

An agroecosystem-based study on the sex ratio of terrestrial isopod, *Philoscia muscorum*

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Abstract

Sex ratio dynamics in terrestrial isopods are crucial for understanding their population stability, reproductive strategies and responses to environmental variability. Studies have shown that sex ratios in isopod populations often deviate from the expected 1:1, with female-biased ratios frequently observed, particularly in stable environments, while fluctuations can occur seasonally or spatially in response to abiotic factors such as temperature, moisture, and habitat disturbance. Temporal patterns are shown which include male activity peaking during warmer months followed by increases in gravid females are indicative of the reproductive cycles and surface activity patterns linked to mating behaviour. Population density of *Philoscia muscorum* was highest during postmonsoon season (71.48 ± 0.2) and lowest during summer season (12.12 ± 0.3). During monsoon season, population density was 42.92 ± 0.2 and 51.44 ± 0.2 during premonsoon season. Female-biased sex ratios are found in all seasons under study.

Keywords: *Philoscia muscorum*, agroecosystem, sex ratio, population structure

Introduction

Soil fauna contribute about 25-35% of all the species present on earth (Decaens *et al.*, 2006) [5]. Population density as well as the population structure of soil fauna influences the dynamics of soil ecosystem and stability of biosphere as a whole. Population structure of diverse species regulates the dynamics of various kinds of interactions within the soil ecosystem such as predator-prey, mutualistic, and competitive interactions (Wardle, 2002) [20]. Terrestrial arthropods form one of the important components of soil ecosystem. Soil isopods are essential for maintaining the balance and health of terrestrial ecosystems. Their role in decomposition of organic matter, nutrient cycling and creation of microhabitats in the ecosystem has elevated their ecological role as ecosystem engineers (Van Gestel and Loureiro, 2018) [18]. They play beneficial roles especially in agricultural systems (Paoletti and Hassall, 1999) [14], and very few of them are reported to be pests of crops. One unusual characteristic of soil arthropods is the parental care shown by females, which involves retaining the eggs and early instars in the marsupium. The Oniscidea are exceptional among terrestrial arthropods in that the females give a lot of maternal care to the eggs and youngones (Surbida and Wright, 2001; Kight and Nevo, 2004) [16, 10].

Population structure and the proportion of males to females in animal populations- sex ratio- is a critical factor influencing the dynamics, health, and sustainability of animal populations. Adult sex ratio in animals is an important factor in determining the patterns of population management on a long-term basis. Skewed sex ratios influence the reproductive output of populations. Female-biased populations may show robust and growing populations while male- biased populations face reduced fecundity thus affecting the soil community structure. Terrestrial isopods in general show approximately equal proportion of sexes in younger stages, while in later life stages, one of the sexes predominate. Many species such as *Armadillidium vulgare* show female-biased sex ratios, due to various factors like *Wolbachia* endosymbionts and

the *f*element (Durand *et al.*, 2023) [6]. Striking difference from the 1:1 expected sex ratio is reported in many other isopods (Frankel *et al.*, 1981; Legrand *et al.*, 1987) [8, 11]. The present study analyses the seasonal population structure and sex ratio of the terrestrial isopod, *Philoscia muscorum*, in an agricultural ecosystem in Thiruvananthapuram district, Kerala.

Material and Methods

The study site was located at Nedumangad in Thiruvananthapuram district. The site was part of a mixed agricultural land. Using random sampling method, soil samples were collected from 5x5x5 cm area during the period March 2019 to February 2020. The monthly data was pooled to seasonal data taking into consideration June-August as Monsoon season; September–November as post monsoon season; December - February as summer season and March - May as pre-monsoon season, for this study. The size and colour of the body of the organism were the primary features for categorisation. Two-way ANOVA was done to find out any significant variation in population structure of *Philoscia muscorum* in the seasons under study. Chi- square test was conducted to find deviation of sex ratio from the normally expected ratio of 1:1 during different months.



Fig 1: *Philoscia muscorum*

Results

Population density of the terrestrial isopod, *Philoscia muscorum* was studied seasonally. It was highest during postmonsoon season (71.48±0.2) and lowest during summer season (12.12±0.3). During monsoon season, population density was 42.92±0.2 and 51.44±0.2 during premonsoon season. Population structure showed a female biased trend throughout the study period. The percentage of females in Nedumangad during the entire period ranged from 71.5 to 60.5 while that of males was from 26.7 to 36.5. During monsoon season (June, July, August) the percentage of females ranged from 65.1 to 71.5 and percentage of males ranged from 28.4 to 30.6. During postmonsoon season (September, October, November) the percentage of females ranged from 63.1 to 62.4 and percentage of males ranged

from 34.3 to 34.02. During summer season (December, January and February) the percentage of females ranged from 66.7 to 64.01 and percentage of males ranged from 27.6 to 31.14. During premonsoon season (March, April, May) the percentage of females ranged from 60.5 to 61.1 and percentage of males ranged from 36.44 to 35.71. The χ^2 value is < 0.05 level of significance; the male to female ratio is not 1:1. The sex ratio varied from 1:2.59 to 1:1.66 in Nedumangad. Two-way ANOVA shows significant difference in the number of females, males, and juveniles of *Philoscia muscorum* in all months (F= 13.66335, F critical=5.143253; P<0.05) but no significant difference between pattern of population structure in various months (F=3.66498, F critical=4.757063; P>0.05).

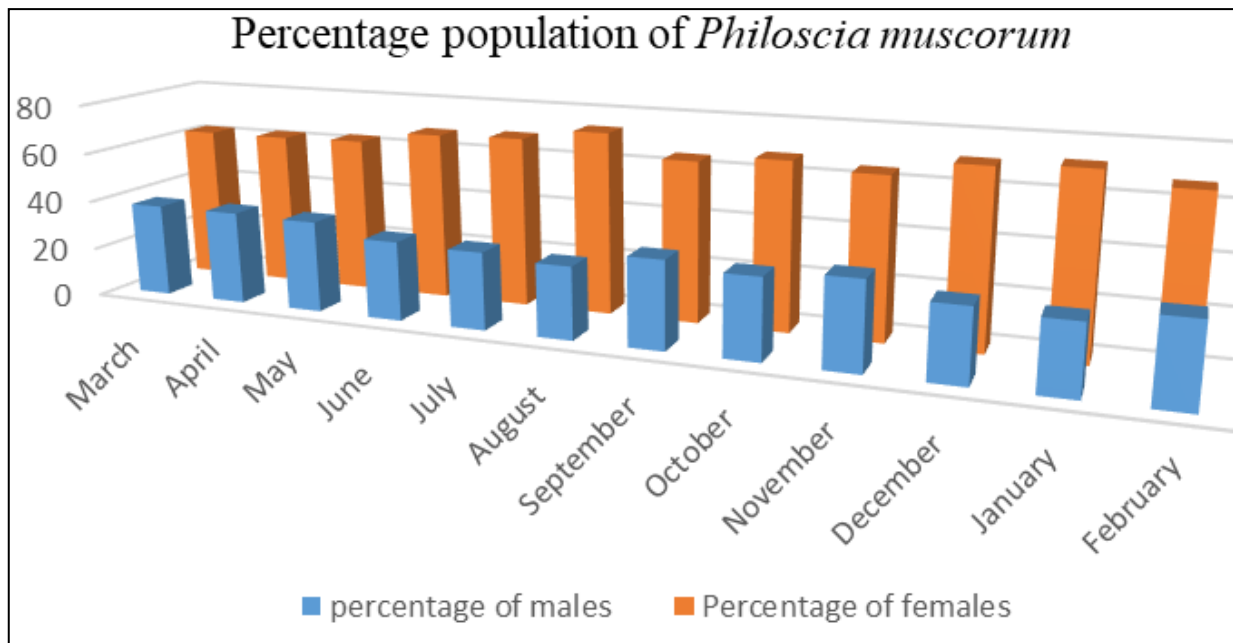


Fig 2: Percentage population of *Philoscia muscorum* in Nedumangad

Table 1: Sex ratio of *Philoscia muscorum* in in agroecosystem at Nedumangad

Month	Total number of organisms	No. of males	No. of females	Percentage of males	Percentage of females	P value	P<0.05	Ratio of male to female
March	1166	438	728	37.56	62.44	2.02E-17	P<0.05	1:1.66
April	1270	478	795	37.55	62.45	6.41E-19	P<0.05	1:1.66
May	1291	476	814	36.90	63.10	4.93E-21	P<0.05	1:1.71
June	1000	320	680	32.00	68.00	5.01E-30	P<0.05	1:2.13
July	1052	329	726	31.18	68.82	2.35E-34	P<0.05	1:2.21
August	1061	310	780	29.19	73.45	2.58E-47	P<0.05	1:2.52
September	1730	610	1120	35.26	64.74	1.46E-34	P<0.05	1:1.84
October	1743	566	1178	32.45	67.55	1.26E-48	P<0.05	1:2.08
November	1726	609	1117	35.28	64.72	2.21E-34	P<0.05	1:1.83
December	307	90	217	29.32	70.68	4.22E-13	P<0.05	1:2.41
January	291	81	210	27.84	72.16	3.97E-14	P<0.05	1:2.59
February	275	90	185	32.73	67.27	1.01E-08	P<0.05	1:2.06

Table 2: Two-way ANOVA showing population structure of *Philoscia muscorum* in agroecosystem at Nedumangad

Anova	SS	df	MS	F	P-value	F crit
Source of Variation						
Rows	3440947	3	1146982	3.66498	0.082451	4.757063
Columns	8552088	2	4276044	13.66335	0.005835	5.143253
Error	1877744	6	312957.3			
Total	13870779	11				

Discussion

Sex ratio of natural populations tend to show deviation from the expected Fisherian 1:1 ratio (Godfray and Werren, 1996)^[9]. Several populations show either male-biased sex ratio or female-biased sex ratios, which may indicate some adaptive strategy from the part of the species and it can be due to differential mortality, habitat preferences or influence of various environmental factors. In the present study, the species under investigation, *Philoscia muscorum* showed female-biased sex ratio consistently during the period of study.

Farkas (1998)^[7] reported that *Trachelipus rathkei* showed a female biased sex ratio and the percentage of females varied slightly during reproductively active seasons. *Porcellio scaber* has also shown a continuous breeding pattern throughout the year and sex ratio was female biased (Nair, 1998)^[21]. A nocturnal terrestrial isopod *Porcellio albinus*, living under xeric conditions also shows a female biased sex ratio, with the number of eggs positively correlating with body size of female (Medini-Bouaziz *et al.* 2017)^[20]. The trend in sex ratio of *Philoscia muscorum* in this study is in concurrence with this observation. Velasco *et al.* (2018)^[19] reported temporal changes in sex ratios in males and non-gravid females, males showing peak activity at summer which is followed by an activity peak of gravid females, due to reproduction driven activities of both sexes. In order to build colonies in harsh environments or when they are moved into new habitats, female isopods have been seen to be able to store sperm and use this store for repeated reproductive events (Suzuki and Ziegler 2005)^[17].

In this study, the number of males, females and juveniles show seasonal differences while the population structure shows stability over different seasons. Maximum density of population was observed during the post-monsoon season. Pre-monsoon season, which coincides with the peak of reproductive period shows comparatively more activity of males. Changing patterns of behaviour in both sexes contribute to the difference in sex ratio of *Philoscia Muscorum*. Consistent female bias in sex ratio was noted by Dangerfield and Telford (1994)^[4] in their study on the population structure of four species of terrestrial isopods in South Africa and they proposed that the variation from the expected ratio could result from the behavioral patterns exhibited by these organisms during the reproductive period; at the beginning of the reproductive season, there are more males because they are seeking females, but later on, there are more gravid females because they are searching for the best microhabitats to raise their offspring. Here, seasonal changes in the sex ratio were caused by differences in the patterns of habitat usage. In this study also, the number of females were consistently more than that of males during the seasons under consideration.

Dangerfield and Hassall (1994)^[3] suggested that the longer period for survivorship and growth of females can be attributed to the shorter brood development time in seasonal environments, which proves advantageous to them. Isopod females are found show spatial variation in habitat use during breeding time. A female-biased sex ratio may be interpreted as an adaptive response to elevated disturbance conditions, where density-independent mortality outweighs the effects of density-dependent mortality. The study site in this study is an agroecosystem with anthropogenic influences such as tillage and application of fertilizers. According to Paoletti and Cantarino (2000)^[15] distortions in

sex ratios might be correlated with a dysfunction of ecological cycles and loss of long-term sustainability. As this study is limited to a single species and a specific rural area, there is a need for the acquisition of additional data regarding other isopod species and diverse geographical regions before drawing general conclusions about the potential bioindicative role of distorted sex ratios in agricultural isopod populations. Population with low rate of immigration as well as migration and with small subpopulations are reported to show large deviations from 1:1 sex ratio (Bulmer, 1986)^[2].

Conclusion

Soil arthropods occupy different niches and various trophic levels. Any abnormal changes in sex ratio patterns can affect the predation rates, foraging behaviour as well the nature of interspecific competition. This can cause change in community composition in that area. The female biased sex ratios are common among terrestrial isopods and the present study also shows that trend. Imbalances in sex ratio can be used as a bioindicator of environmental stress. Monitoring of sex ratios is thus useful in soil ecotoxicology and environmental risk assessments. General conclusions regarding the suggested bioindicative role of skewed sex ratios may be finalised after extending the studies to different geographical areas.

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