in the mangrove. According to Stiling [38], a community with two species can be more diverse than a community with three species if the distribution of individuals between the two species is more even. The similarity between these two ecosystems was 0.77 by the Sorenson similarity index, which means the communities are more similar.

During the pre-flood phase (June – July), eight species were recorded from the Kole wetland and mangrove ecosystem. During the post-flood phase (September – October), eight species were recorded from Kole and five species from Mangrove.

The value of Shannon and Simpson diversity indices indicates that Mangrove ecosystem diversity is decreased after the flood. Shannon equitability index for Kole is higher during the post-flood period, which means that the species are more evenly distributed after the flood (Table 5). Since the mangrove ecosystem is near to river system and Kole lands are low laying area, both these systems were highly affected by the flood. Hence, no species were collected immediately after the flood from both ecosystems. Four species were recorded from mangroves, and few nymphs (which were not considered in this study) were noticed in

Kole in September. Eight species from the Kole and five species from Mangrove were recorded in October. In the Kole wetland, there were more fresh sprouting grasses when compared to the mangrove ecosystem during the post-flood period, which may be the reason for the increasing diversity of grasshoppers in Kole.

Table 1: Distribution of grasshoppers in two habitats

Family	Subfamily	Species	Mangrove	Kole wetland
Acrididae	Acridinae	*Acrida exaltata*	-	+
	Catantopinae	*Choroedocus robustus*	-	+
		Diabolocatantops innotabilis	+	+
		Stenocatantops splendens	-	+
	Cyrtacanthacridinae	*Chondracris rosea*	+	-
	Oedipodinae	*Oedaleus abruptus*	+	+
		Trilophidia annulata	+	+
	Oxyinae	*Oxya fuscovittata*	+	+
		Oxya hyla	+	+
	Spathosterninae	*Spathosternum prasiniferum*	+	+
Pyrgomorphidae	Pyrgomorphinae	*Atractomorpha crenulata*	+	+

Table 2: Number and proportion Grasshoppers

Subfamily	Number of species	%
Acridinae	1	9.09
Catantopinae	3	27.28
Cyrtacanthacridinae	1	9.09
Oedipodinae	2	18.18
Oxyinae	2	18.18
Spathosterninae	1	9.09
Pyrgomorphinae	1	9.09

Table 3: Total number of transect count, species and individual count in both the ecosystems.

Transect counts													
	Total counts	Species in counts	Total individuals	Species per count					Individuals per count				
				Mean	SD	SE	Max	Min	Mean	SD	SE	Max	Min
Kole	14	10	148	3.78	2.39	±0.63	8	0*	10.57	8.78	±2.39	30	0*
Mangrove	14	8	106	4	2.39	±0.63	8	0*	7.57	5.02	±1.3	16	0*

* The study was interrupted during the Kerala floods and no species recorded immediately after the deluge.

Table 4: Diversity indices

	Kole wetland	Mangrove
Taxa (S)	10	8
Individuals	148	106
Simpson (1-D)	0.7761	0.8021
Shannon (H)	1.718	1.792
Equitability (J)	0.7463	0.8617
Fisher's alpha	2.422	2.007

Table 5: Diversity indices in pre-flood and post-flood phases

	Pre-flood phase		Post-flood phase	
	Kole	Mangrove	Kole	Mangrove
Equitability index (J)	0.6127	0. 9254	0.8406	0.9889
Simpson index (1 - D)	0.7537	0.8603	0.8083	0.8233
Shannon index (H)	1.2742	1.9244	1.7479	1.5917

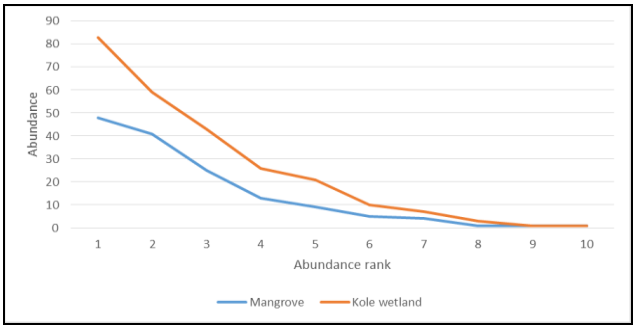

Fig 1: Rank abundance curve for grasshopper species in both the ecosystems.

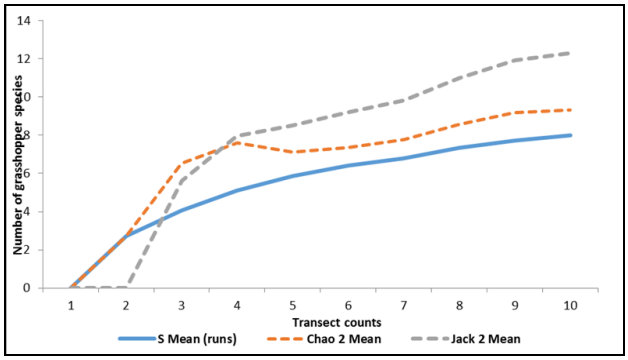

Fig 2: Species accumulation curve of grasshoppers in the Kole wetland ecosystem.

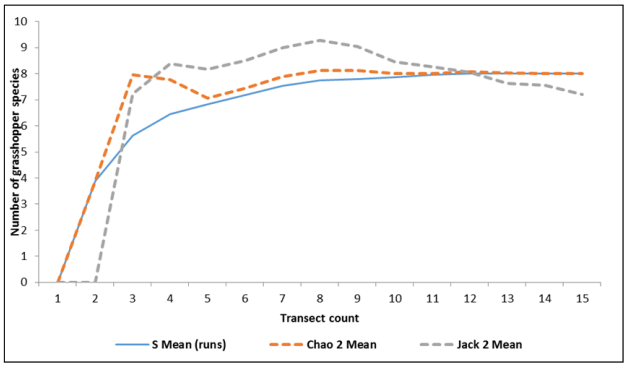

Fig 3: Species accumulation curve of grasshoppers in the Mangrove ecosystem.

Some kinds of threats to the habitats were also noticed during the study period, including plastic wastes and habitat loss due to agricultural practices in the Kole wetland ecosystem. Threats in the mangrove ecosystem include pollution from households, habitat destruction due to human settlement, and human intervention because of various fishing and aquaculture practices.

Conclusion

A long-term study is needed to observe the species occurrence in all seasons and their interaction with the environment to get better and comprehensive information. However, this study will give a baseline data for carrying out future research in this area. A greater understanding by the general public, land managers and conservationists about the importance of conserving these insects is a need of the hour that can be catered through similar future works.

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