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INVESTIGATIONS ON SEASONAL ABUNDANCE OF THE EARTHWORM *OCTOLASION CYANEUM* (SAVIGNY, 1826) (LUMBRICIDAE: ANNELIDA) IN HIGH ALTITUDE FOREST SYSTEM OF THE KUMAUN HIMALAYAS, INDIA

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ABSTRACT

The study was conducted in Nainital 29°23′27.94″ N, 79°26′53.34″ E at 2046 m a.s.l. and describes the population dynamics of earthworm *Octolasion cyaneum* (Lumbricidae: Annelida) during three seasons i.e. summer (March-June), rainy (July-October) and winter (November-February) to determine the density of earthworm *Octolasion cyaneum* and its relationship with climatic and physico-chemical factors of soil. The area is inhabited by the earthworm *Octolasion cyaneum* which has been reported first time in the Kumaun region of Uttarakhand, India and is considered as the inhabitant of higher altitudes of Indian Himalayas. A mean total of 2550 earthworms from 6 field collections were collected in two consecutive study years i.e. 2015-17. The mean density of earthworm ranged between 10 m^{-2} to 48.25 m^{-2} during the study period. The study showed that the maximum density of earthworm was recorded in the upper monolith (0-15 cm) as the organic content is more abundant in upper strata. The age structure of earthworms indicated that the clitellates were more abundant than aclitellates. The mean soil pH from the forest sample was slightly acidic i.e. 6.5 and C: N has been found 11.3. A significant positive correlation has been obtained between worm density and soil temp ($r<0.05$) and soil C ($r<0.05$).

KEYWORDS: *Earthworms, Kumaun Himalayas, Population dynamics, Octolasion cyaneum*

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INTRODUCTION

Forest floor provides a medium where native seedlings fall, germinate and grow. Forest soil is a part of natural ecosystem and helps in smooth driving of many ecosystems that helps in sustainability of diverse organisms. The great Himalayan region has rich biodiversity as these young mountain ranges have expanded broad mixed leaf, dry deciduous and coniferous forest. The Western Himalayan range provides susceptible habitat for fauna to flourish and it helps in maintaining a productive ecosystem. The population of earthworms greatly varies in terms of numbers or biomass and diversity. Earthworms are the extraordinary creature contributing to soil structures which accelerate soil organic matter, humus formation, mineral weathering and nutrients within the soil ecosystem stabilizing the soil properties.[1-5] They transport large quantity of carbon (C) from the surface of the soil to the lower horizons, effectively mixing the soil and increase decomposition and humification rates significantly. The population dynamics of earthworms has been studied in lumbricides because of many interacting factors relating to the environment such as rainfall, temperature and food availability and biological factors such as inter and intra-specific competition, parasitism and predation.[6-8] Earthworm biomass accounts more than 90% of soil invertebrate which comprises of 300 known species.[9-10] The lumbricid species *O. cyaneum* is a polyploid (9n, 10n, probably also other ploids) that reproduces only perthenogenetically.[11-12] It's a sluggish species commonly found in the topsoil of many soil types. Due to their wide distribution, this particular species have significant impact on soil physical properties or not. The objective of this study was to investigate the population dynamics of the earthworm *O. cyaneum* in forest ecosystem followed by the effect of physico-chemical factors on earthworm population and the effect of summer, rainy and winter season on their density.

MATERIALS AND METHODS

Study site

The study was conducted in Ayarpata forest range which is located in Nainital, Kumaun region of Uttarakhand which is situated between 29°23′27.94″ N, 79°26′53.34″ E at 2046 m abovesealevel. The climatic pattern that was selected for the study was categorized into three main local seasons; summer (March-June), rainy (July-October) and winter (November-February). Study site selected for earthworm survey comprised of mature oak (*Quercus leucotrichophora)* which is found to be dominant and deodar trees *(Cedrus deodar)* and small plants. The area selected for sampling is with low or no anthropogenic activity.

Sampling

Earthworms were collected from the forest floor by conventional digging four (50x50 cm) plots with two monoliths (0-15 cm and 16-30 cm) seasonally for two study years by hand sorting the worms[13] and were preserved in 4% formalin for identification. Density was calculated as the number of individuals present per square meter. Random soil samples were collected from study site and standard methods were followed for subsequent analysis[14,36] Soil temperature was recorded every season at 0-15 cm depth using soil probe thermometer. Moisture was determined gravimetrically seasonally at laboratory. Soil pH was determined by Systronic pH model 335. Soil Carbon was determined using wet oxidation and Phosphorus is determined using the wet washing method[15], Potassium was determined using flame photometry and Soil Nitrogen was analyzed by Kjeldahl method.[16]

STATISTICAL ANALYSIS

The result was analysed using software SPSS (SPSS 20.0, Windows 2007). The significance level was set at $\alpha = 0.05$. Pearson's correlation analysis was performed to determine correlations between earthworm density and soil parameters along. The Pearson correlation coefficient (r) is presented throughout the paper.

RESULTS

Earthworm identification

The earthworms collected from the selected site was preserved in 4% formalin solution[17] and further identified by Dr. J.M. Julka former Deputy Director of ZSI, Solan Himanchal Pradesh. The dominant earthworm identified as *Octolasion cyaneum* (Lumbricidae: Annelida) and was reported first time from the Kumaun region.[18]

Pedological characteristics

The pedological characteristic of the soil differed seasonally. Soil pH was found slightly acidic (6.5±0.465) in forest area. The average soil N was

recorded 0.096±0.010. The organic C was found high i.e. 1.02±0.108 due to thick humus layer at higher altitudes. The C: N ratio was found 1:11.3 that seems to be the most important factor of the earthworm distribution in forest system (Table 1.

Table 1
Average Pedological Characteristics in the study site.

Pedological Characteristics	Nainital (2046 m.s.l.) Forest Area
Soil pH	6.5 ± 0.465
Soil Temperature (°C)	17.93 ± 2.29
Soil Moisture (%)	39.67 ± 4.991
C (%)	1.021 ± 0.108
N (%)	0.096 ± 0.010
P (%)	0.0007 ± 0.00001
K (%)	0.007 ± 0.002
C:N ratio	11.3

Values are mean±SE; (n=6)

Depth distribution and age-structure

Depth distribution of earthworm in three seasons showed that worms appeared mainly in the 0-15 cm soil layer (Table 2). In three seasons the higher density was recorded in the 0-15 cm than the 16-30 cm soil layer in summer season than the rainy season. Only two classes have been considered, clitellates and aclitellates. The yearly ratio of clitellate to aclitellate recorded was 1:1.34 (Table 3). It was observed that the *O. cyaneum* density was more in upper strata (0-15cm) of soil during summer for both the study years (Figure 1 & 2).

Table 2
Depth distribution of earthworm number (ind per square meter) in various seasons for 2015-17.

Year	0-15 cm soil Layer Density (no.m^{-2})	16-30cm Soil Layer Density (no.m^{-2})
Summer		
2015-16	660	112
2016-17	156	4
Mean	102	14.5
Rainy		
2015-16	448	8
2016-17	404	52
Mean	106.5	15
Winter		
2015-16	488	36
2016-17	180	4
Mean	83.5	5
Annual		
2015-16	1596	156
2016-17	740	60
Mean	97.3	9

Table 3
Age structure of earthworms in study site.

Season	Total Number of earthworms collected (0-30 cm)		Clitellates: Aclitellates
	Clitellates	Aclitellates	
Summer			
2015-16	460 (115)	312 (78)	1:1.47
2016-17	60(15)	100 (4)	1:0.6
Rainy			
2015-16	260 (65)	196 (49)	1:1.32
2016-17	312 (78)	144 (36)	1:2.16
Winter			
2015-16	280 (70)	244 (61)	1:1.14
2016-17	92 (23)	90 (22.5)	1:1.02
Annual			
2015-16	1000 (333.3)	752 (250.6)	1:1.32
2016-17	464 (154.6)	334 (111.3)	1:1.38
Mean	1464 (732)	1086 (543)	1:1.34

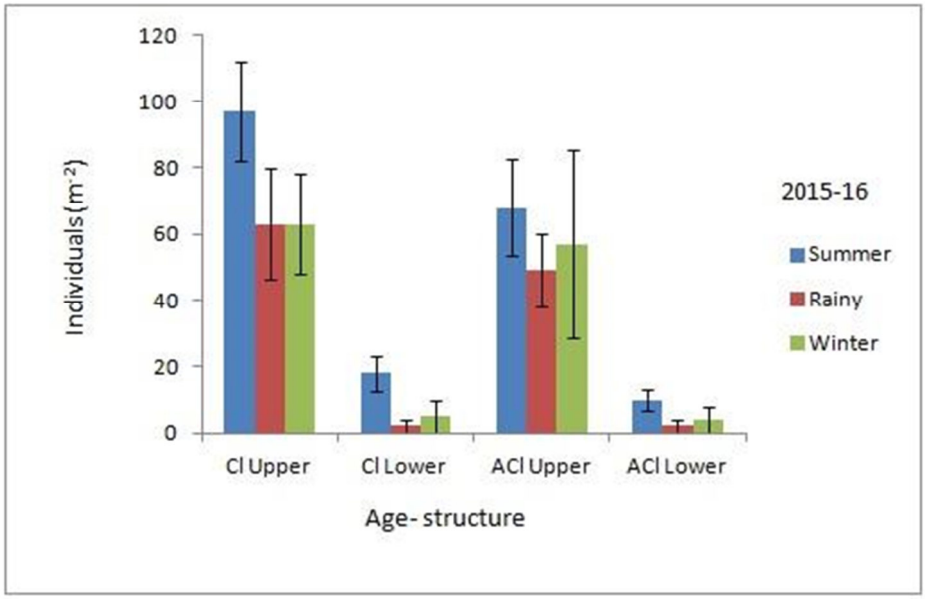

Figure 1
Mean total density (per square meter± S.E.; n=6) of clitellates in upper (0-15cm) and lower (16-30cm) soil depths along with aclitellates in upper (0-15cm) and lower (16-30cm) soil depth in three different seasons during 2015-16 (one-way ANOVA; α=0.05)

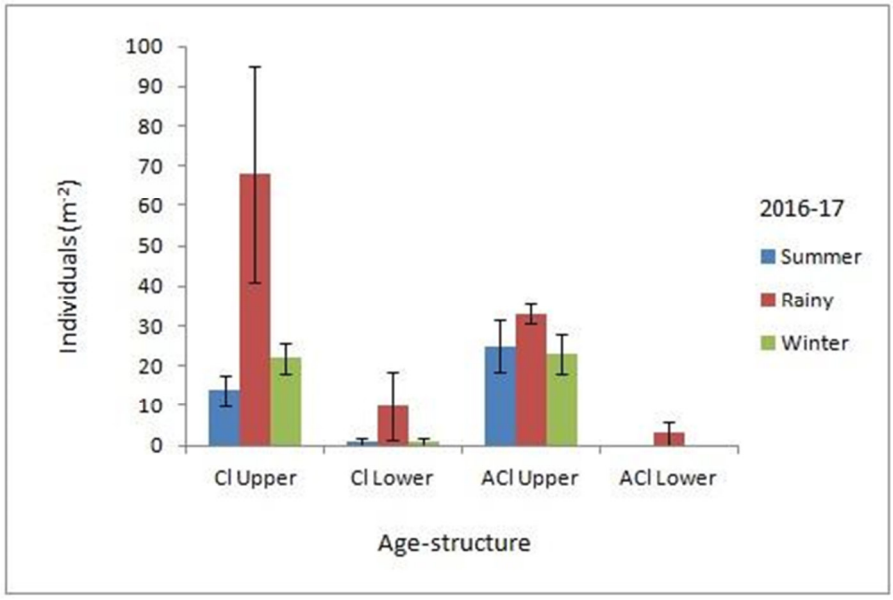

Figure 2

Mean total density (per square meter± S.E.;n=6) of clitellates in upper (0-15cm) and lower (16-30cm) soil depths along with aclitellates in upper (0-15cm) and lower (16-30cm) soil depth in three different seasons during 2016-17 (one-way ANOVA; α=0.05).

Correlation between earthworm density and soil parameters

A significant positive correlation was noted between the size of earthworm population and soil parameters such as moisture, soil temperature, pH, Carbon, Nitrogen and Phosphorus. The *Octolasion cyaneum* showed significantly positive correlation with soil temperature (r=0.874; P<0.05) and soil Carbon (r=0.831; P<0.05) (Table 4) indicating the temperature in the high altitude plays a key role.

Table 4

Pearson correlation coefficient (r) of worm density (ind. per square meter) with soil characteristics collected study site during 2015-17 (n=6).

Parameters	Soil temp.	Ambient temp.	Moisture	Soil pH	Soil C	Soil N	Soil P	Soil K
Worm Density	0.874*	0.616	0.164	0.443	0.831*	-0.278	-0.383	-0.382
Soil temp.		0.966**	0.163	0.656	-0.615	-0.793	-0.756	0.093
Ambient temp.			0.248	0.618	-0.661	-0.838*	-0.637	0.013
Moisture				-0.459	0.301	0.215	-0.354	0.719
Soil pH					-0.743	-0.714	-0.152	-0.707
Soil C						0.908*	0.271	0.145
Soil N							0.416	0.111
Soil P								-0.284

Level of significance: **P<0.01, *P<0.05

DISCUSSION

The forest may have a positive effect on earthworm population as leaf litter contributes in the formation of humus layer[19] and organic matter in turn facilitates the earthworm population by providing them the food they require for their optimal growth. Earthworms belonging to the family Lumbricidae are important members of the soil biological community. They play a major role in the biogeochemical cycles of terrestrial ecosystem because they influence microbial activity, carbon and nitrogen cycle and alter the soil[1,20] One of representative of the family Lumbricidae is *O. cyaneum* which is morphologically characterized by the presence of multilayered clitellum[21]. Species *O. cyaneum* which was first time reported in 1993[22], is an endogeic species living within the soil and feed on the mixture of organic matter and mineral soil.[23-27] They prefer the habitat with higher levels of moisture and relatively cooler temperature.[28] They are also found to be successful in colonizing

disturbed environments. Due to their wide distribution, it is important to know whether this particular species have significant impact on soil physical properties or not. *O. cyaneum* was found exclusively from the forest region of Nainital. The earthworm density is highly affected in the hills with the climatic factors especially temperature, rain and snow. The density of earthworms fluctuated with the advent of seasons in the study area. The area sampled enjoys thick forest cover and humus layer rich in organic matter providing the nourishment to the endemic earthworm species *O. cyaneum*. Earthworm population density at a specific site is the result of the interaction of a number of factors such as soil texture, moisture, temperature, pH and organic content.[29-32] In the present study the abundance of earthworms significantly fluctuated seasonally. A significant change was found in the density of earthworms in a varied seasonal pattern. The density was found highest in summer season as compared to the rainy and winter season. Lumbricids were recorded in highest number during the summer season[33] and the present study showed the same pattern as highest density of *O. cyaneum* i.e. 48.25 m^{-2} was found during the summer season of the area sampled. The change in population of earthworm alters the soil physico-chemical properties and soil temperature which in turn affects the ecosystem.[34-36]

CONCLUSIONS

This endemic species is first time reported from Kumaun Himalayas. The *Octolasion cyaneum* is of great importance in various vermitechnological processes including maintenance of humification, C:N in forest system of higher altitude. This endemic species helps in the nutrient cycling of the forest floor and supports the evergreen cover of the area. The study concludes though the population of earthworm increases in rainy season but the summer season has high impact on the population of *Octolasion cyaneum* showing their higher abundance in this season.

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CONFLICT OF INTEREST

Conflict of interest declared none.

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