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Research Article

Diversity, Abundance and Distribution of Gastropoda in a Tropical Agricultural Village in Kadavoor, Kerala, India

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ABSTRACT

Gastropods are an ecologically significant taxon which take part in crucial ecosystem services like nutrient cycling, food web, calcium cycle, pollination and seed dispersal. The gastropod diversity of Kadavoor village was studied for eight months in monoculture plantations of pineapple, rubber, banana, mixed crop agroecosystems, paddy fields and freshwater bodies. Random sampling was employed monthly in five quadrats of 1 * 1 square metre. A total of 14 species belonging to two subclasses, four orders and nine families were recorded. These include land snails, freshwater snails, slugs and semislugs. Six out of 14 species recorded are endemic to the Indian subcontinent. Two invasive species namely *Laevicaulis alte* and *Allopeas gracile* were recorded. It is notable that *Achatina fulica* was not recorded during our study. Ariophantidae was the most abundant family followed by Subulinidae. The mixed crop agroecosystem was found to be more species-rich than monoculture plantations which might be due to an increase in microhabitats and leaf litter layer. The Simpson's diversity index values are highest for the rubber plantation and lowest for the banana plantation since the species are more evenly distributed in the rubber plantation. *Mariaella dussumieri* is a constant species in all three monoculture plantations since its constancy value is greater than 50%. Sorenson's similarity index for species composition between monoculture ecosystems is high but variable. Microhabitats of snails in all these ecosystems were also recorded. The study is a first attempt at the gastropod diversity of agroecosystems in Kerala and would help in the conservation and management of the gastropods.

Keywords: Snail; slug; semislug; agroecosystem; malacofauna; monoculture

Introduction

Gastropods form a lesser-known taxon despite the multitude of ecological roles played by them (Sen et al., 2012). They are found to inhabit various marine, freshwater and terrestrial ecosystems across the globe (Haszprunar & Wanninger, 2012). In terrestrial ecosystems, snails, slugs and semislugs play significant roles in nutrient cycling, food webs, calcium cycles, pollination, seed

dispersal and even altering plant community structure by herbivory (Cyril & Joseph, 2023). Due to their limited dispersal ability and heat-sensitive nature, they are also one of those invertebrate taxa prone to extinction (Régnier et al., 2009).

Globally, around 40,000 terrestrial gastropod species have been recorded to date (Mordan & Wade, 2008). Indian land snail fauna accounts to more than 1109 species out of which 270 species have been recorded from the Western Ghats (Ramakrishna et al., 2010). About 76% of land gastropods of the Western Ghats are endemic (Aravind et al., 2005). The freshwater mollusc species identified from all over the world account for around 4800 in number out of which around 217 have been reported from India (Mukhopadhyay & Tripathy, 2017; Bohm et al., 2020).

Gastropod diversity in agroecosystems is seldom studied. While gastropods are considered mostly as pests in agricultural lands, they can also act as disease control agents for various crops and accelerate the decomposition of the leaf litter (Hajian-Forooshani et al., 2020). Our present study deals with land gastropod fauna in the state of Kerala. Kerala has a high diversity of land gastropods with about 119 species (Mavinkurve et al., 2005; Vijayan et al, 2021). Most parts of the state of Kerala is also facing serious threats from the invasion of exotic gastropods especially the Giant African Snail (Vijayan et al., 2021; Mathai, 2014; Vijayan, 2016). In Kerala, most of the studies on terrestrial gastropod fauna have been done around invasive snail species. Only a handful of studies have been done on the native gastropods of Kerala (Cyril & Joseph, 2021). Hence, there is a negative trend to salt out any snails and slugs in Kerala on the misconception that they may be invasive, pestiferous and pathogenic. In the present study, the terrestrial as well as freshwater gastropods of Kadavoor village in Ernakulam district of the state of Kerala were studied. It is a first-of-a-kind attempt to explore gastropod diversity in agroecosystems in Kerala. The study would act as baseline data for further studies and pace up the land malacofaunal conservation and invasive species management efforts in Kerala.

Materials and Methods

Study area

The study area Kadavoor is an agricultural village in Paingottoor Gram panchayat in Kothamangalam Taluk at the eastern border of the Ernakulam district, state

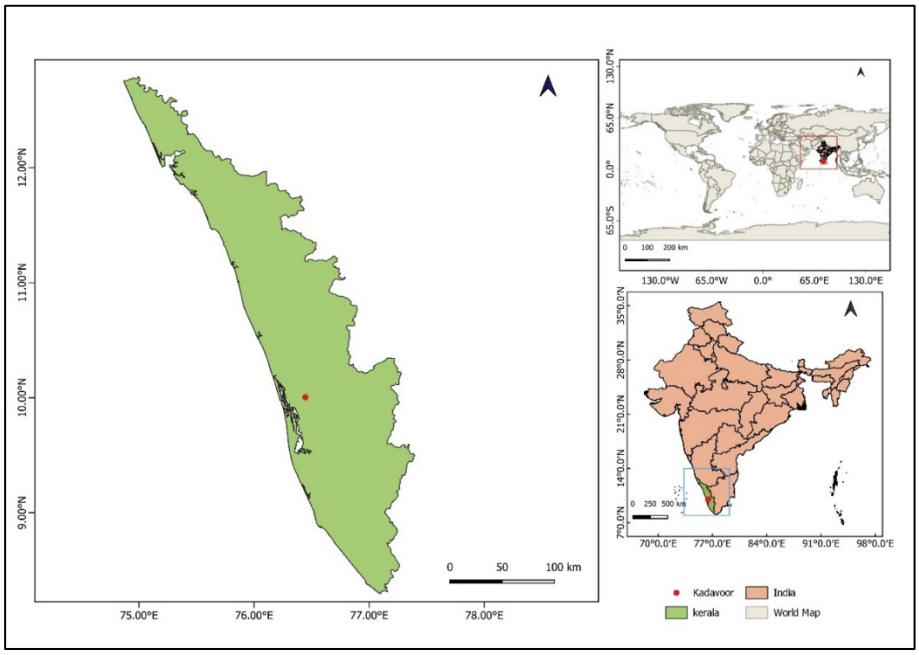

Figure 1. Map showing location of the study area in Kerala state of India.

of Kerala, India **(Figure 1)**. It lies at 10° 0′ 0″ N, 76° 44′ 22″ E. It is located about twenty kilometres away from the nearby towns Muvattupuzha, Kothamangalam and Thodupuzha. The land area consists of various agroecosystems, hilly areas and human settlements. A part of the Kaliyar river locally known as Parithapuzhayar borders Kadavoor village on one side.

Data Collection

Gastropods of Kadavoor village were studied for a period of eight months from December 2021 to July 2022 across various ecosystems. For the feasibility of the study, three monoculture plantations namely, pineapple, banana and rubber plantations were sampled systematically throughout the study period. Random sampling was employed in five quadrats of 1 * 1 square metre in all the sites. Field visits were conducted in the early morning hours on a monthly basis. Occasional sampling was done in other ecosystems like mixed crop agroecosystems, paddy fields and freshwater bodies.

Manual searches for gastropods were conducted on plants, among leaf litter and in the soil at all sites. Photographs of gastropods and their microhabitats were taken in the field. The live gastropods as well as dead shells were collected by

hand. The live specimens were killed by keeping them in a container filled with water, with no air inside the container and leaving the setup undisturbed for approximately 12 hours. After draining the water, they were then preserved in 70% isopropyl alcohol and stored in well-labelled sample bottles. Identification was done using standard textbooks like (Raheem et al., 2014; Blanford,1908; Gude, 1921; Gude, 1914).

Statistical Analysis

Several ecological indices were used to assess the composition of gastropod fauna among the study sites. Constancy index (C) is calculated with the formula: $C = (Pa * 100)/P$; Pa is the number of samples containing a particular species and P is the total number of samples. Value of C can be classified into three categories where ($C \geq 50\%$) means the species is constant in the area, ($25\% < C < 50\%$) means it is an accessory species in the area and ($C \leq 25\%$) means it is an accidental species (Dajoz R., 1975).

Relative Abundance (A) is estimated as the number of a particular species to the total number of all gastropod species in a particular area. The value of A can be used to classify species into common ($A > 50\%$), rare ($25\% \leq C \leq 50\%$) and very rare ($C < 25\%$) (Dajoz R., 1975).

Specific richness (S) quantifies the total number of species in a particular site (Magurran, 2004). Simpson's Diversity Index (D) which gives more weight to evenness than richness was also calculated (Magurran, 2004). The similarity in species composition between the two stations was calculated using Sorenson's similarity index (S) and represented in a proximity matrix (Magurran, 2004). All the statistical analysis and graphical representations were made using MS Excel. The map of the study area was created in QGIS software.

Results and Discussion

Inventory and Structure of Terrestrial Gastropod Communities

The study of gastropod diversity in Kadavoor village led to the inventory of 14 species out of which, eight are land snails, three are freshwater snails, two are slugs and one is a semislug. All these three groups of land gastropods namely, land snails, slugs and semislugs were recorded in previous malacofaunal inventories in agricultural lands across the world (Maheshini et al., 2019). The recorded species belong to two subclasses, four orders and nine families **(Table 1)**. The species endemic to the Indian subcontinent in the study area accounts for 43% of the total species observed (Raheem et al., 2014). The six endemic

species recorded are *Succinea baconi, Satiella* sp., *Ariophanta bistrialis, Mariaella dussumieri, Euplecta indica* and *Glessula* sp.

Two invasive species namely *Laevicaulis alte* and *Allopeas gracile* were recorded. The invasive *Achatina fulica* has been previously reported to be found in all except one of the districts of Kerala (Vijayan et al., 2021). It is notable that *Achatina fulica* was not recorded from our study area. This underlines the fact that various patches of ecosystems are still free from the grasp *Achatina fulica* and it is not late to take ample steps to control the spread of this invasive species.

Table 1. Systematic checklist of gastropod species in Kadavoor village, Ernakulam, Kerala.

Order	Family	Genus	Species
CLASS GASTROPODA			
SUBCLASS: PROSOBRANCHIA			
Mesogastropoda	Paludomidae	*Paludomus*	*tanschuaricus* (Gmelin, 1771)
Mesogastropoda	Ampullariidae	*Pila*	*globosa* (Swainson, 1822)
SUBCLASS: PULMONATA			
Bassommatophora	Planorbidae	*Indoplanorbis*	*exustus* (Deshayes, 1833)
Systellommatophora	Veronicellidae	*Laevicaulis*	*alte* (Férussac, 1822)
Stylommatophora	Succineidae	*Succinea*	*baconi* (Pfeiffer, 1855)
Stylommatophora	Helicarionidae	*Satiella*	sp.
Stylommatophora	Ariophantidae	*Ariophanta*	*bistrialis* (Beck, 1837)
Stylommatophora	Ariophantidae	*Macrochlamys*	*indica* (Godwin-Austen,1883)
Stylommatophora	Ariophantidae	*Mariaella*	*dussumieri* (Gray, 1855)
Stylommatophora	Ariophantidae	*Euplecta*	*indica* (Pfeiffer, 1846)
Stylommatophora	Subulinidae	*Allopeas*	*gracile* (Hutton,1834)
Stylommatophora	Subulinidae	*Zootecus*	*insularis* (Ehrenburg, 1831)
Stylommatophora	Subulinidae	*Glessula*	sp.
Stylommatophora	Streptaxidae	*Gulella*	*bicolor* (Hutton,1834)

The collected gastropods come under the following nine families namely, Ariophantidae, Subulinidae, Streptaxidae, Succineidae, Planorbidae, Paludomidae, Ampullariidae, Veronicellidae and Helicarionidae **(Figure 2)**.

Family Ariophantidae is the most represented family with four species which are *Ariophanta bistrialis, Macrochlamys indica, Euplecta indica* and *Mariaella dussumieri*. Ariophanta was reported as the most abundant family in several gastropod surveys done in agroecosystems across the Indian subcontinent (Altaf et al., 2017; Altaf et al., 2016; Murtaza et al., 2020). Subulinidae is the second

most represented family with three species namely, *Allopeas gracile*, *Zootecus insularis* and *Glessula* sp. The rest of the seven families were represented by one species each.

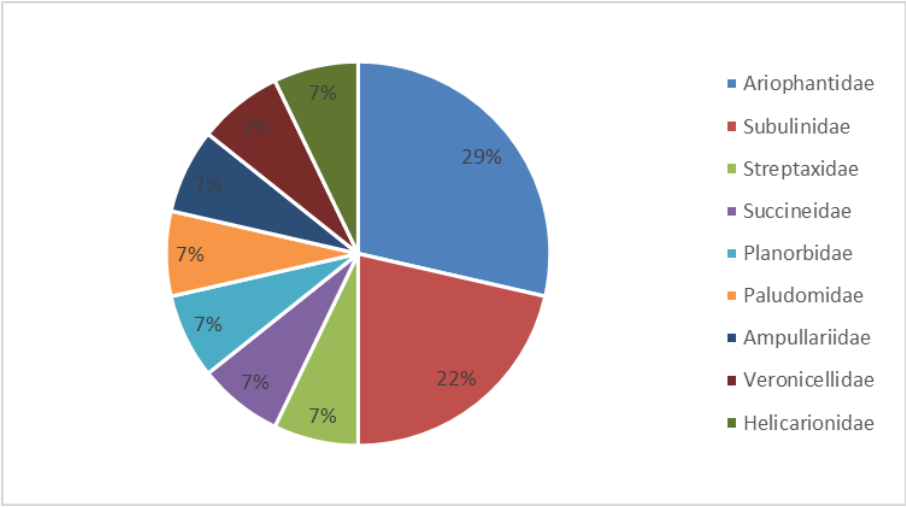

Figure 2. Composition of gastropod families in Kadavoor village.

Patterns in Gastropod Species Distribution Across Different Ecosystems

The mixed crop agroecosystem had a varied gastropod community with 11 species whereas the gastropod communities in monoculture plantations were less diverse **(Figure 3)**. This can be attributed to the habitat heterogeneity hypothesis wherein varied microhabitats present in mixed crop ecosystems support more biodiversity (Gheoca, 2023).

Most of the snails reported only from mixed crop ecosystems in this study are leaf litter dwellers. An increase in the leaf litter layer and the presence of decaying stems or woods in the mixed crop ecosystem might be a reason for the increase in species richness in the mixed crop agroecosystem. The same trend for gastropod diversity and leaf litter layer association was observed in previous studies (Gheoca, 2023; Gheoca, 2021).

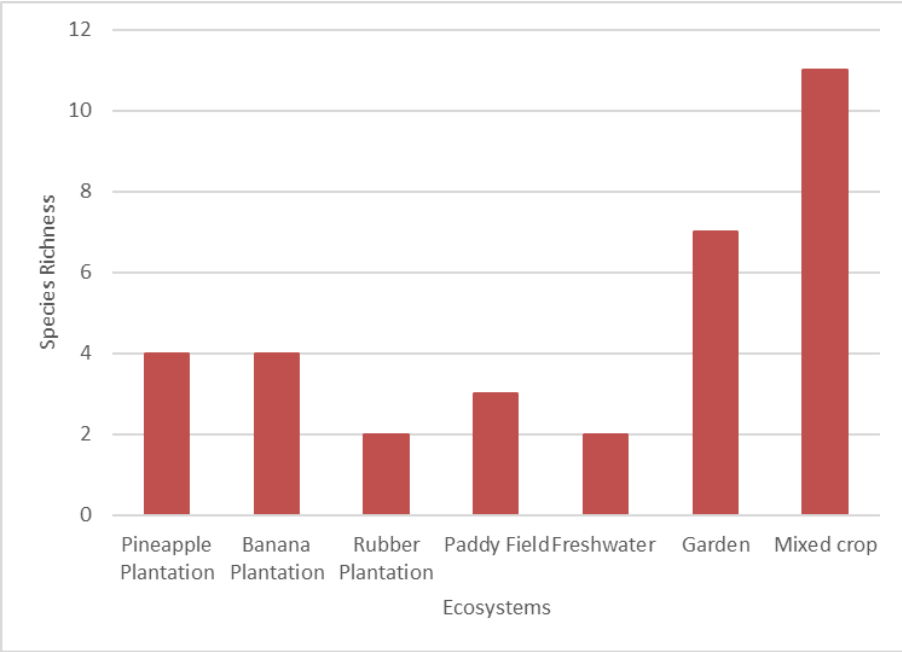

Figure 3. Species richness of land gastropods across different ecosystems.

Among the terrestrial gastropods, *Mariaella dussumieri* and *Satiella* sp. were seen in monoculture as well as mixed crop agroecosystems. *Laevicaulis alte* was seen only in mixed crop agroecosystem. Similarly, this slug was reported from polyculture agroecosystems in Indonesia (Atini & Rusae, 2022). Among the freshwater gastropods, *Indoplanorbis exustus* was observed only in paddy fields whereas *Paludomus tanschuaricus* and *Pila globosa* were observed in paddy as well as other freshwater ecosystems. The presence of different species of gastropods in various ecosystems is visualised in **Table 2.**

Table 2. Patterns of species distribution in various ecosystems of Kadavoor village.

Species	Pineapple Plantation	Banana Plantation	Rubber Plantation	Paddy Field	Freshwater ecosystems	Mixed crop agroecosystem
Ariophanta bistrialis	✓	✓				✓
Macrochlamys indica	✓	✓				✓
Allopeas gracile						✓
Gulella bicolor						✓
Succinea baconi						✓
Zootecus insularis						✓
Euplecta indica						✓
Glessula sp.						✓
Indoplanorbis exustus				✓		
Paludomus tanschuaricus				✓	✓	
Pila globosa				✓	✓	
Laevicaulis alte						✓
Mariaella dussumieri	✓	✓	✓			✓
Satiella sp..	✓	✓	✓			✓

The distribution of gastropod species in different ecosystems is given in **Table 3.** The relative abundance of gastropod species in all three monoculture plantations shows a similar trend with *Mariaella dussumieri* being the most abundant and *Satiella* sp. being the least abundant species in each of these ecosystems. The abundance of Mariaella dussumieri may be due to the fact that it is a slug, the most successful gastropod group in agroecosystems (South, 2012).

Mariaella dussumieri is a constant species in all three monoculture plantations since its constancy value is greater than 50%. Slugs are found to thrive well even in lands that grow crops with high physical disturbance (Port & Ester, 2002). Their limacization makes them less calcium dependent and helps them to get into moist cracks and crevices easily to protect them from adverse conditions (South, 2012; Hausdorf, 2001). *Satiella* sp. is a constant species in banana plantation but an accessory species in rubber plantation (25% < C < 50%) and an accidental species in pineapple plantation (C<25%). *Ariophanta bistrialis* and *Machrochlamys indica* are constant species in pineapple plantation.

Table 3. Constancy and relative abundance of gastropod species in monoculture plantations.

Species	Pineapple Plantation		Banana Plantation		Rubber Plantation	
	Constancy %	Relative Abundance%	Constancy%	Relative Abundance%	Constancy%	Relative Abundance%
Ariophanta bistrialis	50.00	8	25.00	3.27	-	-
Macrochlamys indica	87.50	26	87.50	19.67	-	-
Mariaella dussumieri	100.00	64	62.50	60.65	100.00	88.57
Satiella sp.	12.50	2	100.00	3.27	37.50	11.42

The specific richness for pineapple and banana plantations are same, while but is comparatively low for the rubber plantation **(Table 4)**. The gastropod species richness in rubber plantations was found to be low compared to other croplands in a study in Nigeria (Oke & Chokor, 2011). The Simpson's diversity index values are highest for the rubber plantation and lowest for the banana plantation (**Table 4**). In rubber plantation, though the number of species recorded is low, they are evenly distributed. Hence, the high value of D. Previous studies on soil fauna has also revealed that rubber plantations harbour a lower biodiversity when compared to other ecosystems due to soil degradation and low resource heterogeneity of the rubber plantation (Sing et al., 2019; Hidayat et al., 2018; Miao et al., 2022). The evenness might be due to the ambient conditions like canopy and presence of moist, shady microhabitats (rubber shades, latex groves, damaged trunks) in the rubber plantations that equally favour the survival of both *Mariaella dussumieri* and *Satiella* sp.

Table 4. Simpson's Diversity Index value (D) and Specific richness (S) for study sites.

Sites	D	S
Pineapple plantation	0.526	4
Banana plantation	0.425	4
Rubber plantation	0.791	2

The similarity in species composition between monoculture ecosystems is high but variable. The taxonomic composition between mixed crop agroecosystem and monoculture crops is low. The gastropod community structure of the rubber plantation and mixed agroecosystem was the least similar **(Table 5)**.

Table 5. Sorenson's similarity index values for similarity between taxonomic composition of ecosystems.

	Pineapple	Banana	Rubber	Mixed
Pineapple	100	-	-	-
Banana	100	100	-	-
Rubber	67	67	100	-
Mixed	53	53	29	100

Observations on Microhabitats of Terrestrial Gastropods

The study also recorded the various microhabitats from which the land gastropods were observed in different ecosystems **(Table 6).**The terrestrial gastropods were found from the leaf surfaces and leaf bases of pineapple plant. Some were also found from the soil in pineapple plantation. In banana plantation, they were found on leaf and stem surfaces, leaf bases, in between sheaths of stem, in curled portions of dry leaves, among leaf litter and on soil. In rubber plantation, most slugs were found in between the plastic tapping sheets and tapping marks. Snails were found near roots, on leaf litter and on tree trunks. In a mixed agroecosystem, most snails and slugs were found in the soil and leaf litter layer as well as on plants. The microhabitats are crucial because they provide adequate moisture and shelter for snail species which have limited dispersal ability (Nandy, 2022; Locasciulli & Boag, 1987).

Table 6. Microhabitats of land molluscs in different ecosystems.

Pineapple Plantation	Banana Plantation	Rubber Plantation	Mixed crop Agroecosystem
At the base of leaves	Among the litter near the base of the plant	On the tapping groove near the base of the latex cup	Under the grass cover
On the ground, near the base of the plant	Among the dried sheaths of the main stem of banana plant	On the plastic shade	On the soil
Near the flowers	Along the mid vein of leaf, near to the leaf base	In the trunk crevices	On the plant parts
Among the grass	At the base of leaves	Among the root curves that is seen above ground	In the crevices of rocks that border the land
	On the litter in the ground	On the base of branches	Beneath fallen logs and stones
	Inside the curls of dried leaves	Among the leaf litter	Among the leaf litter

Conclusion

The study shows that Kadavoor village has rich gastropod fauna across its varied ecosystems. Monoculture plantations have small gastropod communities while mixed crop agroecosystems support more species. The study also reveals that there still remain Giant African Snail uninfested patches in Kerala and it is high time to control the spread of this species. The study can be considered a stepping stone to discover more gastropod fauna in the agroecosystems of Kerala. Malacofaunal inventories of such kind would act as a first step in the conservation of the lesser-known molluscan fauna that are crucial to the survival of the ecosystem.

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