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DIVERSITY AND DISTRIBUTION OF EARTHWORMS IN A SUBTROPICAL FOREST ECOSYSTEM OF MOKOKCHUNG DISTRICT, NAGALAND, INDIA

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ABSTRACT

A comparative study on diversity and distribution of earthworms along with the various physico-chemical factors influencing their distribution was carried out in three sites *i.e.* natural reserve forest, plantation area and jhum fallow area of a subtropical hill forest ecosystem located in Mingkong area of Mokokchung district, Nagaland, India. Seven species of earthworms representing the three families Moniligastridae, Octochaetidae and Megascolecidae were recorded during the study period of 2013-15. The earthworm density (individuals) and biomass (weight) in the study sites were found to be maximum during the monsoon season *viz*., plantation area (195.59 ± 5.36 m^{-2}, 96.23 ± 2.50 gm^{-2}) and fallow land (173.48 ± 4.54 m^{-2}, 138.24 ± 3.34 gm^{-2}) however, in the natural forest ecosystem though the density was highest during monsoon (257.71 ± 4.87 m^{-2}), biomass record was maximum during the pre-monsoon season (239.33 ± 3.43 gm^{-2}). The highest annual density (609.68 ± 11.33 m^{-2}) and biomass (549.87 ± 9.05 gm^{-2}) was recorded in the reserve forest ecosystem. Variation of earthworm density and diversity in all the three study sites were found to be affected by different microclimatic and soil physico-chemical factors such as soil moisture content, soil temperature, bulk density and nutrient content viz. organic carbon, and total nitrogen.

INTRODUCTION

Earthworms are considered as useful indicators of the health of soil system due to their role in soil fertility through fragmentation, mixing of the soil with mineral particles and promoting microbial activity (Edwards and Bohlen, 1992). The ingested organic matter is macerated, mixed with ingested inorganic soil, passed through the gut and excreted as a cast, which are enriched with available plant nutrients and thus enhance soil fertility. They are perhaps the most important soil organisms in terms of their influence on organic matter breakdown, soil structural development and nutrient cycling, especially in productive ecosystems (Kooch *et al*., 2007).Earthworms are of very practical importance because of their occurrence in large number and wide distribution; relatively mobile nature and being in full contact with the surrounding soil substrate (Edwards and Lofty, 1972;Ghosh,1993;Sarwar *et al*.,2005;Sathianarayanan and Khan,2006;Sinha *et al*.,2007;Bansiwal and Rai,2010). The presence of a species in a particular habitat and its absence from other habitats shows the species-specific distribution of earthworms in different soil (Tripathi and Bhardwaj, 2004) and is affected by land use system, soil organic carbon, soil moisture, rainfall pattern etc. (Rajkhowa *et al*., 2015). Sinha *et al*. (2013) reported from Jharkhand that the agro ecosystem region had very sparse quantity of earthworm species while the natural habitats harboured a very good number of species. Bhardwaj and Sharma (2016) recorded three earthworm species belonging to three different families in sugar belt of Kurukshetra and Yamuna Nagar of Haryana.Om Prakash (2017) described 50 species with 28 genera and 06 families of earthworms from different regions of Uttar Pradesh state of India. Apart from the soil type, climate and the available organic resources, earthworm distribution and diversity at a given locality is also influenced by the land-use pattern and disturbances (Edwards and Bohlen, 1996). Jhum cultivation, which is the main agricultural practice in Nagaland, results in the loss of huge forest covers affecting earthworm population to a great extent. While certain information on earthworm population distribution pattern is available from other part of north-east India (Chaudhuri and Bhattacharjee, 1999; Halder, 1999, Chaudhuri *et al*. 2008a, 2008b; Chaudhuri *et al*., 2009; Lalthanzara *et al*., 2011; Haokip and Singh, 2012;. Chaudhuri and Dey, 2013; Dey and Chaudhuri, 2013; Jamatia and Chaudhuri, 2017), no work has been carried out in Nagaland. Hence the present study is an attempt to provide preliminary information on species composition, diversity and distribution pattern of earthworms in a subtropical forest ecosystem of Mokokchung District, Nagaland, India.

MATERIALS AND METHODS

Description of study sites

The present study was conducted from November, 2013 to October 2015 in three different sites of a contiguous sub-tropical hill forest ecosystem characterised with gentle to steep slopes viz. reserved forest (site I), plantation (site II) and fallow area (site III) respectively located in Mingkong area which is about 10 km away from Mokokchung town. These sites lie at 29º 15′–30º 15′ north latitude and 77º 55′– 78º 30′ east longitude and altitude ranges from 1400 to 1600 m above MSL. The site I, having an area of 275.32 hectares is a protected natural mixed reserved forest and free from any biotic interference since 1950. The most common tree species are *Atrocarpus chaplasha, Castanopsis tribuloides, Iteamacro* *phylla, Elaeocarpus floribundus, Ficus semicordata*, *Schima wallichii, Kydia calycina, Macarang adenticulata, Firmiana colorata, Mallotus tetracocccus, Trema orientalis, Sapium eugeniifolium*. Shrubs like *Tephrosia candida, Vernonia volkameriifolia, Pavetta indica, Styrax serrulata, Abroma augusta, Leeamacro phylla, Crotalaria cytisoides* are quite common in the study area. The site II *i.e.* plantation area is dominated by *Daubanga grandiflora*. Grasses like *Digitaria* sp., *Panicum* sp., *Saccharum arundinaceum* intermixed with *Musa markkuana* is common in this study area with infrequent biotic disturbances. Site III is Jhum fallow land since 2004 with infrequent tree species like *Macaranga denticulata*, *Mallotu stetracoccus*, *Sapium baccatum*, *Bischofia javanica* , *Ficus hirta, Ficus semicordata, Schima wallichii.* Shrubs flora are dominated by *Mussa endaroxburghii, Rubus indotibetanus, Melastoma malabathricum etc.* Climbers are quite common and dominated by *Dioscore apentaphylla, Smilax perfoliata, Thunbergia grandiflora, Thunbergia coccinea, Paederia scandens etc*. Grasses like *Saccharum arundinaceum, Themada villosa* intermixed with *Digitaria* sp., and *Panicum* sp. are quite common in the area.

Climate of the area

The climate of the area is monsoonal with warm moist summer and cool dry winter. The year is divisible into three seasons viz. summer, rainy and winter. The month of March and October are the transitional months between winter and summer and rainy and winter season respectively. The mean maximum air temperature varied from 25.64°C (January) to 30.8°C (May) and mean minimum air temperature varied from 5.68°C (January) to 23.03°C (July). Minimum monthly rainfall occurred in January (22.5 mm) and maximum in July (203 mm). The area received an average annual rainfall of 1001.6 mm. Relative humidity was recorded to be maximum in the month of August (83.21%).

Earthworm extraction and soil analysis

Sampling of earthworms and soil were done by using the tropical soil biology methodology (Anderson and Ingram, 1993). Earthworms were collected from each site divided into nine locations by digging nine 25 x 25 x 30 cm monoliths at regular monthly interval and hand sorting the worms following Anderson and Ingram (1993) and these were preserved in 4% formalin for further studies. Preserved worms were identified with the help of available keys (arrangement of setae, location and size of clitellum, location of genital openings, shape and number of sperm thecae, location of gizzard and prostate gland (Julka, 1988). Density of earthworms was calculated as the number of individuals present per meter square. Biomass of worms was determined in an electric balance with 0.01 mg accuracy and values are given on a fresh weight basis. The soil samples collected from 0-20 cm depth of the soil monolith were brought to the laboratory, air dried (bigger lumps crushed) and sieved through 2 mm sieve and used for subsequent chemical analysis. Soil temperature was recorded every month at 0-10 cm depth using soil thermometer. Moisture was determined by gravimetric method monthly at 0-10 cm depth and was expressed as a percentage of the weight of the sample after oven drying at 105°Cfor 24 hours. Soil pH was measured in 1:2 soil water solutions using a digital pH meter. Organic carbon was determined following the wet digestion method (Walkley and Black, 1934) and soil total nitrogen (N) by acid digestion Kjeldahl procedure (Anderson and Ingram, 1993). Soil potassium was determined using flame photometry. Available phosphorous was analyzed spectro-photometrically as per the methods described by Anderson and Ingram (1993).

RESULTS AND DISCUSSION

A total of seven species of earthworms belonging to three families were recorded from the subtropical hilly forest ecosystem. The three species of Megascolecidae included *Amynthas corticis*, *Amynthas* sp.1 and *Perionyx* sp., while Moniligastridae, was represented only by *Drawida* sp. The family of Octochaetidae was represented by *Eutyphoes festivus*, *Eutyphoes marmoreus* and *Eutyphoes* sp.1. Of the seven species *Amynthas* sp.1 was collected only from the reserved forest ecosystem. All the other six species were recorded in all the three sites (Table 1). *Perionyx* sp., *Drawida* sp.and *Eutyphoes festivus* were found to be the most common earthworms encountered in the three sites.

Table1: Distribution of earthworms in three study sites of Mingkong area, Mokokchung

Earthworm species	Reserved forest	Plantation	Fallow
Amynthas cortices	"	"	"
Amynthas sp. 1	"	×	×
Perionyx sp.	"	"	"
Drawida sp.	"	"	"
Eutyphoes festivus	"	"	"
Eutyphoes sp.no.1	"	"	"
E. marmoreus	"	"	"
Total 7 6 6			

Table 2: Seasonal density and biomass distribution of total earthworms in the three study sites

Season	Natural forest		Plantation area		Fallow land	
	Density (Nos. m^{-2})	Biomass (g m^{-2})	Density (Nos. m^{-2})	Biomass (g m^{-2})	Density (Nos. m^{-2})	Biomass (g m^{-2})
Winter	130.76 ± 2.81	77.62 ± 1.53	80.64 ± 2.10	35.17 ± 0.92	53.84 ± 1.27	18.34 ± 0.42
Pre-monsoon	221.22 ± 3.92	239.33 ± 3.43	139.27 ± 3.30	85.2 ± 1.90	121.01 ± 3.01	97.97 ± 2.26
Monsoon	257.71 ± 4.87	224.04 ± 4.31	195.59 ± 5.36	96.23 ± 2.50	173.48 ± 4.54	138.24 ± 3.34
Total	609.68 ± 11.33	549.87 ± 9.05	386.1 ± 9.33	216.6 ± 5.33	356.56 ± 8.82	254.58 ± 5.94

Table 3: Average soil characteristics of the three study sites

pH	5.01 ± 0.40	5.32 ± 0.04	5.91±.42
Available Nitrogen (Kg/ha)	257.89±6.69	220.46±6.94	208.06 ±4.83
Organic Carbon (%)	1.72±0.06	1.76±0.05	1.72±0.05
Phosphorous (kg/ha)	17.01±0.52	14.53±0.64	16.18±0.96
Potassium (kg/ha)	93.05±5.31	80.27±5.31	104.09±5.18
Soil temp (°C)	18.1 ± 0.4	20.16 ± 0.36	19.82± 0.30
Soil moisture (%)	33.29 ± 1.04	30.87± 1.02	27.22 ± 1.00

Density of earthworms were recorded to be maximum during monsoon season as compared to pre monsoon and winter season in all study sites, however interestingly maximum biomass was recorded during the pre-monsoon season in forest area having the trend of monsoon> pre monsoon> winter in other two sites. Density of earthworm follows the trend of reserved forest> plantation > fallow ecosystem in all season having the maximum record of 257.71 ± 4.87 m^{-2}, 195.59 ± 5.36 m^{-2} and 173.48±4.54 $^{-2}$ respectively during monsoon period. Maximum biomass of earthworm was recorded in reserve forest (239.33±3.43 gm^{-2} in pre-monsoon season) followed by fallow area (138.24± 3.34 gm^{-2} in monsoon period) and plantation area (96.23± 2.50 gm^{-2} in pre-monsoon period) (Table 2). Earthworm population density at a specific site is the result of the interaction of a number of factors of which moisture is of greater importance (Valle *et al.*, 1997). In the present study, density of worms in reserve forest (609.68± 11.33 m^{-2}), plantation area (386.1± 9.33 m^{-2}) and fallow area (356.56 ±8.82 m^{-2}) corresponds to decreasing level of soil moisture of 33.29 ± 1.04 %, 30.87 ± 1.02% and 27.22 ± 1.02% respectively. The early pre-monsoon showers coupled with good retention of moisture in the area due to the thick forest coverage resulted in increase of earthworm population density which continued up to the monsoon season. Chaudry and Mitra (1983) reported the influence of soil conditions on earthworm population. Similarly, the influence of earthworm activity by the different soil parameters besides their feed was also reported by Edwards and Lofty (1972).Hence, the different soil factors may have influenced the earthworm population even in the present study. The importance of soil moisture content in relation to population of earthworm in India were also reported by Dash and Senapati (1980), Julka (1986) Bhadauria and Ramakrishnan (1989,1991), Blanchart and Julka (1997) and Haokip and Singh (2012). Joshi and Aga (2009) observed that higher rainfall along with favorable relative humidity might lead to increase of earthworm population during that particular season. Low density of earthworm in plantation and fallow land area than natural forest ecosystem is due to destruction of natural forest (Bhadauria and Ramkrishnan, 1991). Curry *et al.* (2002) also observed that earthworm populations in cultivated land are generally lower than those found in undisturbed habitats. Variation of earthworm density and diversity in all the three study sites were found to be affected by several microclimatic or soil physico-chemical factors such as soil moisture content, soil temperature, bulk density and nutrient content viz. organic carbon, and total nitrogen (Haokip and Singh, 2012). The soil pH is a significant factor because it affects the availability of nutrients in the soil. This is due to the fact that many plant nutrients are not readily available to plants in highly alkaline or acidic soils and these essential nutrients are most available to plants at a pH between 6 and 7.5 (Ilangovan and Lethi, 2012). This might have had a profound effect on earthworm population because with healthy plants only the soil gets enough litters for the soil which is important food material for the worms. Further increase of earthworm density corresponding to the decreasing pH value in three different sites respectively suggests that earthworm species generally have narrow range in pH, having restricted to higher acidic soils (Edwards and Lofty, 1977). The pH value of soil in the study area is slightly acidic which is positively correlated in 'maximum habitat with distribution of earthworm (Iqbal *et al.*, 2015).

While total nitrogen was found to be in decreasing trend from forest to fallow land, other chemical contents *i.e.* organic carbon, phosphorus, potassium did not show any significant differences among the three sites (Table 3). However, Goswami and Mondal (2015) observed that the high population density of earthworm species may be due to high nitrogen, high organic carbon, steady moisture range and almost neutral pH range. Similar investigation on diversity and distribution of earthworm population in subtropical forest ecosystems of Uttarakhand, India was made by Joshi and Aga (2009), who recorded soil moisture, temperature, pH, oxidizable organic matter, nitrogen, phosphorous, potassium and calcium as the potential factors influencing the diversity and distribution patterns of earthworm population. Singh *et al.* (2016) reported 5 species of earthworms from different land use patterns in north western parts of Punjab and correlate their distribution with physico-chemical properties of the soil.Change in earthworm population structure due to disturbance and degradation of natural forests have also been reported both in the tropical and temperate regions of the world (Baretta *et al.*, 2007 and Chandran *et al.*, 2012). While investigating on population dynamics of earthworms in relation to alterations in land-use systems, Lalthanzara *et al.* (2011) indicated the existence of diverse earthworm communities in two different agro forestry systems of Mizoram, India. The results, thus, suggests the significance of diverse soil habitats as one of the most influencing factor affecting the overall earthworm distribution (Bhadauria *et al.*, 2000). Phillipson *et al.* (1976) and Baker *et al.* (1993) reported that differences in various chemical properties of soil viz., pH, organic matter, nitrogen, phosphorus and potassium are the factors which are highly responsible for the distribution and abundance of earthworms in the soil of an area and no one factor but a combination of many factors (both climatic and edaphic) play pivotal role in the diversity and distribution of earthworms. The present record of 7 species of earthworms in the reserved forest ecosystem with the highest density (609.68±11.33 m^{-2}) and biomass

(549.87 ± 9.05 gm^{-2}) as compared to the plantation and fallow ecosystems which recorded only 5 species each having lower density and biomass conforms to the study of Lee (1985) who also reported that earthworm diversity to a great extent is found to be more in undisturbed ecosystems than in interfered habitats.

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