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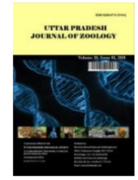

SPATIO-TEMPORAL VARIATIONS IN POPULATION DENSITY OF TERRESTRIAL ISOPOD, *Philoscia muscorum* WITH REFERENCE TO SOIL EDAPHIC FACTORS AT SELECTED AREAS OF THIRUVANANTHAPURAM DISTRICT, KERALA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Author SM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MGS managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Soil is a heterogeneous habitat for diverse group of organisms. Soil fauna render diverse ecological services which are essential for soil health. The present study attempts to find out the impact of edaphic as well as chemical factors in soil on the population density of *Philoscia muscorum* in three areas of Thiruvananthapuram district- Nedumangad, Peppara and Bonacaud. Samples were collected using standard procedures and chemical analysis was done. Two way ANOVA and Principal Component Analysis were done as part of statistical analysis. Physico chemical parameters- gravel, silt, clay, sand, exchangeable acid, exchangeable base showed seasonal variation as well as site-wise variation while there was no significant variation- sitewise and seasonal – in organic carbon content. The chemical factors- Nitrogen, Phosphorus, Potassium, Calcium and Magnesium showed site-wise and seasonal variations. Population density was highest during post-monsoon season in all the study areas (Nedumangad 71.48±0.204, Peppara 75.68±0.458 and Bonacaud 82.08±0.329). Clay, gravel, sand, pH, exchangeable acid, Nitrogen, Phosphorus, Calcium and Magnesium are identified as the Principal Components influencing population density of *Philoscia muscorum* in the study areas.

Keywords: Soil edaphic factors; terrestrial isopod; *Philoscia muscorum*; population density; spatio-temporal variations.

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1. INTRODUCTION

Soil is a complex and heterogeneous natural resource, an interface of air, minerals, water and life. It arises from parent material by the combined action of different factors such as climate, topography, faunal factors, vegetational type and anthropological activities. Thus it differs from the parent material in structure, texture and physico-chemical characteristics. Soil provides a heterogeneous habitat which differs in physical, chemical and biological characteristics across space and time. The nature of the habitat is determined by the intensity of the interaction of geology, climate, and vegetation and also interaction of biological components taking part in its formation. It has diverse range of niches for predators, prey, producers, consumers and parasites, thus providing one of the most complex habitats for millions of organisms belonging to thousands of species. A large number of properties of soil which determine the fertility of the soil are also determinants of the soil faunal component. Quality of soil thus determines the colonization of fauna in the soil [1].

Soil organisms are those which spend all or part of their life in soil. They serve diverse ecological functions such as modification of physical structure of soil, enhance the efficacy with which plants acquire nutrition, regulate carbon sequestration by soil and regulate the dynamics of organic matter in soil [2]. Leaf litter invertebrates physically break up the organic material thus enhancing decomposition of leaf litter [3].

Terrestrial isopods are crustaceans belonging to Malacostraca. They are typical cryptozoans, living under logs, barks or similar habitats. Oniscidea successfully inhabit all biomes, except the poles and at latitudes above 4,800 m [4]. Terrestrial isopods are considered as key system regulators of ecosystem functions such as decomposition and nutrient recycling, and affect physical properties of soil. These organisms are phytosaprophagous, forming an important component of decomposer communities [5]. Their key role in soil ecosystem is litter breakdown. The digestive processes in the terrestrial isopods involve complex biochemical processes involving detoxification of ingested phenolics in the foregut, digestion by endogenous and bacterial enzymes in the anterior hindgut and absorption of nutrient [6]. The soil fauna mediates a number of essential ecological processes that are vital to the entire ecosystem,

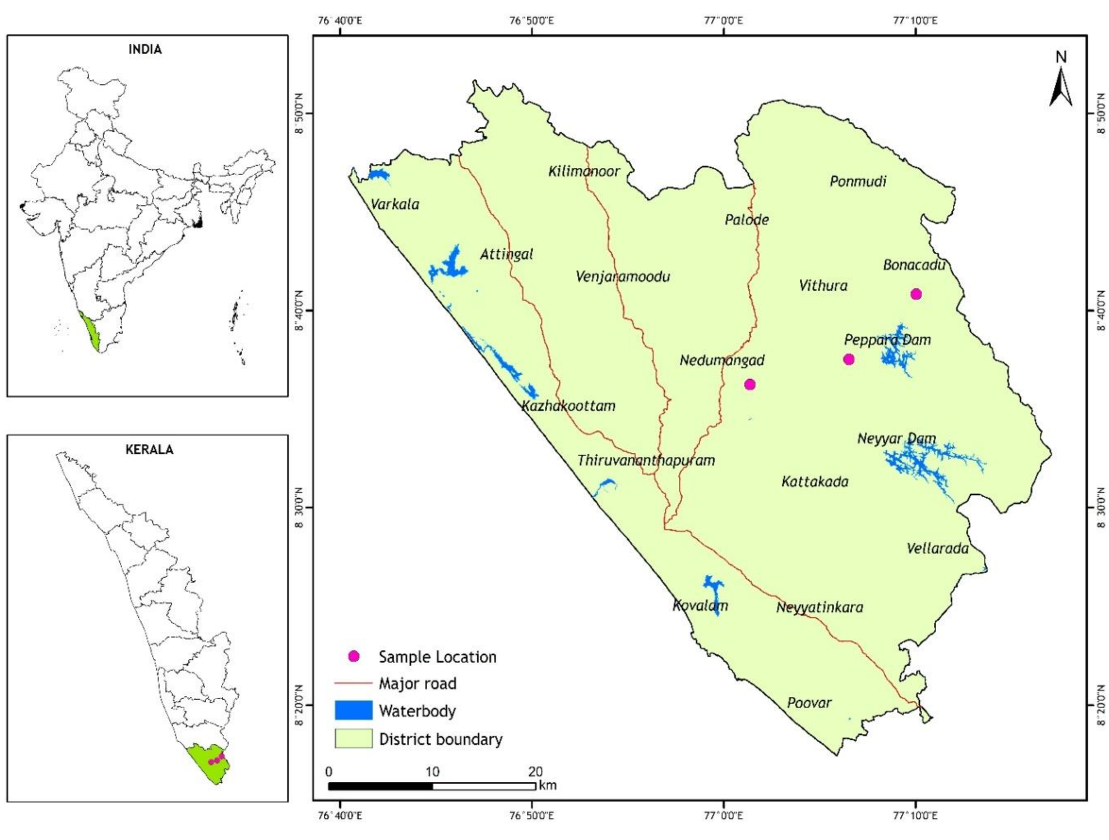

Fig. 1. Study area

such as the degradation of organic matter, cycling of nutrients, sequestration of carbon, and the development and maintenance of soil structure. Terrestrial isopods (woodlice) process dead organic matter and facilitate bacterial and fungal decomposition by mechanically breaking up residues and dispersing microbial propagules [7]. Litter arthropods are described as members of BFW- the brown food web [8].

Philoscia muscorum is common striped woodlouse. It is a terrestrial isopod of about 11mm length. It prefers an environment with moisture and sustain on decomposing leaf litter, hardwood or grass. High population density of woodlice indicates high habitat quality, thus they are acting as bioindicators [9]. Comparison of the density and diversity of arthropod fauna inhabiting forest soil and other diverse habitats with respect to edaphic and climatic parameters shall indicate stability of the system and impact of abiotic parameters in regulating the biological functioning and faunal activities [10]. The present study aims to find out the impact of various soil edaphic and chemical factors on population density of *Philoscia muscorum* in three areas of Thiruvananthapuram district. Nedumangad- 8°30'28.57"N 77°00'10.76"E, Peppara- 8°37'31.62"N 77°06'31.55"E and Bonacaud 8°40'50.06"N 77°10'02.05"E. (Fig. 1).

2. MATERIALS AND METHODS

Collection of soil sample: Twenty five sampling sites were identified from each of the study area. Soil samples were collected randomly from a region with 5x5 cm^2, from depths, 0-10 cm, 10-20 cm and 20-30 cm. Soil auger was used to collect the soil samples. The collected samples were packed in polythene bags and labeled properly.

Duration of the study: The study was conducted in four seasons, considering June-August as monsoon season, September-November as post-monsoon season, December-February as summer season and March-May as pre-monsoon season. The study was done during the year 2019.

Analysis of soil sample: Edaphic factors considered were gravel, silt, clay, sand, organic carbon, pH, exchangeable acid and exchangeable base. Edaphic factors were estimated with the standard procedure of Trivedi and Goel [11]. Chemical factors considered were Nitrogen, Phosphorus, Potassium, Calcium and Magnesium. Total nitrogen in the sample was determined using Kjeldahl distillation method. Phosphorus content was determined using flame photometry method [12]. Exchangeable acid, exchangeable base, Calcium and Magnesium were estimated by the method of Jackson [13].

Statistical analysis: Two way ANOVA was done to find out the variation in soil parameters as well as population density in the study sites and the seasons. Principal Component Analysis was done to find out the principal components among the soil parameters that influence population density of the organism. Data was analysed using SPSS 1.7 software.

3. RESULTS AND DISCUSSION

The major types of soil found in Thiruvananthapuram district are red loams, coastal alluvium, riverine alluvium, lateritic soil, and brown hydromorphic soil and forest loam, as per the report of Department of Mining and Geology. Midlaterite type of soil is found in the study sites. The collected soil samples were analyzed for physical as well as chemical properties.

The gravel content was higher during summer season and lowest in monsoon season in all the sites. The highest value is recorded at Bonacaud and lowest at Nedumangad. At all the three sites, the silt content is found to be highest during monsoon season and lowest in pre-monsoon season. Highest content of silt is found at Nedumangad and lowest at Bonacaud. Sand content is found to be highest during pre-monsoon season at all the three study sites, recording highest mean value at Bonacaud. Clay content is highest during monsoon season in all the three areas, with Nedumangad recording the highest value and Bonacaud the lowest. pH at all sites is moderately acidic, 5.21 -4.24. Soils from arid climates are commonly alkaline with high soil pH; by contrast, soils from humid climates are commonly acidic with low soil pH [14]. The highest (5.21 ± 0.03) and lowest values of pH are recorded at Bonacaud during pre-monsoon season and monsoon season (4.24 ± 0.03) respectively. Organic carbon content was found to be highest during monsoon season and lowest during pre-monsoon season. Among the three sites, content of exchangeable acid is found to be highest during summer season and lowest in monsoon season, highest value being Nedumangad. Among the three sites, content of exchangeable base is found to be highest during post-monsoon season and lowest during summer season. Highest value was recorded at Bonacaud. Nedumangad recorded highest values for Nitrogen, Phosphorus, Potassium and Magnesium while calcium content at that site was the lowest among the three study sites. The higher content of Nitrogen, Phosphorus and Potassium can be due to fertilizer inputs in the predominantly agricultural area. Human activities may increase inputs of Nitrogen and Phosphorus to the ecosystems [15]. At all the sites

Table 1. Seasonal mean values of soil physico-chemical factors at three sites

Study sites	**NEDUMANGAD**				**PEPPARA**				**BONACAUD**			
Season	**Monsoon**	**Post-monsoon**	**Summer**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Summer**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Summer**	**Pre-monsoon**
Gravel (%)	20.58 ± 0.25	23.71 ± 0.34	25.83 ± 0.40	23.22 ± 0.35	20.74 ± 0.39	23.47 ± 0.26	25.47 ± 0.16	23.55 ± 0.16	30.54 ± 0.37	32.98 ± 0.34	35.50 ± 0.24	33.06±0.30
Silt (%)	19.20 ± 0.32	18.38 ± 0.28	17.16 ± 0.26	16.08 ± 0.23	15.51 ± 0.27	14.83 ± 0.28	13.80 ± 0.28	13.15 ± 0.31	12.88 ± 0.26	12.24 ± 0.33	11.46 ± 0.30	10.73±0.29
Sand (%)	74.29 ± 0.21	72.89 ± 0.16	74.77 ± 0.18	75.80 ± 0.16	74.41 ± 0.40	72.84 ± 0.38	75.09 ± 0.34	76.30 ± 0.39	85.33 ± 0.34	83.64 ± 0.30	85.36 ± 0.24	85.92±0.29
Clay (%)	14.95 ± 0.30	14.19 ± 0.30	13.03 ± 0.27	12.18 ± 0.26	8.44 ± 0.11	8.07 ± 0.11	7.54 ± 0.10	7.19 ± 0.11	8.05 ± 0.08	7.81 ± 0.08	7.37 ± 0.09	7.10 ± 0.08
pH	4.26 ± 0.03	4.42 ± 0.03	4.68 ± 0.04	4.89 ± 0.04	4.54 ± 0.12	4.74 ± 0.09	4.97 ± 0.09	5.21 ± 0.09	4.24 ± 0.03	4.51 ± 0.03	4.90 ± 0.03	5.16 ± 0.03
OC (%)	5.78 ± 0.04	5.58 ± 0.04	4.99 ± 0.03	4.84 ± 0.04	5.96 ± 0.03	5.76 ± 0.03	5.52 ± 0.03	5.22 ± 0.04	4.79 ± 0.07	4.63 ± 0.07	4.42 ± 0.06	4.18 ± 0.07
EA (%)	3.24 ± 0.03	3.43 ± 0.04	3.67 ± 0.03	3.39 ± 0.03	3.33 ± 0.05	3.50 ± 0.05	3.71 ± 0.04	3.45 ± 0.04	2.29 ± 0.06	2.44 ± 0.05	2.65 ± 0.05	2.41 ± 0.05
EB (%)	11.16 ± 0.12	12.01 ± 0.16	10.81 ± 0.13	11.32 ± 0.12	12.75 ± 0.28	13.70 ± 0.23	12.29 ± 0.25	12.33 ± 0.27	12.79 ± 0.20	13.62 ± 0.21	12.10 ± 0.18	12.29 ± 0.17
N (ppm)	3961.01 ± 3.60	3965.41 ± 3.51	3972.80 ± 3.36	3977.34 ±3.26	3849.12 ±24.34	3855.00 ±24.20	3860.94 ± 24.27	3865.16 ± 24.22	3924.16 ± 7.74	3928.56 ± 7.61	3933.20 ± 7.69	3937.65 ± 7.66
P (ppm)	11.42 ± 0.21	11.10 ± 0.21	10.76 ± 0.19	11.03 ± 0.21	8.05 ± 0.16	7.75 ± 0.15	7.44 ± 0.15	7.84 ± 0.16	7.71 ± 0.07	7.42 ± 0.07	7.13 ± 0.08	7.52 ± 0.06
K (ppm)	704.58 ± 7.76	710.21 ± 8.29	713.90 ± 8.56	707.07 ± 7.71	259.93 ± 3.67	263.22 ± 3.79	268.98 ± 3.79	264.684 ± 3.69	252.67 ± 3.17	255.62 ± 3.25	261.56 ± 3.31	358.04 ± 3.30
Ca (ppm)	156.56 ± 3.93	157.10 ± 4.01	161.32 ± 4.08	165.57 ± 4.16	346.20 ± 4.47	349.24 ± 4.47	353.48 ± 4.45	358.41 ± 4.48	342.66 ± 4.01	346.41 ± 3.94	349.89 ± 4.16	354.39 ± 4.39
Mg (ppm)	90.15 ± 0.49	93.06 ± 0.42	95.31 ± 0.36	98.15 ± 0.36	87.86 ± 0.74	90.19 ± 0.78	92.71 ± 0.75	95.21 ± 0.79	80.69 ± 0.43	83.20 ± 0.34	85.76 ± 0.32	88.18 ± 0.38

Potassium and Calcium content recorded the lowest values during monsoon season. Among the three study sites Magnesium content was highest during pre-monsoon season and lowest during monsoon season (Table 1).

Significance level (P=.05) was generated for the physico-chemical parameters at the study sites by two-way ANOVA. Two way ANOVA results showed that there is significant difference in between sites regarding values of gravel, sand, clay, silt, Exchangeable Acid, exchangeable base, nitrogen, phosphorus, potassium, calcium and magnesium. These parameters showed significant variation in values between the different seasons also. But, pH showed significant variation only between the different seasons while the sites showed no significant difference. pH variation is dependent on organic carbon content and porosity of soil [16]. The seasonal variation in pH can be due to variation in porosity of soil, which is determined by the physical characteristics of soil particles.

Two-way ANOVA result showed that there is no significant variation in pH between the three sampling sites ($P>.05$) and there is significant difference in pH in different seasons ($P<.05$). Fatubarin and Olojugba, [17] in their study on seasonal variations in physico-chemical properties of soils, reported higher pH during dry season and pre-rainfall season. And the seasonal difference in pH in the study is in concordance with this observation. There is no significant variation in organic carbon content between the three sampling sites ($P>0.05$) and there is no significant difference in organic carbon content in different seasons. ($P>0.05$). Organic carbon content of soil is influenced by the composition of litter. Plant tissues are the main source of organic matter, which influences the physico-chemical characteristics of soil [18]. Bangroo et al. [19] reported that forst diversity, topographic features and climate change influence SOC and nitrogen stocks in soil. SOC content is influenced more vegetational type than climatic conditions [20]. According to the soil survey report of Kerala Forest Department [21] the vegetational type of two of the study locations – Peppara and Bonacaud- is of tropical deciduous forest type. Thus, the litter in these two areas which is similar in nature may be affecting the SOC of these areas. According to Manna et al. [22], tillage, application of fertilizers, residue management and the quantity of organic material returned to the soil have impact on the organic carbon content of soils in agricultural systems. The third study site, Nedumangad is predominantly an agrarian ecosystem where farming practices may influence the SOC.

The population density of *Philoscia muscorum* was estimated in the three study areas and the seasonal trend in population density was analyzed. In all the three study areas highest density of population of *Philoscia muscorum* was recorded during the post-monsoon season while the lowest population density was recorded during summer (Fig. 2). Reddy [23] has reported that larger densities of arthropods occurred during the wet season in tropical deciduous forest. Moisture is an important factor regarding the survival of microarthropods [24]. According to Stachurska and Hagen [25] isopods are susceptible to drought because lack of waxy epicuticle and inability of most of the species to burrow through the soil. Pillai & Singh [26] recorded definite pattern of population fluctuation with peak during rainy season followed by winter and in the hot and dry summer months soil arthropod population was very low. Among the three sites the highest value of population density of *Philoscia muscorum* is shown in Bonacaud site during post-monsoon season. It is reported that under no-tillage regimes or minimum tillages regimes biomass of isopods is high [27]. The population density and metabolic rates of decomposer animals are comparatively high in tropical rain forests [28]. Bonacaud site is a forest area which is less agriculture intensive than Nedumangad and Peppara. Coarse woody debris is an important structural component that serves as a habitat for many saprophagous species and thus locally improves the nutritional situation of a forest stand [29]. The lowest value of population density of *Philoscia muscorum*, among the three study areas is recorded at Nedumangad, which is predominantly an agricultural area, during summer season (Table 2).

Table 2. Population density of *Philoscia muscorum* at Nedumangad, Peppara and Bonacaud during different seasons

Seasons	Sites		
	Nedumangad (mean± SE)	**Peppara (mean± SE)**	**Bonacaud (mean± SE)**
Monsoon	42.92±0.270	50.96±0.243	71.56±0.283
Post-monsoon	71.48±0.204	75.68±0.458	82.08±0.329
Summer	12.12±0.312	21.84±0.302	41.8±0.265
Pre-monsoon	51.44±0.216	62.48±0.339	62.2±0.374

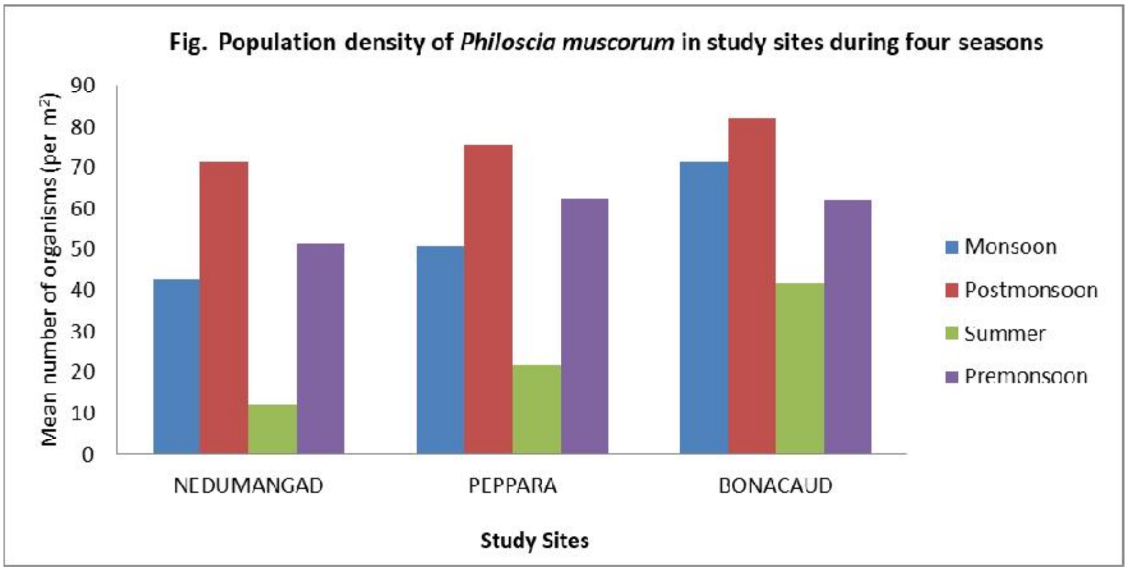

Fig. 2. Population density of *Philoscia muscorum* in study sites during four seasons

3.1 Population Density of *Philoscia muscorum*

The principal components in soil that affect the population density of *Philoscia muscorum* in the three study areas were found out using Principal Component Analysis.

The principal components affecting population density of *Philoscia muscorum* during monsoon season at Nedumangad are Phosphorus, organic carbon and pH; Phosphorus, clay and exchangeable acid during post monsoon season and clay, Nitrogen and silt during summer season. During pre-monsoon season the principal components affecting population density of *Philoscia muscorum* are exchangeable acid, gravel and Nitrogen. At Peppara, during monsoon season the principal components affecting population density of *Philoscia muscorum* are gravel, clay and Calcium; Magnesium, clay and gravel during post monsoon season; Exchangeable base, pH and clay during summer season and Potassium, Calcium and Organic carbon during pre-monsoon season. Soil acidity and reduced calcium availability strongly affect soil invertebrates, which require calcium to build exoskeletons. Calcium availability is assumed to limit survival of terrestrial isopods [30]. At Bonacaud, during monsoon season the principal components affecting population density of *Philoscia muscorum* are Exchangeable acid, Phosphorus and clay; pH sand and gravel during post monsoon season; Gravel, pH and Magnesium during summer season and clay, exchangeable acid and pH during pre-monsoon season (Table 3).

pH is found to be a principal factor affecting population density in different study sites at different seasons. Parwez, H., & Sharma, N [31] has reported that pH had almost no direct effect on population of soil microarthropods and it contributes to fluctuation by its influence on vegetation and other physico-chemical properties of the soil. pH influences the quantity of Phosphorus as well as Calcium in the soil, which in turn influences biological activities of the organisms. Isopods and diplopods are found to have limitations in surviving in acidified and nutrient-poor environment due to their large calcium requirement for cuticular calcification. Shachak [32] reported that terrestrial isopods in general are cryptozoic animals preferring cool, humid microhabitats and they burrow into soil to prevent dehydration during summer.

In the three study areas, during monsoon season and post-monsoon season, the physical characteristic of soil such as clay, gravel and sand are found to be identified as principal components affecting population density of *Philoscia muscorum*. Mechanical qualities of soil influences soil fauna and they react sensitively to physical characteristics or soil. Brown and Steinberger [33] reported that the geological formation partly influences the selection of burrowing sites by isopods. In the summer and pre-monsoon season chemical factors predominate as principal components affecting population density. Thus, the physical as well as the chemical parameters analysed in the present study, has influence on population density of the terrestrial isopod, *Philoscia muscorum*.

Table 3. Principal Components and Eigen values of soil factors affecting population density of *Philoscia muscorum*

Site	Seasons							
	Monsoon		Post-monsoon		Summer		Pre-monsoon	
	Parameter	Eigen value	Parameter	Eigen value	Parameter	Eigen value	Parameter	Eigen value
Nedumangad	P	0.47108	P	0.52935	Clay	0.42418	EA	0.43052
	OC	0.45904	Clay	0.38673	N	0.36468	Gravel	0.35425
	pH	0.35722	EA	0.32978	Silt	0.34562	N	0.3439
Peppara	Gravel	0.37384	Mg	0.42984	EB	0.44199	K	0.57427
	Clay	0.35237	Clay	0.38401	pH	0.42457	Ca	0.42568
	Ca	0.34956	Gravel	0.35782	Clay	0.38001	OC	0.37626
Bonacaud	EA	0.4143	pH	0.41179	Gravel	0.49075	Clay	0.44961
	P	0.41818	Sand	0.36256	pH	0.46355	EA	0.36942
	Clay	0.40665	Gravel	0.35983	Mg	0.35188	pH	0.36919

4. CONCLUSION

The ecological services done by soil microarthropods are crucial in maintaining a healthy soil ecosystem. Maintaining a healthy population of these organisms is vital to soil fertility and maintaining nutrient cycling. Soil edaphic factors, climatic factors and anthropogenic interferences are found to influence the density as well as diversity of these group organisms. The present study reveals that the population density of an isopod, *Philoscia muscorum* is affected by the chemical factors as well as the edaphic factors. Population density was highest during post-monsoon season in all the study areas. Among the soil edaphic and chemical parameters considered, all factors except pH and organic carbon content showed site wise as well as seasonal variations. pH did not vary with sites and but with seasons while organic carbon showed no site wise and season wise variation. the study brings out the seasonal variations in physico-chemical factors in soil. These variations influence the population density of the organisms, which has implications in litter decomposition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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