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A Contribution to the Earthworm Survey Fauna of Doon Valley in Uttarakhand, India with Special Reference to a Search for Vermicomposting Species

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ABSTRACT

Based on a survey of earthworms in Doon valley of Western Himalayan region conducted in September 2009, the present report enlists 12 species belonging to 7 genera and 4 families. Information on earthworms' scientific name, family, origin, locality & voucher specimen number, date of collection, general habitat are given for each species discussed in the text. *Drawida nepalensis*, *Entyphoeus orientalis*, *Lampito mauritii* and *Perionyx sansibaricus* have been identified as potential species for vermicomposting with a preference for dung heap. The study provides contemporary information on earthworm biodiversity in the study area with particular reference to vermicomposting species.

Keywords: biodiversity, relative density, relative frequency, species diversity, vermicompost, western Himalaya

INTRODUCTION

Indian earthworm fauna is predominantly represented by native species, which constitutes about 89% of total earthworm diversity in the country (Julka and Paliwal 2005; Verma *et al*. 2010). Earthworm explorations in Western Himalaya dates back to 1889 when Bourne described the earthworm species of *Typhoeus masoni* (syn. *Eutyphoeus orientalis*) for the first-time from Dehradun (Uttarakhand). Subsequently, Fedarb (1898) discovered *Lennogaster parvus* from the same area. Michaelsen (1907, 1909) and Stephenson (1914, 1916, 1922) significantly added to the knowledge on earthworm diversity in Western Himalaya. Stephenson (1923) listed 28 species of earthworms from this region in the publication "*Fauna of British India"* (Volume on Oligachaeta). Information on diversity of earthworms of this region was further enriched by Cernosvitov (1931), Gates (1945, 1951), Soota (1970), Sharma and Kaul (1974), Soota and Halder (1980), Julka (1979, 1981, 1988, 1995), Halder and Ghosh (1997), Julka and Paliwal (2000) and Paliwal and Julka (2005). Thereafter, the taxonomical studies in this region have been more or less neglected. However, some reports are available on earthworm systematics of Western Ghats (Blakemore 2006), West Bengal (Chaudhuari *et al*. 2008), North-east (Bhadauria and Saxena 2010) and Gangetic plains (Verma *et al*. 2010) of India.

Large-scale developmental activities like rapid industrialization and urbanization has eventually caused degradation of forests (Kabzoglu 2008). Therefore, the native species are threatened because of extensive destruction of their natural habitats (Aryal *et al*. 2009). Conservation of earthworm biodiversity can only be achieved through protection of biological habitats that require a detailed periodical survey (Eisenhauer *et al*. 2008) and inventory of the existing bioresources (Zirbes *et al*. 2009). The present investigation is based on this rationale and updates existing knowledge about the earthworm diversity in the study area.

MATERIALS AND METHODS

Field work was carried out in September 2009. The methodology adopted for earthworm collection was based on Julka (1988). Collected worms were washed in fresh water and stored in test tubes in the field. Ethyl alcohol was gradually added to the test tube and then transferred to the dish containing a solution of 5% formalin for fixation and kept for a period 6-8 hrs, followed by their preservation in 70% ethyl alcohol or 5% formalin. All specimens were serially numbered. Earthworms were identified with the help of monographs and other available literature on the subject (Stephenson 1923; Gates 1972; Julka 1988) at the Vermiculture Research Station (VRS), D.S. College, Aligarh. Voucher specimens collected and examined in the present work are deposited in the Museum of VRS, for future reference and study.

Study site

Uttarakhand, a newly created State in India, is surrounded by Nepal in the East, China in the North, Himachal Pradesh in West and UP in South. The area from which data were derived is situated at 235 km North-East of Delhi, between 30° 19 N latitude and 78° 04 E longitude (**Fig. 1**). The areas and their surroundings visited include Dehradun, Mussoori and Rishikesh rural and forest pockets. Doon valley is surrounded by the Mussoori in the north and the Shiwalik hills in the south west, the rivers Ganga and Yamuna in the east and west respectively. The entire valley is drained by the river Song. Climate of the area is temperate and humid. Temperature ranges between 36 and 16.7°C during summer (March – June) and 23.4 to 5.2°C (November – February); mean annual rainfall is 15.23 cm (July – October). Forest types are diverse ranging from temperate to dry deciduous (**Table 1**).

Earthworm and soil sampling

Earthworms and soil samples for taxonomic studies were collected by digging and hand sorting method. Samples were collected from diverse ecological niches viz. dense forest; grass land (ungrazed); grass land (grazed); cultivated land (maize crop); dung heap; stream bank; under stones; and bank of river.

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Research Note

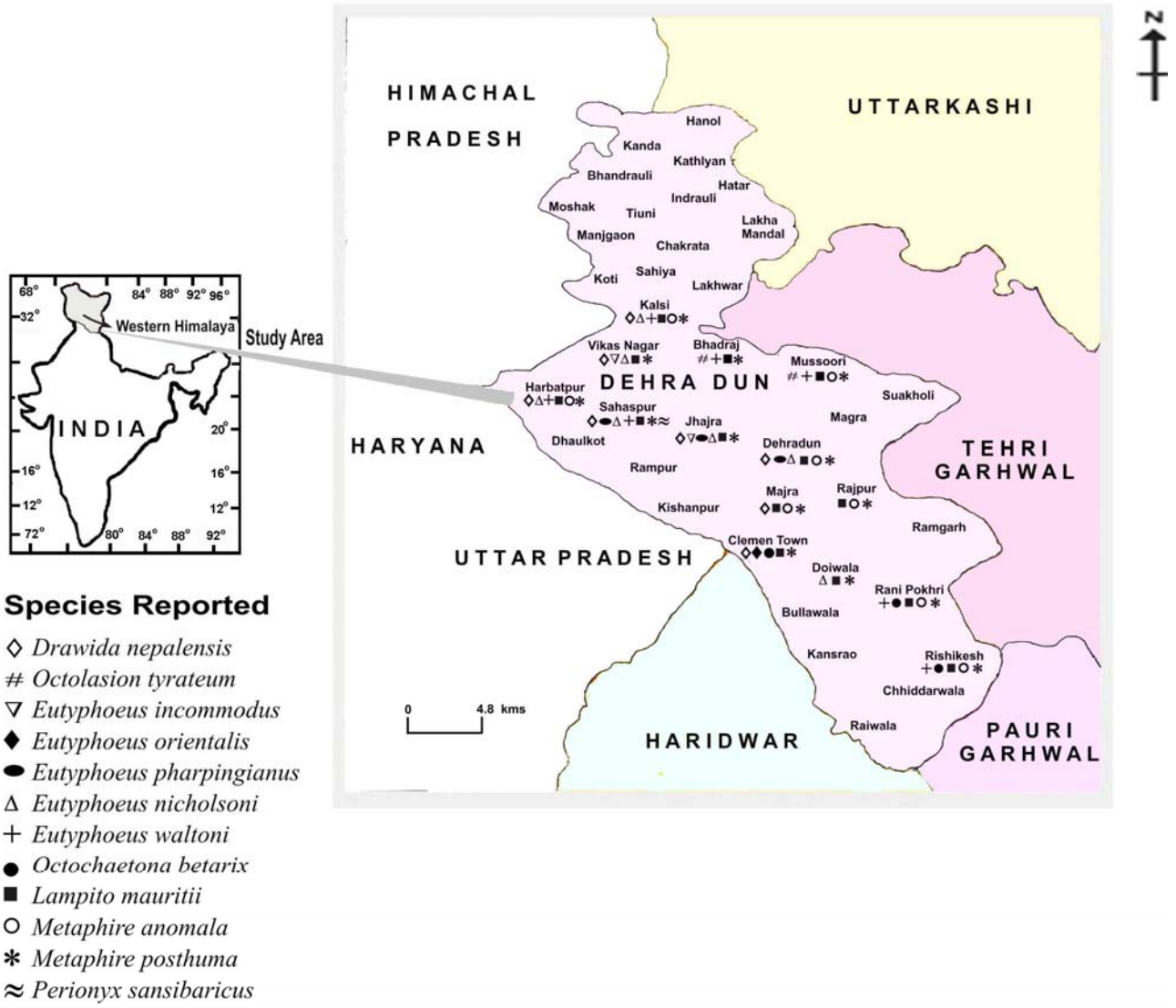

Fig. 1 Study area: Doon Valley, Uttarakhand, India.

Table 1 Survey record of earthworm diversity in the study area.

Date(s) of survey	Location covered	Altitude	Latitude	Longevity	Collection no.
04-09-09	Rishikesh	532 M	30.12° N	78.08° E	a/01 to a/03
04.09.09	Ranipokhri	485 M	30.18° N	78.12° E	b/01 to b/03
04.09.09	Doiwala	496 M	30.11° N	78.07° E	c/01 to c/03
05.09.09	Kalsi	309 M	30.46° N	77.77° E	d/01 to d/05
05.09.09	Vikasnagar	452 M	30.43° N	78.01° E	e/01 to e/05
05.09.09	Harbatpur	427 M	30.45° N	77.71° E	f/01 to f/05
05.09.09	Sahaspur	420 M	30.38° N	77.80° E	g/01 to g/03
05.09.09	Jhajra	410 M	30.35° N	77.71° E	h/01 to h/03
06.09.09	Mussoori	1.823 M	30.45° N	78.67° E	i/01 to i/03
06.09.09	Bhadraj	208 M	30.48° N	77.95° E	j/01 to j/03
07.09.09	Majra	218 M	30.69° N	77.86° E	k/01 to k/03
07.09.09	Clementown	393 M	30.27° N	78.07° E	l/01 to l/03
07.09.09	Rajpur	258 M	30.48° N	30.28° E	m/01 to m/03

Analysis of soil samples

Soil samples were analyzed for soil texture by international pipette method (Piper 1966); pH by a digital meter (Misra 1968) (**Table 2**).

Experimental design and statistical analyses

On each sampling site (dense forest, grassland, cultivated land, dung heap, stream bank and bank of river), earthworms were hand-sorted from three soil monoliths (50 × 50 × 20 cm) placed at the apices of a 10-m side triangle. Specimens were preserved in formalin, then identified and counted. Relative diversity and frequency were calculated following Cousins (1991).

RESULTS AND DISCUSSION

Systematic enumeration

The earthworm species collected and identified from the study area are arranged family-wise in alphabetical order. Each entry gives the information in sequence: earthworms´ scientific name, voucher specimen no, date of collection and general habitat. A brief introductory note on each family is also preceded before the text.

Table 2 Analyses of soil samples.

Collection sites	Soil texture	pH
Rishikesh	Balui	5.42
Ranipokhri	Balui domat	5.74
Doiwala	Stony balui	6.72
Kalsi	Balui domat	5.84
Vikasnagar	Balui	7.57
Harbatpur	Balui domat	5.42
Sahaspur	Clay	5.58
Jhajra	Balui	6.14
Mussoori	Stony	6.17
Bhadraj	Stony	5.85
Majra	Baluidomat	7.19
Clementown	Baluiblack	6.33
Rajpur	Stony balui blakish	6.80
Dehradun	Baluisoil	6.52

Moniligasteridae

A family of primitive earthworms in East and south Asia. A few species are hydrophilous and some are common in arable soils but most are confined to primary forests. Of the Indian genera *Desmogaster*, *Drawida* and *Moniligaster* are the largest genera in terms of number of species. Its natural distribution extends from the Indian peninsula to the Eastern Himalaya. Occurrence of *Drawida nepalensis* in the Western Himalaya is suspected to be due to recent introduction (Julka and Paliwal 2005).

1. Drawida nepalensis **Michaelsen**

Origin: Native
Locality and collection no.(s): Kalsi: d/02, d/03, d/04, d/05; Vikasnagar: e/01, e/02, e/03, e/04; Harbatpur: f/01; Shaspur: g/01, g/02, g/03; Jhajra: h/01, h/02, h/03; Majra; k/01, k/02; Clementown: I/01; Dehradun: n/01, n/04.
Date(s) of Collection: 05.09.09 to 08.09.09
General habitat: cultivated land (maize crop), sewage, river bank, grass land (ungrazed) and dung heap.

Lumbricidae

Lumbricids occurring in western Himalayas are well known peregrines which have possibly been transported to this region in soil around roots of exotic plants. They have successfully colonized certain areas of hills.

2. Octolasion tyrateum **Savigny**

Origin: Exotic
Locality and collection no(s): Mussoori: i/01; Bhardraj: j/02
Date of collection: 06.09.09
General habitat: cultivated land.

Octochaetidae

Endemic Octochaetids in this region belong to the genus *Eutyphoeus* are represented by fairly large sized geophagous worms of 5 species which are inhabitants of sandy loam soil. They form casts on soil surface in the form of coiled towers. *Octochaetona betarix*, a native worm occurs in agriculture land (paddy crop) and soil rich in organic matter.

3. Eutyphoeus incommodus **Beddard**

Origin: Native
Locality and collection no(s): Vikasnagar: e/02, e/03
Dates of collection: 05.09.09
General habitat: under stones embedded in stream water, grass land (ungrazed).

4. Eutyphoeus orientalis **Stephensen**

Origin: Native
Locality and collection no(s): Clementown: e/01
Date(s) of collection: 07.09.09
General habitat: dense forest (grazed), dung heap.

5. Eutyphoeus pharpingianus **Michaelsen**

Origin: Exotic
Locality and collection no(s): Shahaspur: g/02, g/03; Jhajra: h/01; Dehradun: n/02
Date(s) of collection: 05.09.09 to 08.09.09
General habitat: cultivated land (sugarcane), mixed forest.

6. Eutyphoeus nicholsoni **Beddard**

Origin: Native
Locality and collection no(s): Doiwala: c/01, c/03; Kalsi: d/02, d/03, d/04, d/05; Vikasnagar: e/01, e/02, e/04; Harbatpur: f/02, f/03; Shaspur: i/03; Jhajra: h/01, h/02; h/03; Dehradun: n/04, n/05.
Date(s) of collection: 4.09.09 to 09.09.09
General habitat: agriculture land (maize crop), garden (ungrazed), dense forest (grazed), river bank.

7. Octochaetona betarix **Beddard**

Origin: Native
Locality and collection no(s): Rishikesh: a/02; Ranipokhri: b/02, b/03; Clementown: e/01;
Date(s) of collection: 04.09.09 to 09.09.09
General habitat: dense forest, cultivated land, grassland (ungrazed), stones embedded under stream line.

8. Eutyphoeus waltoni **Michaelsen**

Origin: Native
Locality and collection no(s): Rishikesh: a/01, a/02, a/03; Ranipokhri: b/02; Kalsi: d/01, d/02; Harbatpur: f/02, f/03; Sahaspur: g/01, g/02; Mussoori : i/03
Date(s) of collection: 04.09.09 to 06.09.09
General habitat: under high mountains, stream bank above water line, leaf litter, grassland (ungrazed).

Megascolecidae

Its distributional range extends between warm-temperate Asia and Australia. Native species of *Lampito mauritii* have been recorded from almost all western Himalayan districts in Uttarakhand. *Metaphire anomala* is well known inhabitant of litter and *Metaphire posthuma* inhabits in gravelly soils near water line. Endemic Megascolecids in this region belong to the genus *Perionyx*. Species explosion seems to have occurred in the Eastern Himalaya, a region with considerable and regular rainfall and high organic matter in the soil.

9. Lampito mauritii **Kinberg**

Origin: Native
Locality and collection no(s): Rishikesh: a/01, a/02, a/03; Ranipokhri: b/01, b/02; Doiwala: c/01, c/02; Kalsi : d/01, d/02, d/03, d/04, d/05; Vikasnagar: e/01, e/02, e/03; Harbatpur: f/02, f/03; Sahaspur: g/01; Jhajra: h/02, h/03; Mussoori: i/01, i/02; Bhadraj: j/01, j/02, j/03; Majra: k/01, k/02; Clementown: l/01, l/03; Rajpur: m/01, m/02, m/03; Dehradun: n/01, n/02, n/03, n/04.
Date(s) of collection: 4.09.09 to 8.09.09.
General habitat: cultivated land (maize crop), sewage, garden (ungrazed), leaf litter, river bank, under stones embedded in streams, under high mountain, dense forest (graze), grass land (grazed), dung heap.

Table 3 Fauna of Western Himalayan region (Doon valley).

Fauna	Rishikesh	Ranipokhri	Doiwala	Kalsi	Vikas nagar	Harbat- pur	Sahaspur
Family: Moniligastridae							
Drawida nepalensis	-	-	-	+	+	+	+
Family: Lumbricidae							
Octolasion tyrateum	-	-	-	-	-	-	-
Family: Octochaetidae							
Eutyphoeus incommodus	-	-	-	-	+	-	-
Eutyphoeus orientalis	-	-	-	-	-	-	-
Eutyphoeus pharpingianus	-	-	-	-	-	-	+
Eutyphoeus nicholsoni	-	-	+	+	+	+	+
Eutyphoeus waltoni	+	+	-	+	-	+	+
Octochaetona betarix	+	+	-	-	-	-	-
Family: Megascolecidae							
Lampito mauritii	+	+	+	+	+	+	+
Metaphire anomala	+	+	-	+	-	+	-
Metaphire posthuma	+	+	+	+	+	+	+
Perionyx sansibaricus	-	-	-	-	-	-	+
	5	5	3	6	5	6	7
Fauna	**Jhajra**	**Mussoori**	**Bhadraj**	**Majra**	**Clemen- town**	**Rajpur**	**Dehradun**
Family: Moniligastridae							
Drawida nepalensis	+	-	-	+	+	-	+
Family: Lumbricidae							
Octolasion tyrateum	-	+	+	-	-	-	
Family: Octochaetidae							
Eutyphoeus incommodus	+	-	-	-	-	-	
Eutyphoeus orientalis	-	-	-	-	+	-	
Eutyphoeus pharpingianus	+	-	-	-	-	-	+
Eutyphoeus nicholsoni	+	-	-	-	-	-	+
Eutyphoeus waltoni	-	+	+	-	-	-	
Octochaetona betarix	-	-	-	-	+	-	
Family: Megascolecidae							
Lampito mauritii	+	+	+	+	+	+	+
Metaphire anomala	-	+	-	+	-	+	+
Metaphire posthuma	+	+	+	+	+	+	+
Perionyx sansibaricus	-	-	-	-	-	-	
	6	5	4	4	5	3	6

+ Present, - absent

10. Metaphire anomala Michaelsen

Origin: Native
Locality and collection no(s): Rishikesh: a/01, a/02, a/03; Ranipokhri: b/03; Kalsi: d/04; Harbatpur: f/02, f/03; Mussoori: i/02; Majra: k/01; Clementown: l/01; Rajpur : m/02, m/03; Dehradun n/04, n/05
Date(s) of collection: 04.09.09 to 09.09.09
General habitat: leaf litter, cultivated land, dense forest, river bank, under high mountains and grassland (grazed).

11. Metaphire posthuma Vaillant

Origin: Exotic
Locality and collection no(s): Ranipokhri: b/02; Doiwala: c/01, c/02, c/03; Kalsi: d/02, d/05; Vikasnagar: e/01, e/02, e/03, e/04; Harbatpur: f/01, f/03; Shaspur: g/01, g/02, g/03; Jhajra: h/02, h/03; Majra: k/01, k/03; Clementown: l/01, l/02, l/03; Rajpur: m/01, m/02, m/03; Dehradun: n/05, Mussoori: i/02, i/03, Bhadraj: j/02
Date(s) of collection: 4.09.09 to 9.09.09.
General habitat: sloped ground, riverbank, under stone embedded in streams, cultivated land (paddy crop), dense forest and grass land (ungrazed).

12. *Perionyx sansibaricus* Michaelsen

Origin: Native
Locality and collection no(s): Sahaspur: g/02
Date of collection: 05.09.09
General habitat: river bank, dung heap, dense forest.

The present study records 12 species of earthworms from Doon valley of Uttarakhand State in India, representing 7 genera and 4 families. Of these, *Megascolecidae* represents the most active earthworms and *Lampita mauritii* and *Metaphire posthuma* are predominant species with wide distribution in the study area at all sites (**Table 3**). The moderately active earthworms of the family Octochaetidae and Moniligastridae move over short distances.

Diversity of earthworms

High diversity of earthworms at moderate altitudes may be due to soils rich in organic matter, and subtropical and mild temperate climate (Somniyam and Suwanwaree 2009). However, Tondoh (2006) have reported low number of species at higher elevations is possibly due to extreme cold, and unfavorable soil conditions. The present observations agree with the species-altitudes relationship studies in other parts of the world (Mileu *et al*. 2008; Eisenhauer *et al*. 2009; Postma *et al*. 2010). Lee (1959) recorded an inverse relationship between number of species of Megascolecidae and altitude on mountains in North Island of New Zealand. Cernosvitov (1937) and Bouche (1972) have also opined that the number of Lumbricid species decrease with rise in altitude in Russia and France respectively.

Potential vermicomposting species

The study indicates that of the species recorded from the study area, 9 are native to Indian subcontinent and the remaining 3 are well known peregrine of extra Indian origin. *Drawida nepalensis*, *Eutyphoeus orientalis Lampito mauritii* and *Perionyx sansibaricus* have been identified as potential species for vermicomposting, with a preference for dung heap comprising very high organic matter (**Table 4**). Since these species thrive well in cattle dung and soils rich

Table 4 Relative density (RD %) and Relative frequency (RF %) of earthworms in different habitats in Western Himalaya, (Doon valley) India.

Habitat	Cultivated land		Grassland (ungrazed)		Grassland (grazed)		Mixed forest		Stream bank		Dung heap	
	RD	RF	RD	RF	RD	RF	RD	RF	RD	RF	RD	RF
Drawida nepalensis	4.4	80	5.2	20	6.6	40	6.6	40	0.9	20	5.0	80
Octolasion tyrateum	6.5	20	-	-	-	-	-	-	-	-	-	-
Eutyphoeus incommodus	-	-	6.5	20	-	-	-	-	-	-	-	-
E. orientalis	-	-	-	-	-	-	7.7	20	-	-	0.9	60
E. pharpingianus	6.5	10	-	-	-	-	0.9	20	-	-	-	-
E. nicholsoni	9.4	40	9.4	40	-	-	77.5	100	-	-	-	-
E. waltoni	9.4	60	6.5	40	-	-	-	-	0.9	20	-	-
Octochaetona betarix	41.4	60	9.4	60	6.8	60	-	-	0.9	10	-	-
Lampito mauriti	40.4	80	52.5	100	16.8	40	60.4	80	-	-	60.9	80
Metaplire anomala	-	-	-	-	33.6	20	70	20	-	-	-	-
M. posthuma	80.0	60	56.4	60	-	-	70.4	40	0.9	10	-	-
Perionyx sansibaricus	-	-	-	-	-	-	77.5	80	0.9	10	94.1	100

in organic matter, they could be best suited and used in vermicomposting because of their affinities for high organic matter.

Density of earthworms

The majority of native species of earthworms have been recorded from 1000 to 2000 m altitudes whereas exotic species are found between 300 and 4000 m. Species from other biogeographical regions occur primarily at elevations between 300 and 2000 m. Further, the peregrine exotic species in Western Himalaya are suspected to have been introduced to Doon hills, possibly as a result of their transportation in soil around roots of exotic plants and through other agencies (Julka and Paliwal 2005; Kouadio *et al*. 2008). Introduction of peregrines in soil around roots of plants or otherwise has also been recognized by Gates (1972) during his studies on the oligochaetes intercepted by U.S. Bureau of Plant Quarantine. Out of 50 exotic species so recorded by Gates, incidentally, 20 species were reported in Western Himalaya.

Species-habitat preference

Table 4 indicates the species habitat preference for each of the 12 species collected from the study area. This shows that three species viz. *Drawida nepalensis*, *Octochaetona betarix* and *Lampito mauritii* show preference for a wide range of ecosites. *D. nepalensis* is the most eurytopic (able to adapt to a wide range of environmental conditions) species, recorded in cultivated land, grassland (ungrazed and grazed), mixed forest, stream bank and dung heap but with higher frequencies in ungrazed grassland. Kouadio *et al*. (2008) also reported the distribution of this species in different habitats in West Africa. Among lesser eurytopics, *E. nicholsoni* was recorded in cultivated land, ungrazed grassland and mixed forest, while *E. waltoni* thrives best in cultivated and ungrazed grassland, stream bank and *Metaphire posthuma* in cultivated land, ungrazed grassland, mixed forest, stream bank, *D. nepalensis*, *E. orientalis*, *L. mauritii* and *P. sansibaricus* are indeed coprophilous (grow on excreta); they are encountered in other habitats as well, but with very low frequency except *D. nepaleansis* which has been recorded from wide range of habitats. Species with restricted habitat preference are *Octolasion tyrateum*, *E. incommodus*, *E. orientalis*, *E. pharpingianus*, and *Metaphire anomala*. These observations on species-habitat preference of earthworms in the present study agree with the concept of diversity-invasibility relationship designed by Eisenhauer *et al*. (2008).

CONCLUDING REMARKS

The study indicates that of the species recorded from the study area, 9 are native to Indian subcontinent and the remaining 3 are well known peregrine of extra Indian origin. *Drawida nepalensis*, *Eutyphoeus orientalis*, *Lampito mauritii* and *Perionyx sansibaricus* have been identified as potential species for vermicomposting, with a preference for dung heap comprising very high organic matter (**Table 4**). Since these species thrive well in cattle dung and soils rich in organic matter, they could be best suited and used in vermicomposting because of their affinities for high organic matter.

The studies represent a contribution to our present knowledge on the contemporary biodiversity of earthworm resources in the study area and contribute material for the preparation of earthworm inventory for the region. It is likely that through such investigations in unexplored areas, new species which are very specific in vermicomposting may be discovered.

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REFERENCES

Aryal A, Shrestha TK, Sen DS, Uprati B, Gautam N (2009) Conservation regime and local population ecology of Sarus crane (*Grus antigone*) in west-central region of Nepal. *Journal of Wetlands Ecology* **3**, 1-11

Bhadauria T, Saxena KG (2010) Role of earthworms in soil fertility maintenance through the production of biogenic structures. *Applied and Environmental Soil Science* Article ID 816073, 7 pp

Blakemore RJ (2006) Glossary of earthworm. *Records of Australian Museum* **52 (2)**, 187-222

Bouche MB (1972) *Lombriciens de France Ecologie et Systematique,* Institute National de la Recherché Agronomique, Paris, 671 pp

Bourne AG (1889) On certain earthworms from the Western Himalayas and Dehradun. *The Journal of Asiatic Society of Bengal* **58**, 110-117

Cernosvitov L (1931) Revision des lumbricus submontame Vejdovsky. *Zoologischer Anzeiger* **95**, 59-62

Cernosvitov L (1937) Zur Kenntins der oligochaeta fauna des Balkans. *Zoologischer Anzeiger* **95**, 312-27

Chaudhuari PS, Sabyasachi N, Paliwal R (2008) Earthworm population of rubber plantations (*Heva brasiliensis*) in Tripura, India. *Tropical Ecology* **49 (2)**, 225-234

Cousins SH (1991) Species diversity measurement choosing the right index. *Trends in Ecology and Evolution* **6**, 190-192

Eisenhauer N, Mileu A, Sabais AC, Scheu S (2008) Animal ecosystem engineers modulate the diversity-invasibility relationship. *PlosOne* **3 (10)**, 3489

Eisenhauer N, Mileu A, Nitschke N, Sabais AC, Scherbeo C, Scheu S (2009) Earthworm and below ground competition effects on plant productivity in a plant diversity gradient. *Oecologia* **161 (2)**, 291-301

Fedarb SM (1898) On some earthworms from British India. *Proceedings of Zoological Society of London*, pp 445-450

Gates GE (1945) Another species of *Pheretima* from India. *Science and Culture* **10**, 403-404

Gates GE (1951) On the earthworms of Saharanpur, Dehradun and some Himalayan hill stations. *Proceedings of the Natural Academy of Sciences India (Part I)* **21**, 16-22

Gates GE (1972) Burmese earthworms: An introduction to the systematics and biology of megadrile oligochaetes with special reference to Southeast Asia. *Transactions of American Philosophical Society* **62 (7)**, 1-326

Halder KR, Ghosh GC (1997) Annelida. In: Fauna of Nanda Devi Biosphere Reserve: Fauna of Conservation Areas. *Records of Zoological Survey of India*, pp 31-34

Julka JM, Paliwal R (2000) Oligochaeta, In: Fauna of Renuka Wetland: Wetland ecosystem series. *Records of Zoological Survey of India*, pp 21-25

Julka JM, Paliwal R (2005) Distribution of earthworms in different agro-climatic regions of India. In: Ramakrishnan PS, Saxena KG, Swift MJ, Rao KS, Maikhuri RK (Eds) *Soil Biodiversity, Ecological Processes and Landscape*, Oxford and ABH Publications Co. Pvt. Ltd., New Delhi, pp 3-13

Julka JM (1979) First record of *Lumbricus castaneus* (Savigny) from India (Lumbricidae: Oligochaeta). *Journal of the Bombay Natural History Society* **76 (1)**, 191-192

Julka JM (1981) Anthropachorous earthworms of Lahaul valley (Himachal Pradesh) with notes on their ecology. In: Veeresh GK (Ed) *Progress in Soil Biology and Ecology in India*, UAS Tech Ser 37, University of Agricultural Science, Banglore, pp 69-76

Julka JM (1988) The fauna of India and adjacent countries. Megadrile: Oligochaeta (earthworms). Haplotaxida: Lumbricina: Megascolecoidea: Octochaetdae. *Records of the Zoological Survey of India*, 406 pp

Julka JM (1995) Oligochaeta. In: Himalayan Ecosystem series: Fauna of Western Himalaya, Part 1: Uttar Pradesh. *Records of the Zoological Survey of India*, pp 17-22

Kabzoglu T (2008) Determination of environmental degradation due to urbanization and industrialization in Turkey. *Environmental Engineering Science* **25 (3)**, 429-438

Kouadio KN, Diomands D, Ouattara A, Kone YJ, Gourene G (2008) Taxonomic diversity and structure of benthic macroinvertebrates in Aby lagoon (Ivory coast, West Africa). *Pakistan Journal of Biological Sciences* **11 (18)**, 2224-2230

Lee KE (1959) The earthworm fauna of New Zealand. *Bulletin of New Zealand Scientific Industrial Research* **130**, 1-486

Michaelsen W (1907) New Oligichaten Von Vonder – Indian. Ceylon, Birma and den Anaman- Inseln. *Jahrubuch der Hamburgischen Wissenshaftlichen Anstalten* **24**, 143-188

Michaelsen W (1909) The Oligochaeta of India, Nepal, Ceylon, and the Andaman Islands. *Indian Museum* **1**, 103-253

Mileu A, Partsch S, Scherber C, Weisser WW, Scheu S (2008) Earthworms and legumes control litter decomposition in a plant diversity gradient. *Ecology* **89 (7)**, 1872-1882

Mirjana S, Milutinovic T, Spasenija K (2008) Earthworm (Lumbricidae) diversity in the central Balkans: An evaluation of their conservation status. *Journal of Soil Biology* **44 (1)**, 57-64

Misra R (1968) *Ecology Work Book*, Oxford and IBH Publishing Co., Calcutta, India

Paliwal R, Julka JM (2005) Checklist of earthworms of Western Himalaya, India. *Zoos Print Journal* **20 (9)**, 1972-1976

Piper CS (1966) *Soil and Plant Analysis*, Hans Publishers, Bombay, 368 pp

Postma MB, Goedi RG, Bloem, J, Faber JH, Brussaard L (2010) Soil biota community structure and abundance under agricultural intensification and extensification. *Ecology* **91 (2)**, 460-473

Sharma BD, Kaul TK (1974) Note on the distribution of four genera of earthworms in Jammu and Kashmir state. *Indian Journal of Animal Research* **8 (1)**, 46

Somniyam P, Suwanwaree P (2009) The diversity and distribution of terrestrial earthworms in Sakaerat environmental research station and adjacent areas, Nakhon Ratchasima, Thailand. *World Applied Sciences Journal* **6 (2)**, 221-226

Soota JD, Halder KR (1980) On some earthworms from Western Himalaya. *Records of the Zoological Survey of India* **64**, 173-184

Soota TD (1970) A taxo-ecological study of the earthworm fauna of Doon valley. *Records of the Zoological Survey of India* **64**, 173-184

Stephenson J (1914) On a collection of Oligochaeta, mainly from Northern India. *Records of the Indian Museum* **10**, 321-365

Stephenson J (1916) On a collection of Oligochaeta belonging to the Indian Museum. *Records of the Indian Museum* **12**, 299-354

Stephenson J (1922) On some earthworms from Kashmir, Bombay and other parts of India. *Records of the Indian Museum* **24**, 425-443

Stephenson J (1923) *Oligochaeta: The Fauna of British India Including Ceylon and Burma*, Taylor and Francis, London, 518 pp

Tondoh JE (2006) Seasonal changes in earthworm density and community structure in Central Cote d' Ivoire. *European Journal of Soil Biology* **42**, 334-340

Verma D, Bharti S, Yadav S (2010) Biodiversity of earthworm resources in gangetic plain of Uttar Pradesh, India. *Tropical Natural History* **10 (1)**, 53-60

Zirbes L, Collin C, Dufey J, Khanh TP, Duyet N, Francis F, Lebailly P, Hauburge E, Brostaux Y (2009) Relationship between earthworm diversity and soil characteristics at Thua Thien Hue (Central Vietnam). *Conservation Science* **2 (3)**, 382-398