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Seasonal Variation on Earthworm Community Structure under Three Different Land Use Systems of Kumaun Himalaya, District Champawat, Uttarakhand

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ABSTRACT This paper highlights the diversity, density, and biomass of earthworm population under three different land use systems (mixed forest, agricultural soil, and tea garden). Earthworms were collected by hand sorting method in every season (summer, rainy, and winter) and were sorted on the basis of their age structure (clitellates and aclitellates). Thirteen earthworm species belonging to three families were recorded, out of which *Amynthas corticis* was the most abundant species found in all land use systems. Earthworm density and biomass were significantly higher in mixed forest compared to agricultural and tea garden. Their population increases during monsoon season and clitellates were more abundant than aclitellates in all land uses. The present investigation is the first report on earthworm composition from different land use system of Champawat, Kumaun Himalaya and suggests to implement adequate land use management strategies for sustaining earthworm population in hilly areas.

KEY WORDS Abundant, Biogenic, Dynamics, Population, Strategies, Sustaining

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INTRODUCTION

Earthworm dominates the invertebrate biomass approximately 80% (Nainawat and Nagendra, 2001) and maintains as well as conserves the natural fertility of soil (Anderson and Ingram, 1993). In fact, Darwin, 1881, first scientifically explained the beneficial role of earthworm in various terrestrial ecosystem. Later, positive impact of earthworms on crop yields was also reported by Walsh *et al*. (2019). The Western Himalayan range provides susceptible habitat for fauna to flourish, thus making India a rich mega biodiversity country. Moreover, India constitutes 11.1% of total global earthworm's diversity (Chaudhuri and Nath, 2011; Suthar, 2011). Furthermore, recently, Bora *et al*. (2021a) discovered 505 earthworm species from India. The distribution pattern of earthworms is usually irregular (Goswami and Mondal, 2015) and varies with variation in climatic factors such as mean annual precipitation (MAP), winter low temperatures, summer high temperatures (Walsh and Johnson-Maynard, 2016), and physicochemical properties of soil (Singh *et al*., 2020a). Hence, earthworm population responds sensitively to these factors (Li *et al*., 2018), therefore regarded as bioindicators of microclimate and physical status of soil (Varga *et al*., 2018). Meanwhile, the spatial and temporal distribution of earthworm population is significant to understand the soil functionality in any ecosystem (Bayranvand *et al*., 2017). However, the efficiency and strength of various ecosystems directly depend on type of earthworm species present at various habitats (Singh *et al*., 2020b). Indeed, earthworm also represents species specific distribution in several pedoecosystems (Sankar and Patnaik, 2018).

Land use and soil management are key factors exerting pressure on soil, earthworm dynamics, and further on the ecosystem services. In fact, any changes in land use pattern alter the species composition of earthworm in various agro-climatic zones (Kamdem *et al*., 2018). Therefore, for better understanding, a few researches were carried out in various ecosystems to explore and characterize the earthworm

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fauna across the globe, namely, from Tripura (Debbarma and Chaudhuri, 2019), U.P (Rai, 2017), Pondicherry (Sathianarayanan and Khan, 2006), and even from Kashmir valley (Najar and Khan, 2011), besides such, studies are reported also from Himalayan region by Kaushal and Bisht (1994) and Bhadauria *et al*. (2000). Bisht *et al*. (2003), and Kandpal (2018) documented earthworm population dynamics from Terai region of Kumaun Himalaya. Since, information pertaining to diversity and taxonomic richness of earthworm species in Kumaun region is limited. Therefore, the present study was undertaken to explore the composition of earthworm under different soil habitats. The present research work is the first to report diversity, density, and biomass of earthworm from three different land use systems of Champawat, Kumaun Himalaya.

MATERIALS AND METHODS

Characteristics of Study Area

Three different and contrasting land use systems of Champawat were selected which were previously not studied for such studies. The climate of the study area is sub-temperate with distinct warm, cold, and general dryness seasons in a year. The geo-coordinates lie between 29°20’09.97” N and 80°05’27.70” E at an altitude of about 1615 m above mean sea level in the Himalayan region. Monsoon and pre-monsoon periods have maximum and high maturity of earthworms.

Earthworm Sampling

Earthworms were sampled from three different land use systems for three consecutive seasons. Earthworms were extracted by hand sorting method then washed and properly stretched and fixed in 4% formalin (Anderson and Ingram, 1993). On the basis of clitellum development, preserved earthworms were categorized into two age classes: Clitellates and aclitellates. The collected earthworm samples were weighed, then placed in polythene bags properly labeled with place name, date of collection, and other requisite details. Further taxonomic identification was done in Zoological Survey of India (ZSI) up to species level. Earthworm density and biomass were calculated per square meter. Microsoft Excel and GraphPad Prism 8 were used for statistical analysis.

RESULTS AND DISCUSSION

Earthworm Community Structure

A total of 13 different species belonging to three families such as Megascolecidae with eight species (*Amynthas corticis*, *Metaphire posthuma*, *Metaphire houlleti*, *Metaphire birmanica*, *Perionyx excavatus*, *Perionyx bainii*, *Perionyx nainianus,* and *Lampito mauritii*), Lumbricidae with three species (*Eisenia fetida*, *Allolobophora parvus,* and *Aporrectodea caliginosa trapezoides*), and Octochaetidae with remaining two species (*Eutyphoeus waltoni* and *Eutyphoeus nainianus*) were identified from three different study sites. Mixed forest has highest earthworm diversity followed by agricultural then tea garden. Although tea garden has acidic soil, the earthworm community structure was good in density as well as in biomass. According to Bora *et al*. (2021b), earthworm present in hilly regions has the potential to survive in acidic soils too. The results of our study also go in line with this statement. *A. corticis* shows maximum density of 66.2 during the rainy season and lowest was recorded by *M. birmanica* (0.7) as elucidated in Table 1. Furthermore, highest biomass was recorded by *E. fetida* during the monsoon period while *L. mauritii* have the lowest (Table 2). Moreover, the total density as well biomass of earthworms were reported maximum in mixed forest as they provide a humus-rich surface for the sustainability of earthworms with less involvement of anthropic factors. Similar observations were also made by Whalen (2004) and Li *et al*. (2020).

Seasonal Variation in Biomass and Density

The total biomass of 13 different species is presented in Fig. 1. Out of which, *E. fetida* shows successful establishment by having maximum biomass than the others. The inherent

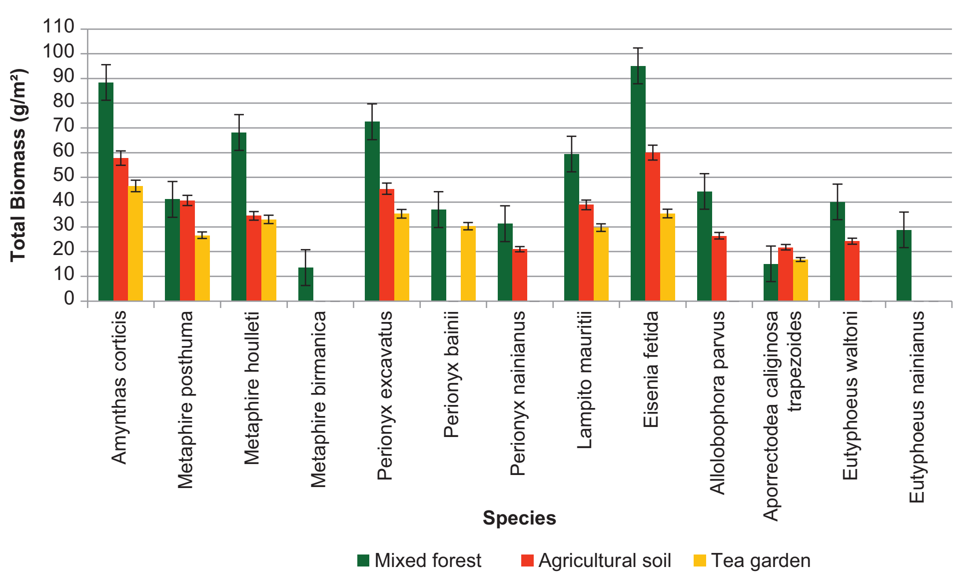

Fig. 1: Total biomass (g/m²) of 13 earthworm under different landuse system

Table 1. Seasonal variation in earthworm population density (individual m^{-2}) across different sampling sites (All values are mean ± S.E)

Earthworm species	Sites	Season		
		Summer	Rainy	Winter
	Mixed Forest	31.5±0.30	66.2±0.88	10.1±0.11
Amynthas corticis	Agricultural soil	26.7±1.13	31±2.03	9.8±1.23
	Tea garden	10.2±1.01	23.9±2.14	6.1±1.06
	Mixed Forest	11.1±2.34	18.7±1.76	7.1±2.11
Metaphire posthuma	Agricultural soil	12±1.67	18.9±1.52	-
	Tea garden	9.6±0.32	6.5±0.93	1.2±0.84
	Mixed Forest	12±0.96	20.9±1.09	2.3±1.34
Metaphire houlleti	Agricultural soil	11.9±0.23	15.6±0.08	6.5±1.01
	Tea garden	11.2±1.97	16.7±1.29	3.6±0.98
	Mixed Forest	4.7±2.11	9.7±1.02	0.7±1.19
Metaphire birmanica	Agricultural soil	-	-	-
	Tea garden	-	-	-
	Mixed Forest	15.9±2.15	21.9±1.23	5.1±1.12
Perionyx excavatus	Agricultural soil	14.1±2.21	17.8±2.14	2.7±0.31
	Tea garden	11±1.01	16.1±1.45	4±2.13
	Mixed Forest	13.4±0.09	16.5±1.23	-
Perionyx bainii	Agricultural soil	-	-	-
	Tea garden	7.8±1.02	9.7±1.45	2.1±2.11
	Mixed Forest	10.9±2.11	15.9±2.01	-
Perionyx nainianus	Agricultural soil	7.8±1.19	10.1±2.10	-
	Tea garden	-	-	-
	Mixed Forest	15.4±0.08	19.9±1.03	1.8±1.11
Lampito mauritii	Agricultural soil	11.7±1.12	17.8±2.01	0.9±2.11
	Tea garden	8.9±1.32	10.9±2.11	1.8±1.01
	Mixed Forest	21.2±0.32	39.4±1.21	8.8±2.11
Eisenia fetida	Agricultural soil	19.8±1.12	24.5±2.01	5.4±2.31
	Tea garden	16.5±0.03	21.9±2.22	4.6±1.93
	Mixed Forest	10.7±2.11	18.9±0.93	4.3±0.31
Allolobophora parvus	Agricultural soil	8.6±1.78	11.1±1.99	3.5±2.57
	Tea garden	-	-	-
	Mixed Forest	3.2±2.34	7.7±1.12	-
Aporrectodea caliginosa trapezoides	Agricultural soil	6.7±0.65	9.5±1.56	-
	Tea garden	2.4±1.45	7.6±2.21	-
	Mixed Forest	13.8±0.21	16.9±1.32	1.5±0.51
Eutyphoeus waltoni	Agricultural soil	5.2±2.31	8.8±3.01	2.3±1.23
	Tea garden	-	-	-
	Mixed Forest	12.2±2.11	15.5±2.01	0.8±0.31
Eutyphoeus nainianus	Agricultural soil	-	-	-
	Tea garden	-	-	-

ability of exotic earthworm helps them to withstand anthropogenic disturbances and can also tolerate wide range of pedological factors in any land use system. These statements corroborated with the findings of Jamatia and Chaudhuri (2017). It was observed during the study that all the earthworm species can restore their population during monsoon because of high reproduction rate and more availability of food, thus present abundantly. While due to cold and dry weather, earthworm population tends to decrease in winter season. The present observations are also in agreement to the findings of Joshi and Aga (2009); Singh *et al*. (2016); and Rajwar *et al*. (2021).

Both *Eutyphoeus* species showed rare distribution due to narrow range of ecological tolerance and not found in

Table 2. Seasonal variation in earthworm biomass (gm^{-2}) under 3 different landuse system (All values are mean ± S.E)

Earthworm species	Sites	Season		
		Summer	Rainy	Winter
	Mixed Forest	18.42±1.09	61.02±1.72	8.95±1.78
Amynthas corticis	Agricultural soil	13.07±0.11	39.62±0.03	5.11±0.76
	Tea garden	13.41±1.24	28.47±1.49	4.66±1.19
	Mixed Forest	10.69±1.56	20.70±0.41	9.76±0.91
Metaphire posthuma	Agricultural soil	15.00±1.09	25.68±0.13	-
	Tea garden	11.43±1.16	13.20±1.04	2.00±0.08
	Mixed Forest	14.00±0.04	52.58±1.15	1.57±0.54
Metaphire houlleti	Agricultural soil	10.80±1.08	18.02±1.19	5.64±0.08
	Tea garden	9.46±0.09	21.48±0.16	2.08±1.14
	Mixed Forest	3.80±0.05	8.20±0.08	1.50±0.32
Metaphire birmanica	Agricultural soil	-	-	-
	Tea garden	-	-	-
	Mixed Forest	18.00±0.10	45.96±1.72	8.55±0.47
Perionyx excavatus	Agricultural soil	13.80±1.19	29.60±0.31	2.03±0.50
	Tea garden	9.98±0.07	20.18±0.15	5.14±0.61
	Mixed Forest	17.00±1.11	20.00±2.01	-
Perionyx bainii	Agricultural soil	-	-	-
	Tea garden	9.80±2.07	15.90±0.03	4.59±0.06
	Mixed Forest	12.90±0.06	18.42±1.77	-
Perionyx nainianus	Agricultural soil	9.20±1.01	11.79±0.05	-
	Tea garden	-	-	-
	Mixed Forest	14.90±1.26	41.55±2.08	3.00±1.09
Lampito mauritii	Agricultural soil	14.00±0.42	24.00±1.12	0.9±0.03
	Tea garden	10.40±0.08	17.30±1.06	2.00±0.65
	Mixed Forest	16.31±1.32	68.40±1.09	10.38±0.49
Eisenia fetida	Agricultural soil	18.21±1.01	36.00±0.01	5.78±1.11
	Tea garden	10.48±0.03	21.9±2.22	3.04±0.09
	Mixed Forest	15.00±0.09	22.43±2.11	6.90±1.58
Allolobophora parvus	Agricultural soil	9.35±0.04	14.22±0.21	2.84±0.74
	Tea garden	-	-	-
	Mixed Forest	5.80±0.33	9.26±0.03	-
Aporrectodea caliginosa trapezoides	Agricultural soil	8.11±0.08	13.66±0.02	-
	Tea garden	5.98±0.21	10.83±1.06	-
	Mixed Forest	14.32±1.08	22.00±0.08	3.78±1.07
Eutyphoeus waltoni	Agricultural soil	7.00±0.09	11.45±2.09	5.80±0.03
	Tea garden	-	-	-
	Mixed Forest	9.90±0.04	17.80±1.57	1.09±1.45
Eutyphoeus nainianus	Agricultural soil	-	-	-
	Tea garden	-	-	-

agricultural and tea garden, as density is dependent on interaction of number of factors. Haokip and Singh (2012) also reported restricted distribution of *Eutyphoeus* and concludes that diversity, distribution, and abundance of earthworms totally depend on several climatic and edaphic factors. In addition, Rajkhowa *et al*. (2014) concluded that any alteration in land use system directly influences the earthworm composition. According to Najar and Khan (2011), *A. caliginosa trapezoides* were predominantly present in human controlled ecosystems. During the study, most of the earthworms collected from the sites were sexually mature (clitellates), as shown in Fig. 2. Indeed, there number (clitellates and aclitellates) rapidly increases in wet periods as per the findings of Rajwar *et al*. (2018). *A. corticis* expressed itself as dominant over other earthworms and occurred more frequently among all land use systems on the basis of its relative abundance (20.69%), as depicted in Fig. 3. According to rank abundance curve, *A. corticis*, *E. fetida, and P. excavatus* occupied Ist, IInd,

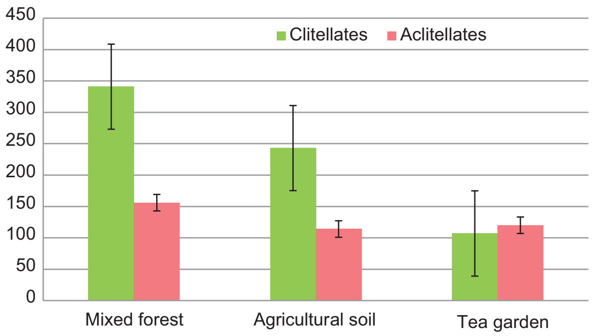

Fig. 2: Age structure of earthworm under 3 landuse system

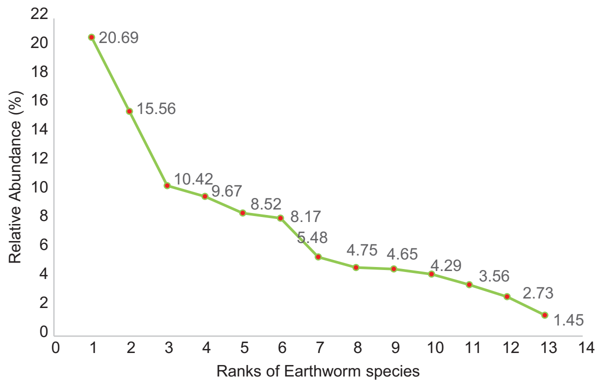

Fig. 3: Rank abundance curve depicting relative abundance of collected earthworms from 3 different soil system

and III[rd] rank, respectively. However, *M. birmanica* was poorly observed during the present study and Debbarma and Chaudhuri (2019) also documented ranks of earthworm.

CONCLUSION

In our study, 13 species were identified and any change in land use system can have plethora of effects on earthworm community. In particular, density as well as biomass of earthworms were higher in mixed forest due to lesser human interference and presence of more organic matter. On the other hand, earthworm population also increases during rainy season because of higher moisture content. Furthermore, the presence of different earthworms from different sites reflects their habitat preferences. Therefore, these results highlight the importance of earthworm in view of maintaining long-term soil productivity. This observational study is the first one carried out in Champawat, Kumaun Himalaya, thus acts as a baseline information for the future studies on these invertebrates in Kumaun Himalaya.

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