Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2022; 10(5): 127-132

Received: 05-06-2022
Accepted: 08-07-2022

Anjana Sharma
Faculty of Basic Sciences, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

JM Julka
Faculty of Basic Sciences, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Shakoor Ahmed
Faculty of Basic Sciences, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Corresponding Author:
Anjana Sharma JM Julka
Faculty of Basic Sciences, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Earthworm diversity and distribution in district Mandi, Himachal Pradesh of Northwest Himalaya, India

Anjana Sharma, JM Julka and Shakoor Ahmed

DOI: https://doi.org/10.22271/j.ento.2022.v10.i5b.9050

Abstract
The present survey of diversity and distribution of earthworms in District Mandi of Northwest Himalayan region conducted in two year from May 2013 to April 2015. Based on study reported 17 species belonging to 4 families. Information on earthworms scientific name, family, number, locality and general habitat are given for each species discussed in the text. Out of these 17 species, 6 native and 11 exotic species are recorded. There are 3 species which are firstly recorded in the study area these includes *Eisenia fetida, Argilophilus sp.* and *Amynthas morrisi*. The study provided extended information on earthworms' diversity in the study area with special reference to change in species along with change in vegetation and altitude.

Keywords: Diversity, Earthworms, habitat preference, Northwest Himalayas

Introduction
The great Himalayan mountain ranges on northern border of the Indian subcontinent hold key to the ecological security of the region (Negi, 2009) [55]. Rampant deforestation in these mountains, especially in the low and mid hills, has led to severe ecological imbalance in the entire subcontinent (Giri *et al*., 2003; Bolland *et al*., 2007; Kohli *et al*., 2009) [28, 11]. Furthermore, Pandit *et al*. (2009) [57] have estimated that dense forests (> 40% canopy) in the Himalayas would decrease to 10% of its geographical area by the end of this century. Because of extensive ecological degradation and loss of native vegetation, the Himalayas are included in the list of biodiversity hotspots for priority conservation (Myers *et al*., 2000; Mittermeier *et al*., 2004) [54, 53].

The state of Himachal Pradesh in the northwestern Himalayas, the area of present studies, has undergone rapid changes in the land use systems (Shah and Sharma, 2015) [62]. These changes not only affect the aboveground communities, but also a thriving rich belowground biodiversity, which is crucial for functioning of soil ecosystem (Saxena *et al*., 2005; Decaens, 2010; Eisenhauer *et al*; 2019) [61, 20, 22]. Earthworms are one of the most abundant soil macro fauna involved in the formation of soil and maintenance of soil fertility. The present investigations are aimed to update our knowledge on the diversity and distribution of these organisms in some selected land use systems of mid Himalayan hills.

Earthworms are well known invertebrate distributed throughout the world and play an important eco-functional role in soil ecosystem by influencing physical, chemical, biological properties of the soil. Earthworms play an essential role in carbon turnover, nitrogen mineralization, soil formation, cellulose degradation and humus accumulation etc (Ansari and Ismail 2012) [4]. Approximately 4,400 different species of earthworms have been identified worldwide (Sinha 2003) [65], with reports on diversity of earthworms in various parts of the world including those of Tasi *et al*. (2000); Blakemore (2003); Blakemore *et al*. (2006) [8]. Julka *et al*. (2009) reported 590 species of earthworms from india and although earthworm are well studied in other parts of india (Chaudhuri *et al*.2008; Karmegam & Daniel 2007; Sathianarayanan & Khan 2006; Tripathi & Bhardwaj 2004; Bist *et al*. 2003) [60, 8, 72].

Earthworms from the West Himalayan ranges had been explored by various oligochaete taxonomists (Bourne, 1889; Fedarb, 1898; Michaelsen, 1907b, 1909; Stephenson, 1914, 1916, 1922) [12, 24, 51, 52, 69, 70, 71].

Various studies, during the last ninety years or so, had brought to light additional species of earthworms from the area (Cernosvitov, 1937; Gates, 1945c, 1951; Soota and Julka, 1970; Sharma and Kaul, 1974; Soota and Halder, 1980; Julka, 1979, 1981, 1988, 1995; Halder and Ghosh, 1997; Julka and Paliwal, 1993a, 1994, 1995, 2000) [14, 25, 26, 66, 63, 54]. Paliwal and Julka (2005) [36] included 51 species in their checklist of earthworms of the Western Himalayas. Recently, new records of two species more species had been added to the list, raising the number to 53 species from these mountains (Kumari *et al*., 2017; Ahmed and Julka, 2017) [46, 2, 47]. The latest figures for the earthworm diversity of India showed the existence of 421 species (Julka, 2014; Ahmed & Julka, 2017) [2], which constituted to about 10.5% of world's known species estimated at 4,000 by Reynolds (1995) [59].

Material and Method

Study site

The study area is located in the Himalayan state of Himachal Pradesh between 30.2240° N to 33.1240° N latitude and 75.4555°E to 79.0420° E longitude.

The present investigations were carried out at Karsog in District Mandi, Himachal Pradesh. Located at an altitude of 1404 m amsl, Karsog is a small town at a distance of about 120 km from Mandi and 109 km from Shimla. It is situated between 31°15′ 42''N and 31°31́ 55′N latitude and between 77° 6́ 15′E to 77°23́ 25′E longitude. The area experiences four seasons, *viz*., winter (December - February), spring (March – May), summer (June –August) and autumn (September - November). Earthworms were collected by digging and hand sorting method. Earthworms were sampled following the standard technique as described by Anderson and Ingram (1993) [3]. A plot of 10 m × 10 m was randomly selected for earthworms and soil sampling. Sampling was done bimonthly for two years (May 2013 – May 2015).

All the earthworms were dropped directly into 5-10% formalin. After 5-6 hours of fixation these were preserved in 70% ethanol. Directly fixed worms get uniformly contracted and provide useful characteristics of external region. The preserved earthworms were sealed in vials before being transported to the laboratory and later identified in the laboratory, counted and weighed. Each lot of preserved earthworms was accompanied by a label indicating collection locality and date of collection.

Soil samples of depth 0-30 cm were collected; plant residue gravel and other foreign matter were discarded. The soil sample was air dried on a clean sheet of paper and kept in a polythene bags for further soil physical and chemical analysis. Soil temperature of the habitat was recorded by using soil thermometer, soil moisture by using gravimetric method, soil pH by digital pH meter and organic carbon by wet digestion method as described by Walkley and Black (1934) [73]. Available nitrogen was analyzed by Micro-Kjeldahl method (Bremner, 1996). Available phosphorus was analyzed by Oelson's and Bray's method. Available potassium was analyzed by using flame photometer (Stanford and English, 1949) [68].

Results

The earthworm survey conducted in district Mandi revealed that the occurrence of seventeen species of earthworms belonging to four families namely *Moniligastridae*, Lumbricidae, Octochaetidae and Megascolecidae. Earthwom were collected from different habitat such as forest area, grassland, land near shallow water, road side, vegetative garden, cultivation land and orchard. The different species of earthworms are given in table 1.

Table 1: List of Earthworm Species, Families and Ecological Categories

S. No.	Species	Below 1500	1500-2500	2500-3500		
Moniligastridae						
1	*Drawida japonica* (Michaelsen, 1892)	+	+	+	Exotic	Endogeic
2	*Drawida nepalensis* Michaelsen, 1907 [51]	+	+	-	Native	Endogeic
Lumbricidae						
3	*Bimastos parvus* Eisen, 1874	-	+	+	Exotic	Epigeic
4	Aporrectodea *caliginosa caliginosa* (Savigny 1826)	-	+	+	Exotic	Endogeic
5	Aporrectodea *caliginosa trapezoids* (Duges, 1828)	-	+	+	Exotic	Endogeic
6	Aporrectodea rosea *rosea* (Savigny 1826)	-	+	+	Exotic	Endogeic
7	*Dendrodrilus rubidus* (Savigny 1826)	-	+	+	Exotic	Endogeic
8	*Eisenia fetida** (Savigny 1826)	+	+	+	Exotic	Epigeic
9	*Octolasion tyrtaeum* (Savigny 1826)	-	+	+	Exotic	Endogeic
Acanthodrilidae						
10	*Argilophilus raigarhensis***	-	-	+	Native	Endogeic
Octochaetidae						
11	*Lennogaster pusillus* (Stephenson, 1920)	+	+	-	Native	Endogeic
12	*Octochaetona Beatrix* (Beddard, 1902)	+	+	-	Native	Endogeic
Megascolicidae						
13	*Amynthas corticis* (Kinberg, 1867)	+	+	-	Exotic	Epi-endogeic
14	*Amynthas morrisi** (Beddard, 1892)	+	+	-	Exotic	Epi-endogeic
15	Metaphire houlleti (Perrier, 1872)	+	+	-	Exotic	Epi–endogeic
16	*Perionyx barotensis* Julka and Paliwal, 1993	-	+	+	Native	Epigeic
17	*Perionyx excavatus* Perrier, 1872	+	+	+	Native	Epigeic

*First record from Mandi

** New species

Diagnostic account and distribution of earthworm species

Moniligastridae

1. *Drawida japonica* (Michaelsen, 1892)

Material Examined - 4ex., Pangana alt 1482 m; 6ex., Dhawas alt 1540 m; 2ex., Kamrunag alt 2790 m; 3ex., 4ex., Jagot alt 1450 m; 5ex., Bakhrot alt 1929 m; 7ex., Dhamoon alt 2420 m; 3ex., Kayrgi alt 1450 m;

General Habitat - Cultivation land, Vegetative Garden,

Orchard, Grassland, Mixed forest

2. **D*rawida nepalensis* Michaelsen, 1907** [51]
Material Examined Locality – 3ex., Dhawas alt 1540 m;4ex., Nagara alt 1865 m; 2ex., Jagot alt 1450 m; 3ex., Kutachi alt1785 m;
General Habitat - Cultivation land, Mixed Forest

Lumbricidae
3. Bimastos parvus
Material Examined –2ex., Chakra alt 1765 m;3ex., Surachi alt 1665m;6ex., Raigarh alt 2710 m; 5ex., Nahrinala alt 2650 m; 2ex., Shikaridhar alt 3145 m; 5ex.,Bhulah alt 2670m
General Habitat - Mixed Forest, Cultivation, Shallow water bank

4. Aporrectodea *caliginosa caliginosa*
Meterial Examined – 4ex., Bakhrot alt 1929m; 5ex., Kamrunag alt 2790m; 3ex., Restadhar alt 1920m;
General Habitat – Grassland, Deodar Forest, Ban Forest

5. Aporrectodea *caliginosa trapezoides* (Duges)
Material Examined - 5ex., Sayanj alt 2018m; 4ex., Kamrunag alt 2790 m; 7ex., Shankardehra alt1750 m; 6ex., Katanda alt 2570 m; 4ex., Pandar alt2550 m; 6ex., Dhamoon alt 2420 m; 4ex., Restadhar alt 1910 m; 5ex., Bakhrot alt1929 m;
General Habitat - Grassland, Mixed forest, Steam bank

6. *Aporrectodea rosea* rosea (Savigny)
Material Examined-6ex., Restadhar 1910 m; 3ex., Seribanglo 2087m; 4ex., Shikaridhar 3145m;
General Habitat - Orchard, Mixed Forest

7. *Dendrodrilus rubidus* (savigny)
Material Examined-4ex., Nagara alt 1865m; 3ex., Katanda alt 2578m; 5ex., Pandar alt 2550m;
General habitat - Cultivation land, Mixed Forest

8. Eisenia fetida
Material Examined-4ex., Pangana alt 1482m; 7ex.,Churag alt 1895m; 5ex., Seribanglo alt 2080m; 4ex., Monala Narash and Monala alt 2110m; 5ex., Kamru nag alt 2790m; 11 ex., Chatri alt 1840m; 8ex., Janjahli alt 2100m; 7ex., 5ex., Nahri nala alt 2600m; 5ex., Kandi alt 2100m; 9ex., Raigarh alt 2760 m; 4ex., Nagara alt 1865 m; 6ex.,Kayragi alt 1450 m;

General Habitat-Cultivation land, Orchard, Forest, Veg. Gardan

9. *Octolasion tyrtaeum* (Savigny)
Material Examined-5ex., Pangana alt 1482m; 3ex., Churag alt 1840 m; 2ex., Monalanarash and Monala alt 2110m; 4ex., Kamrunag alt 2790m; 4ex., Pander alt 2550m; 5ex., Katanda alt 2200m; 6ex., Magroo alt 2880 m; 3ex., Dhamoon alt 2420 m; 5ex., Chowki alt 1848m;

General habitat-Orchard, Grassland, Mixed Forest, Road side area

Octochaetidae
10. *Lennogaster pusillus* (Stephenson)
Material Examined-4ex., Dhawas 1540m; 5ex. Jagot 1450m;

General Habitat - Cultivation land

11. *Octochaetona beatrix*
Material Examined-6ex., Jagot alt 1450 m;
General Habitat-Cultivation land

Megascolecidae
12. Amynthas corticis
Material Examined-5ex., Karsog alt 1450 m; 4ex., Jarli alt 1450 m; 3ex., kutachi alt 1785 m
General Habitat-Orchard, Cultivation land

13. *Amynthas morrisi* (Beddard)
Material Examined-5ex., Jarli alt 1450m; 1ex., Nagara alt 1865m;

General Habitat-Orchard, Cultivation land

14. Metaphire houlleti
Material Examined-5ex., Shankerdehra alt 1750 m; 4ex., Jarli alt 1450 m; 4ex., Jagot alt 1450 m;
General Habitat-Forest, Orchard, Cultivation

15. *Perionyx excavatus* (Perrier)
Material Examined-4ex., Kamrunag alt 2790m; 3ex., Seribanglo alt 2080 m; 4ex., Kandi alt 1880m; 3ex., Raigarh alt 2760m; 4ex., Katanda alt 2200m; 6ex., Dhamoon alt 2420m; 4ex., Chatri alt 1840m; 5ex., Shankerdehra alt 1750m; 7ex., Kayargi alt 1450m

General Habitat-Cultivation land, Veg. Gardan, Orchard, Grassland, Mixed forest

16. Perionyx barotensis
Material Examined – 4ex., Katanda alt 2200m; 2ex., Surachi alt 1665m; 4ex., Kamrunag alt 2790m; 3ex., Janjahli alt 2034m; 2ex., Jakhrinala alt 2680m;
General Habitate – Forest, Grassland

Acanthodrilidae
17. *Argilophilus sp.*
Meterial Examined-3ex., Raigarh alt 2710m; 5ex., Shikaridhar alt 3145m; 2ex., Jhakrinala alt 2680m; 4ex., Nahrinala alt 2650m.

General Habitat-Fir and Spruce Forest

Discussion
The earthworm diversity in present studies comprised of exotic and native peregrine species. Habitat fragmentation was primarily responsible for establishment and predominance of exotic earthworms at places occupied by native species (Kalisz and Wood, 1995). Reynolds (1995) [59] and Julka (2014) attributed global spread of exotic species to rise in various anthropogenic activities. Blanchart and Julka (1997) [10] opined that changes in land use pattern directly affected species composition of earthworms. Studies showed that, native earthworms were threatened due to rapid and extensive destruction of their natural habitats (Julka *et al.*, 2007) [33]. At the same time, intense disturbances in primary forests caused loss of native and proliferation of exotic species (Lavelle *et al.*, 1987; Barros *et al.*, 2003; Geissen *et al.*, 2009) [48, 5, 27]. Addison (2009) [1] indicated that climate changes due to global warming were responsible for the establishment of exotic earthworms. Range expansion of some exotic species was linked to changing climatic

conditions (Melody and Schmidt, 2012; Kumari *et al.*, 2017; Ahmed and Julka, 2017) [50, 2, 46, 47].

Functional categories of earthworms are modified by changes in land cover and edaphic parameters. In present studies show that both natural and impacted land use types were dominated by endogeic earthworms. Bhadauria *et al*. (2000) [6] also recorded similar results for Central Himalayan land use systems. Endogeic earthworms were found to be most resistant to disturbance in impacted habitats (Jouqet, *et al*., 2010) [31]. Endogeics species *Aporrectodea rosearosea* occurs in all land use types; *Drawida japonica* in all land use types except in mixed forest; *Octochaetona beatrix*, *Drawida nepalensis* and *Lennogaster pusillus* only in cropland; Aporrectodea *caliginosa trapezoides* restricted to grassland. High population of endogeic earthworms in croplands and vegetable could be due to increased food resource due to incorporation and inversion of organic materials in soil during ploughing and tilling (Chan, 2001; Curry, 2004; Ernst and Emmerling, 2009) [16, 19, 23]. Epi-endogeic earthworms, consuming leaf litter and top mineral soil, were found in all land use types except in grasslands. Shartell *et al*. (2015) [64] opined that epi-endogeic worms had strong association with human impacted habitats and ability to coexist with other functional groups.

Anecic functional group of earthworms was not found in any of the land use types under the present study that were either degraded or highly disturbed. According to Lee (1985) [49] and Curry (2004) [19], population of anecic worms tended to be low in croplands as tillage damaged their vertical burrows. Transformation of forests into agroecosystems led to elimination of anecic species and predominance of endogeic worms (Blanchart and Julka, 1997; Zou *et al*., 2006; Gonzalez *et al*., 2008) [10, 29]. Studies show that anecics worms were strongly affected by disturbance as they required stable environment (Norgrove *et al*. 2009) [56]. No earthworms of epigeic functional group were encountered in any of the five land use types of this study. Curry and Good (1992) [18] attributed decline in number of epigeic earthworms due to the disappearance of surface litter after deforestation and degradation of forests.

References

1. Addison JA. Distribution and impacts of invasive earthworms in Canadian forest ecosystems. Biological Invasions. 2008;11(1):59-79.
2. Ahmed S, Julka JM. First record of exotic earthworm, *Amynthas hupeiensis* (Michaelsen, 1895) (Oligochaeta: Megascolecidae), From India. Megadrilogica. 2017;22(7):151-154.
3. Anderson JM, Ingram JSI. Tropical soil biology and fertility: A handbook of methods. Wallingford: CAB International, 1993.
4. Ansari AA, Ismail SA. Earthworm and vermiculture technology. In: Management of organic Waste,
5. Barros E, Girmaldi M, Sarrazin M, Chauvel A, Mitja D, Desjardins T, Lavelle P. Soil physical degradation and changes in macrofaunal communities in Central Amazon. Applied Soil Ecology 2003;26(2):157-168.
6. Bhadauria T, Ramakrishnan PS, Srivastava KN. Diversity and distribution of endemic and exotic earthworms in natural and regenerating ecosystems in the central Himalayas, India. Soil Biology and Biochemistry 2000;32(14):2045-2054.
7. Bisht R, Pandey H, Bharti D, Kaushal BR. Population dynamics of earthworms (Oligochaeta) in cultivated soil of central Himalayan Tarai region. Tropical Ecology. 2003;44(2):227-232.
8. Blakemore RJ, Chang C-Han, Chen JH, Chuang SC, Ito MT, James S, *et al*. Biodiversity of earthworms in Taiwan: a species checklist with the confirmation and new records of the exotic lumbricids Eisenia fetida and Eiseniellatetraedra. Taiwania. 2006;51(3):226-36.
9. Blakemore RJ. Cosmopolitan earthworms an eco-taxonomic guide to the peregrine species of the world. 1st CD edition, VermEcology, Australia, 2002, 419.
10. Blanchart E, Julka JM. Influence of forest distribution on earthworms (*Oligochaeta*) community in Western Ghats (South India). Soil Biology and Biochemistry. 1997;29(3):303-306.
11. Bolland LP, Ellis EA, Gholz HL. Land use dynamics and landscape history in La Montana, Campeche, Mexico. Landscape and Urban Planning 2007;82(4):198-207.
12. Bourne AG. On certain earthworms from the western Himalayas and Dehra Dun. Journal of the Asiatic Society of Bengal. 1889;58:110-117.
13. Bray RH, Kurtz LT. Determination of total, organic and available forms of phosphate in soils. Soil Science. 1945;59(1):39-45.
14. Cernosvitov L. On a collection of Indian earthworms of the family Lumbricidae. Rec. Indian Mus. 1937;39(2):105-111.
15. Chan KY, Barchia I. Soil compaction controls the abundance, biomass and distribution of earthworms in a single dairy farm in south-eastern Australia. Soil and Tillage Research. 2007;94(1):75-82.
16. Chan KY. An overview of some tillage impacts on earthworm population abundance and diversity implications for functioning in soils. Soil and Tillage Research. 2001;57(4):179-191.
17. Chaudhuri PS, Nath S, Paliwal R. Earthworm population of rubber plantation (*Hevea brasiliensis*) in Tripura, India. Tropical Ecology. 2008;49(2):225-234.
18. Curry JP, Good JA. Soil fauna degradation and restoration. Advances in Soil Science. 1992;17:171-215.
19. Curry JP. Factors affecting the abundance of earthworms in soils. In: Edwards,C. (Ed.), Earthworm Ecology. 2nd edition. CRC Press, Boca Raton. 2004 Mar 29;9:113.
20. Decaens T. Macroecological patterns in soil communities. Global Ecology and Biogeography 2010;19(3):287-302.
21. Deforestation driving loss of endemic biodiversity in Indian Himalaya. Biodiversity conservation. 2007;16:153-163.
22. Eisenhauer N, Bonn A, Guerra C. Recognizing the quiet extinction of invertebrates. Nature Communications 2019;10(1):50.
23. Ernst G, Emmerling C. Impact of five different tillage systems on soil organic carbon content and the density, biomass, and community composition of earthworms after a ten year period. European Journal of Soil Biology. 2009;45(3):247-251.
24. Fedarb SM. On some earthworms from British India. Journal of Zoology. 1898;66(3):445-450.
25. Gates GE. On the earthworms of Saharanpur, Dehra Dun and some Himalayan Hillstations. Proceedings of the National Academy of Sciences of India. 1951;21:16-22.
26. Gates GE. The earthworms of Allahabad. Proceedings of the National Academy of Sciences, India 1945;15:44-56.

27. Geissen V, Pena-Pena K, Huerta E. Effects of different land use on soil chemical properties, decomposition rate and earthworm communities in tropical Mexico. Pedobiologia. 2009;53(1):75-86.
28. Giri C, Defourny P, Shrestha S. Land cover characterization and mapping of continental Southeast Asia using multi-resolution satellite sensor data. International Journal of Remote Sensing. 2003;24(21):4181-4196.
29. Gonzalez G, Huang CY, Chuang SC. Earthworms and post agricultural succession. In: Myster RW, editor. Post-Agricultural Succession in the Neotropics. New York, Springer, 2008, 115-140.
30. Halder KR, Ghosh GC. Annelida. In: Fauna of Nanda Devi Biosphere Reserve: Fauna of Conservation Areas 9. Zoological Survey of India, Calcutta, 1997, 31-34.
31. Jouquet P, Plumere T, Thu TD, Rumpel C, Duc TT, Orange D. The rehabilitation of tropical soils using compost and vermicompost is affected by the presence of endogeic earthworms. Applied Soil Ecology 2010;46(1):125-133.
32. Julka JM, Paliwal R. First records of *Microscolex phosphoreus* and *Malabaria levis* (Oligochaeta: Acanthodrilidae) from India. Megadrilogica 1995;6(6):60-62.
33. Julka JM, Paliwal R, Kathireswari P. Biodiversity of Indian Earthworms- An Overview. Proceedings of the International workshop on Vermitechnology in Human Welfare, Departments of Zoology and Biochemistry, Kongu Nadu Arts and Science College, Coimbatore, Tamil Nadu, India 4th- 7th, June 2007, Eds. C. A. Edwards, R. Jeyaraaj and Indira A. Jayraaj, 2007, 18-37.
34. Julka JM, Paliwal R. Oligochaeta. In: Wetland Ecosystem Series 2: Fauna of Renuka Wetland. Zoological Survey of India, Calcuta, 2000, 21-25.
35. Julka JM, Paliwal R. A new species of Perionyx Perrier (Megascolecidae, Oligochaeta) from Northwest Himalaya, India. Journal of the Bombay Natural History Society. 1993;90(3):461-462.
36. Julka JM, Paliwal R. Distribution of earthworms in different agroclimatic regions of India. In: Ramakrishnan PS, Saxena KG, Swift MJ, Rao KS, Maikhuri RK. (Eds.), Soil Biodiversity: Ecological processes and Landscape Management. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 2005, 3-13.
37. Julka JM, Paliwal R. On a new species of *Plutellus* Perrier (Acanthodrilidae: Oligochaeta) from northwest Himalaya, India. Research Bulletin of the Panjab University. 1994;44(1-4):217-220.
38. Julka JM. Anthropochorous earthworms of Lahaul Valley (Himachal Pradesh) with notes on their ecology. UAS tech series-India, University of Agricultural Sciences, Bangalore, 1981, 6976.
39. Julka JM. Diversity and distribution of exotic earthworms (Annelida, Oligochaeta) in India-A review. In: Chaudhuri PS, Singh SM, editors. Biology and Ecology of Tropical earthworms. New Delhi: Discovery Publishing House Pvt. Ltd. 2014, 73-83.
40. Julka JM. Diversity and distribution of exotic earthworms (Annelida, Oligochaeta) in India-A review. In: Chaudhuri PS, Singh SM, editors. Biology and Ecology of Tropical earthworms. New Delhi: Discovery Publishing House Pvt. Ltd, 2014, 73-83.
41. Julka JM. First record of Lumbricus castaneus Savigny from India (Lumbricidae: Oligochaeta). Journal of Bombay Natural History Society. 1979;76:191-192.
42. Julka JM. Oligochaeta. In Himalayan Ecosystem Series: Fauna of Western Himalaya, Part 1. Utter Pradesh. Zoological survey of India Calcutta, 1995, 17-22.
43. Julka JM. Oligochaeta. In Himalayan Ecosystem Series: Fauna of Western Himalaya, Part 1. Utter Pradesh. Zoological survey of India Calcutta, 1995, 17-22.
44. Julka JM. The fauna of India and the adjacent countries. Megadrile: Oligochaeta (Earth worms). Haplotaxida: Lumbricina: Megascolecoidea: Octochaetidae. Zoological Survey of India, Calcutta. 1988;14:400.
45. Karmegam N, Daniel T. Effect of physico-chemical parameters on earthworm abundance: A quantitative approach. Journal of Applied Sciences Research. 2007;3(11):1369-1376.
46. Kumari S, Julka JM, Reynolds JW. First record of exotic earthworm *Dichogaster saliens* (Beddard) (Oligochaeta: Octochaetidae) from the Western Himalayas, India. Megadrilogica. 2017;22(1):24-27.
47. Kumari S, Julka JM, Reynolds JW. First record of exotic earthworm *Dichogaster saliens* (Beddard) (Oligochaeta: Octochaetidae) from the Western Himalayas, India. Megadrilogica 2017;22(1):24-27.
48. Lavelle P, Barois I, Cruz I, Fragoso C, Hernandez A, Pineda A, Rangel P. Adaptive strategies of *Pontoscolex corethrurus* (Glossoscolecidae, Oligochaeta), a peregrine geophageous earthworm of the humid tropics. Biology and Fertility of Soils. 1987;5:188-194.
49. Lee KE. Earthworms their Ecology and Relationships with Soils and Land Use. Academic press, 1985, 389.
50. Melody C, Schmidt O. Northward range extension of an endemic soil decomposer with a distinct trophic position. Biology Letters. 2012;8(6):956-959.
51. Michaelsen W. Neue Oligochäten von Vorder-Indien, Ceylon, Birma und den Andaman-Inseln. Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten, Hamburg. 1907b;24(2):143-188.
52. Michaelsen W. The Oligochaeta of India, Nepal, Ceylon, Burma and the Andaman Islands. Mem. Indian Mus. 1909;1:103-253.
53. Mittermeier RA, Gil RP, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, *et al*. Hotspots evisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX, 2004, 392.
54. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J Biodiversity hotspots for conservation priorities. Nature. 2000;403(6772):853-858.
55. Negi SP. Forest cover in Indian Himalayan states an overview. Indian Journal of Forestry. 2009;32(1):1-5.
56. Norgrove L, Csuzdi C, Forzi F, Canet M, Gounes J. Shifts in soil faunal community structure in shaded cacao agroforests and consequences for ecosystem function in Central Africa. Tropical Ecology. 2009;50(1):71-78.
57. Pandit MK, Sodhi NS, Koh LP, Bhaskar A, Brook BW. Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. Biodiversity and Conservation. 2007 Jan;16(1):153-63.
58. Reynolds JW. Status of exotic earthworm systematics and biogeography in north America; in Hendrix PF, ed. Earthworm ecology and Biogeography in North America Boca Raton (FL) Lewis Publishers, 1995, 1-28.
59. Reynolds JW. Status of exotic earthworm systematics and biogeography in north America; in Hendrix PF, ed.

Earthworm ecology and Biogeography in North America Boca Raton (FL) Lewis Publishers, 1995, 1-28.
60. Sathianarayanan A, Khan AB. Diversity, distribution and abundance of earthworms in Pondicherry region. Tropical Ecology. 2006;47(1):139-144.
61. Saxena KG, Maikhuri RK, Rao KS, Ramakrishnan PS. Soil biodiversity, ecological processes and sustainable management of natural resources: Where do we stand? In: Ramakrishnan PS, Saxena KG, Swift MJ, Rao KS, Maikhuri RK, editors. Soil Biodiversity, Ecological Processes and Landscape Management. Delhi, India: Oxford and IBH Co. Pvt. Ltd, 2005, 285-297.
62. Shah S, Sharma DP. Land use change detection in Solan Forest Division, Himachal Pradesh, India. Forest Ecosystems. 2015;2(1):26.
63. Sharma BD, Kaul TK. Note on the distribution of four genera of earthworms in J & K State. Indian Journal of Animal Research. 1974;8(1):46.
64. Shartell LM, Corace RG, Storer AJ, Kashian DM. Broad and local-scale patterns of exotic earthworm functional groups in forests of National Wildlife Refuges of the Upper Midwest, USA. Biological Invasions. 2015;17(12):3591-3607.
65. Sinha B, Bhadauria T, Ramakrishnan PS, Saxena KG, Maikhuri RK. Impact of landscape modification on earthworm diversity and abundance in the Hariyali sacred landscape, Garhwal Himalaya. Pedobiologia. 2003;47(4):357-370.
66. Soota TD, Julka JM. Notes on earthworms of the Andaman and Nicobar Islands, India. In Proceedings of the Zoological Society. 1970;23:201-206.
67. Sotta JD, Halder KR. Some earthworms from Western Himalayas. Records of Zoological Survey of India. 1980;76(1-4):195-205.
68. Stanford S, English L. Use of flame photometer in rapid soil test of K and Ca. J Agron. 1949;41:446-447.
69. Stephenson J. On a collection of Oligochaeta belonging to the Indian Museum. Rec. Indian Mus. 1916;12(7):299-354.
70. Stephenson J. Some earthworms from Kashmir, Bomabay, and other parts of India. Rec. Indian Mus. 1922;24(4):427-443.
71. Stephenson J. Zoological results of the Abor Expedition, 1911-1912. Oligochaeta. Records of Indian Museum 1914;8:365-410.
72. Tripathi G, Bhardwaj P. Earthworm diversity and habitat preference in arid region of Rajasthan. Zoo's Print Journal 2004; 19(17):1515-1519.
73. Walkley A, Black IA. Determination of Organic carbon in Soil. Soil Science. 1934;37:29-31.
74. Wood JG. The distribution of Earthworms (Megascolecidae) in relation to soils, vegetation and altitude on the slope of Mt Kosciusko, Australian Journal of Animal Ecology. 1972;43:87-106.