

EARTHWORM ABUNDANCE AND SPECIES COMPOSITION IN A CULTIVATED SYSTEM OF KUMAUN HIMALAYA

¹J.H. Naik, ²M. Singh, ³H. Pande, ⁴D. Goswami and ⁵B. R. Kaushal

^{1,2}Student, Department of Zoology, Kumaun University, Nainital, India

^{3,4}Assistant Professor, Department of Zoology, Kumaun University, Nainital, India

⁵Professor, Department of Zoology, Kumaun University, Nainital, India

Abstract- Earthworm abundance and species composition were studied in a cultivated system in Kumaun Himalaya where annual rainfall is 2225 mm and the climate is subtemperate. The soil is silty loam and contains 43.5% sand 31.2% silt and 25.3% clay. Twelve species were found: 8 Megascolecidae, 3 Lumbricidae and 1 Moniligastridae. Abundance ranged from 0 to 214.4 ind. m⁻². Biomass ranged from 0 to 74.8 g m⁻². Depth distribution of earthworms indicated a mean of 61.5% of worm number and 53.3% of total biomass were collected at 0-10 cm soil layer. Age structure of earthworms indicated that acitellates were more abundant than clitellates. Several significant correlations were obtained between numbers and biomass of earthworms and soil properties. Casts collected from the study site showed an increase in pH and available C, N, P and K (%) compared with the non-ingested soil in the study site. C:N ratio of casts was lower than that of non-ingested in the study site.

Index terms- Earthworms, abundance, species composition, depth distribution, Kumaun Himalaya

I. INTRODUCTION

Terrestrial Oligochaete worms, and notably earthworms are detritivorous docile creatures of soil and can dramatically change the physical, chemical and biological properties of soil by their feeding, burrowing and casting activities (Chaudhuri and Nath, 2011), hence considered as “soil engineers”. Due to their dominant position in the soil animal biomass (80-90%) except in acidic soils and high contribution to rates of soil turnover, earthworms are of special importance for soil fertility (Sharpley et al, 1979). The importance of earthworms in nutrient cycling is well known through many studies on temperate agroecosystems (Norgrove and Hauser, 2000; Birang et al, 2003).

Most studies are from temperate regions (Borges and Alfaro, 1997; Cameron et al, 2015; Edwards, 2004). India has a rich earthworm fauna that include over 450 known species (Julka, 1988). Few studies have been reported from tropical soils in India (Blanchart and Julka, 1997; Bhaduria and Ramakrishnan, 2005; Dash and Dash, 2005). However, information on the distribution and abundance of these species and other factors influencing them in different land-use systems in Kumaun Himalaya is still scarce (Bisht et al, 2003 & Pande et al, 2012). The influence of earthworms, either native or introduced on soil structure and fertility is poorly understood.

This paper deals with the species composition, abundance and the influence of variety of environmental factors and soil properties on their distribution in cultivated system in Kumaun Himalaya.

II. MATERIALS AND METHODS

The study was conducted in cultivated land systems during May 2016 to April 2018 at Beluwakhan region comprising of villages Aarukhan, Baldiakhan and Naina gaon about 17 kms from Nainital in Kumaun Himalaya (29°21' N latitude, 79° 28' E longitude; altitude 1605 m). On the basis of climatic variations, the year is divisible into three seasons: summer (March-June), monsoon (July-October), and

winter (November-February). However, in finer seasonal division, the period from mid September to November can be regarded as autumn, and from March to mid April as spring seasons. The site is sub temperate and average annual maximum and minimum temperature and precipitation observed at S.M.R.A. Govt. Inter College Nainital, were 25.9 °C, 5 °C and 2225 mm, respectively.

The soil is silty loam, ranging from light to dense brown and contains 43.5% sand 31.2% silt and 25.3% clay. Mixed crops were grown in a year: maize, potato and pulses (June to November); wheat, mustard and peas (January to May) alongwith the seasonal vegetables and fallow period (December). The tillage system in the cultivated soils is manual and tilled depth is about 5-10 cm.

Soil samples were taken from five random collections from each of the two monoliths (0-10 and 10-20 cm) at each earthworm sampling date every month. Soil temperature and soil moisture were measured at 0-10 and 10-20 cm soil layers on each sampling date. Surface casts of earthworms were collected with a fine brush from the same area where earthworms were sampled. Soil and casts were air dried, ground, passed through a 2 mm sieve and stored for subsequent nutrient analysis. Organic C was determined using wet sieving oxidation and available P by wet ashing method (Jackson, 1958). N was determined by Kjeld auto Vs-KTP Nitrogen analyser based on micro-Kjedahl technique (Misra, 1968). K was determined by flame photometry. Main properties of soil are listed in Table 1.

Earthworms were sampled in five plots on each sampling occasion every month using a quadrat (0.5x0.5m) to a depth of 20 cm. Earthworms were hand sorted, stored in plastic bags and identified (Julka, 1988). Fresh weight of earthworms was recorded after the worms were rinsed with water and dried with paper towels on the same day when they were collected. The individuals were classified in two developmental stages, a clitellates and clitellates.

The regression (r) between earthworm density and biomass was calculated with soil pH, soil moisture, soil temperature, soil C, N, P and K using simple correlation coefficient (SAS, 1987).

III. RESULTS AND DISCUSSION

A. Soil properties: Soil pH ranged from slightly acidic (6.4) to slightly alkaline (7.3) with a mean of 6.9 ± 0.06 . The maximum soil moisture was 14.9% and 14.5% at 0-10 and 10-20 cm soil layer and the minimum soil moisture was 7.2% and 7.5% at 0-10 and 10-20 cm soil layer, respectively. Organic C and available N (%) decreased with increasing depth (Table 1). The efficacy of the hand sorting method used in the present study for the extraction of earthworm has been previously tested (Pande et al, 2012). This method has the advantage that it can be adapted to extract earthworms at all stages of their life cycle. It provided the population in the 20 cm of upper soil layer in the present study.

Table 1: Average soil characteristics in the study site (mean \pm SE: n=24)

Soil characteristics	Cropland (soil layers)		
	0-10 cm	10-20 cm	0-20 cm
Soil pH	6.9 \pm 0.06	6.8 \pm 0.07	6.8 \pm 0.33
Soil Temp. ($^{\circ}$ C)	17.7 \pm 1.23	17.2 \pm 1.16	17.4 \pm 1.17
Soil moisture (%)	10.9 \pm 0.48	11.1 \pm 0.36	11 \pm 0.42
Available C (%)	4.58 \pm 0.28	3.93 \pm 0.20	4.25 \pm 0.23
Available N (%)	0.433 \pm 0.042	0.372 \pm 0.018	0.403 \pm 0.022
Available P (%)	0.0070 \pm 0.0005	0.0065 \pm 0.0006	0.0067 \pm 0.0004
Available K (%)	0.0184 \pm 0.0013	0.0189 \pm 0.0028	0.0187 \pm 0.0016
C:N ratio	10.55 \pm 0.001	10.56 \pm 0.002	10.55 \pm 0.001

B. Species composition and abundance of earthworms: A total of 3400 earthworms from 480 samples were collected from the study site (Table 2). Twelve species were identified belonging to three families (Megascolecidae- eight species; Lumbricidae - three species and Moniligastridae – one species). Megascolecidae was the most dominant family with 32% of earthworms, Lumbricidae 5%, Moniligastridae 1% and acitellates 62% in the cultivated soils of study site.

The abundance and biomass of earthworms fluctuated seasonally. Worm density ranged from 0 to 113.6 ind. m⁻² during summer season (March to June); 20 to 214.4 ind. m⁻² in monsoons (July to October) and from 0 to 70.4 ind. m⁻² during winters (November to February). Worm biomass ranged from 0 to 74.8 g m⁻² during summer season (March to June); 11.2 to 65.1 g m⁻² in monsoons (July to October) and from 0 to 37.1 gm⁻² during winters (November to February). Higher density and biomass was of worms were found to be maximum during rainy season.

Table 2: Species composition of earthworms at the study site

SPECIES	CROPLANDS	
	Number	%
MEGASCOLECIDAE	1085 (84)	32
<i>Amyntas corticis</i> (Kinberg, 1867)	648	19
<i>Amyntas alexandri</i> (Beddard, 1900)	204	6.0
<i>Amyntas gracilis</i> (Kinberg, 1867)	68	2.0
<i>Amyntus morrisi</i> (Beddard, 1892)	54	1.6
<i>Metaphire birmanica</i> (Sims and Easton, 1972)	38	1.2
<i>Metaphire houlleti</i> (Perrier, 1872)	26	0.8
<i>Metaphire anomala</i> (Michaelsen, 1907)	19	0.5
<i>Perionyx excavatus</i> (Perrier, 1872)	28	0.9
LUMBRICIDAE	170 (13.1)	5.0

<i>Octolasion tyrtaeum</i> (Savigny, 1826)	44	1.3
<i>Aporrectoeda caliginosa trapezoids</i> (Savigny, 1826)	42	1.3
<i>Eisenia fetida</i> (Savigny, 1826)	84	2.4
MONILIGASTRIDAE	37 (2.9)	1.0
<i>Drawida nepalensis</i> (Michaelsen, 1907)	37	1.0
ACLITELLATES	2108	62
TOTAL EARTHWORMS	3400	100.0

C. Depth distribution: Depth distribution of earthworms in the two crops when combined together showed that worms appeared mainly in the 0-10 soil layer (Table 3). A mean of 60.18% of total earthworms and 50.69% of total biomass were collected at the 0-10 soil layer (Table 3).

Table 3: Depth distribution of earthworms number and biomass in the cultivated soils at the study site. (Figures given in parentheses are percent values)

Year	0-10 cm soil layer		10- 20 cm soil layer	
	Number	Biomass (g)	Number	Biomass (g)
Maize, potato and pulses				
2016	690(56.2)	222.192(44.5)	537(43.8)	276.656(55.5)
2017	798(66.7)	216.424(62)	399(33.3)	132.432(38)
Mean	744(44.3)	219.308(51.8)	936(55.7)	204.544(48.2)
Wheat, mustard and peas				
2016-2017	287(59.4)	74.88(59)	196(40.6)	51.87(41)
2017-2018	261(62.5)	76.688(56.7)	157(37.5)	58.512 (43.3)
Mean	274(60.8)	75.784(57.9)	176.5(39.2)	55.191(42.1)
Fallow				
2016	26(52)	9.84(52.9)	24(48)	8.776(47.1)
2017	19(76)	6.504(67.5)	6(24)	3.128(32.5)
Mean	22.5(60)	8.172(57.8)	15(40)	5.952 (42.2)
Total worms				
2016-2017	333(61.6)	306.912(47.6)	208(38.4)	337.302(52.4)
2017-2018	282(61.4)	299.616(60.7)	177(38.6)	194.072(39.3)
Mean	307.5(61.5)	303.264(53.3)	192.5(38.5)	265.687(46.7)

D. Age structure: Only two age classes have been considered: clitellates and a clitellates. The yearly ratio of clitellates to a clitellates was 1:1.65. In the wet periods the number of both a clitellates and clitellates showed an increase. In case of a clitellates, the winter drop in numbers was rapid and abrupt in the study site.

The seasonal dynamics over an annual cycle in the present study showed that earthworm population and biomass were higher during wet periods and low in winter and summer. The rainy season peak in earthworm population size and activity is more common and is due to favourable soil moisture, temperature and humidity (Edwards and Lofty, 1977). Absence of earthworms during the winter season in cultivated soils could be due to the fact that worms moved below 20 cm and were not captured.

Earthworms display a variety of strategies varying in their vertical and horizontal distributions (Bouche, 1977 & Lavelle, 1983). The majority of the studies have reported earthworms in the top 20 cm of soil (Mckenzie and Dexter, 1993; Valle et al, 1997) but there are species that habitually penetrate down as far as 50 cm (Lavelle, 1983). Data on depth distribution of earthworms in the present study suggests that earthworms move through the profile in accordance with rainfall, migrating towards the top 20 cm during humid months and burying themselves deeper during drier periods.

A clitellates were recorded higher in numbers during the wet periods in the present study. Similar results have also been reported (Mckenzie and Dexter, 1993).

E. Earthworm / soil properties relationship: Correlation coefficients for monthly values of soil properties and earthworms are summarized in Table 4. Significant correlations were obtained between worm density and worm biomass ($r = 0.890$; $P < 0.01$), worm density and soil moisture ($r = 0.570$; $P < 0.01$). Worm biomass was positively correlated with soil moisture ($r = 0.689$; $P < 0.01$) worm biomass and pH ($r = 0.045$; $P < 0.05$); worm biomass and soil C ($r = 0.144$; $P < 0.05$). Several physical and chemical environmental factors have been reported that effects the distribution and abundance of earthworm populations. These include available moisture, temperature, soil texture, soil depth, organic content, C:N ratio and pH (Borges & Alfaro, 1997; Dash & Dash, 2008; Bisht et al, 2003; Valle et al, 1997; Lee, 1985). Significant positive correlations have been observed between earthworm density and biomass with soil moisture, soil pH, organic C, N, and P; and negative correlations with K in the present investigation.

Table 4: Correlation coefficient (r) for soil characteristics and earthworms number and biomass in cultivated soils

Parameters	Worm biomass	Soil pH	Soil temp.	Soil moisture	Soil C	Soil N	Soil P	Soil K
Worm density	0.890**	0.112	0.406	0.570*	0.330	0.330	0.013*	-0.462
Worm biomass		0.045	0.0.428	0.689*	0.144	0.143	0.041	-0.506

Level of significance: * $p < 0.05$

** $p < 0.01$

F. Chemical properties of casts: Chemical properties of non-ingested soil and casts collected from the study site are presented in Table 5. pH of the casts was not significantly different from that of field soil. C, N, P, and K were significantly higher in casts than that of field soil. C:N ratio of casts was lower (10.52) than field soil (10.54).

Table 5: Nutritional properties of undigested soil and casts produced by earthworms in study site.

Soil characteristics	Undigested soil	Casts	% change in relation to field soil
Soil pH	6.8	6.9	1.47
Soil Temp.(°C)	23.2	-	-
Soil moisture (%)	11.2	-	-
Available C (%)	5.46	6.0	9.9
Available N (%)	0.518	0.570	10.03
Available P (%)	0.0013	0.0025	92.3
Available K (%)	0.0184	0.0315	71.2
C:N	10.54	10.52	-0.19

An important role of earthworms is increasing the pH of a given soil type as observed here and also by others (Sharpley and Syers, 1976). Several authors have also reported that pH values of earthworm casts are higher than those of surrounding soil (Lee, 1985). They increase microbial activity and N fixation in the soil so that the N gain in the casts may be due, at least in part, to this rather than to concentration by earthworms. Earthworm's casts contain more C, N, P and K than that of the non-ingested soil (Norgrove & Hauser, 2000; Subler et al, 1997). Similar results have also been observed in the present study. Lower C: N ratio of casts in relation to the non-ingested field soil is probably due to the mineralization of plant-derived organic material during passage through the gut of earthworms. Similar results have also been reported for endogeic species (Fragoso et al, 1999). It is thus concluded that earthworms play an important role in nutrient cycling in the cultivated land systems by locally concentrating nutrients in the surface worm casts.

References

1. Bhadauria, T. and Ramakrishnan, P. S. (2005). Soil Biodiversity, Ecological Processes and Landscape Management, Oxford and IBH Publishers, New Delhi, India.
2. Birang, M.A., Hauser, S., Brussard, L. and Norgrove, L. (2003). Farmer's perception of the effects of earthworms on soil fertility and crop performance in Southern Cameroon. *Pedobiologia*, 47(5-6): 819-824.
3. Bisht, R., Pandey, H., Bharti, D. and Kaushal, B. R. (2003). Population dynamics of earthworms (Oligochaeta) in cultivated soils of central Himalaya tarai region. *Tropical Ecology*, 44: 227- 232.
4. Blanchart, E. and Julka, J.M. (1997). Influence of forest disturbance on earthworm (Oligochaeta) communities in the Western Ghats (South India). *Soil Biology and Biochemistry*, 29: 303–306.
5. Borges, S. and Alfaro, M. (1997). The earthworms of Bano de Oro, Luquillo Experimental Forest, Puerto Rico. *Soil Biology and Biochemistry*, 29: 231-234.
6. Bouche, M.B. (1977). In: Soil Organisms as Components of Ecosystems. *Biological Bulletin*, Stockholm.
7. Cameron, E.K., Decaens T., Lapied E., Porco D. and Eisenhauer, N. (2015). Earthworm databases and ecological theory: Synthesis of current initiatives and main research directions. *Applied Soil Ecology*, 20: 23-29.
8. Chaudhuri, P.S. and Nath, S. (2011). Community structure of earthworms under rubber plantations and mixed forests in Tripura, India *Environmental Biology*, 32: 537-541.
9. Dash, M.C. and Dash, S. P. (2008). Conservation and sustainable management of belowground biodiversity: A review on the functional role of soil fauna in Indian ecosystems with particular reference to earthworms. *International Journal of Environmental Sciences* 34: 223-243.
10. Edwards, C. A. and Lofty, J. R. (1977). *Biology of Earthworms*, Chapman and Hall, London.
11. Edwards, C. A. (2004). The importance of earthworms as key representatives of soil fauna. In: *Earthworm Ecology*, CRC Press, NY, Washington, USA.
12. Fragosa, C., Barios, I., Gonzalez, C., Arteaga, C. and Partan, J. C. (1999). Relationship between earthworms and soil organic matter levels in natural and managed ecosystems in the Mexican tropics In: *Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture*. pp: 231-239.
13. Jackson, M. L. (1958). *Soil Chemical Analysis*. Prentice Hall Inc., New Jersey, USA.
14. Julka, J.M. (1988). The fauna of India and the adjacent countries (Megadrile Oligochaeta). *Zoological Survey of India*, Kolkata, India.
15. Lavelle, P. (1978). Ivoire Les Ver de terre de la savana de Lamto, Cote d'ivoire, populations et fonctions dans P ecosystems; *Pub. Lab. Zool. E.N.S.12*: 301.
16. Lee, K.E. 1985. *Earthworms, their Ecology and Relationships with soils and Land use*. Academic Press, Australia.
17. McKenzie, B.M. and Dexter, A.R. (1993). Workshop on Methods of Research on Soil Structure/Soil Biota Interrelationships. *Geoderma*, 56: 233–241.
18. Misra, R. (1968). *Ecology Work book*. Oxford and IBH Publishing Company, Calcutta, India.
19. Norgrove, L. and Hauser, S. (2000). Production and nutrient content of earthworm casts in a tropical agrisilvicultural system. *Soil Biology and Biochemistry* 32:1651–1660
20. Pande, H., Goswami, D. and Kaushal, B.R. (2012). Earthworm Communities And Dynamics in Some Cropping Systems of Kumaun Himalaya. *Journal of Environment Biology Science*, 26(2); 83-88.

21. SAS, Inc. (1987). Guide for personal computers, 6th edn. Cary, North Caroline, USA.
22. Sharpley, A.N. and Syers, J.K. (1976). Potential role of earthworm casts for the phosphorus enrichment of run-off waters. *Soil Biology and Biochemistry* 8:341–346
23. Sharpley A.N., Syers, J.K. and Springett, J.A. (1979). Effect of surface-casting earthworms on the transport of phosphorus and nitrogen in surface runoff from pasture. *Soil Biology and Biochemistry* 11: 459–462.
24. Subler, S., Baranski, C. M. and Edwards, C. A. (1997). Earthworm additions increased short-term nitrogen availability and leaching in two grain-crop agroecosystems. *Soil Biology and Biochemistry*, 29: 413-421
25. Valle, J.V., Moro, R.P., Garvin, M.H., Trigo, D. and Diaz, D.J.C. (1997). Annual dynamics of the earthworm *Hormogaster elisae* (Oligochaeta, Hormogastridae) in central Spain. *Soil Biology and Biochemistry*, 29: 309-312.

