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**Research Article**

# Earthworm Diversity and Distribution in Kathmandu, Bagmati Province, Central Nepal

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## Abstract

Earthworms are of ecological and economic significance and are directly related with human health through biogeochemical cycle. Such a valuable faunal group needs immediate intensified taxonomic treatment in Nepal for their sustainable use, efficient commercial production and biodiversity conservation. Systematic random sampling was used for site selection and hand sorting method was used for sample collection from the field. Collected specimen were photographed in field and preserved in ethanol for lab study with tagging. In total, study reported eight species belonging to two families Lumbricidae and Megascolecidae. External morphological features helped on identification and taxonomic key preparation. Among two sites 6 species were common and abundantly recorded from almost habitats whereas, 1/1 species were different in each site with uncommon reporting from harsh environment. Cultivated crop land with litter and compost was known to be more diverse in species richness than other habitats. Detail taxonomic study and distribution mapping is an essential for Earthworms in Nepal to complete the global database and national soil engineer documentation for organic and healthy environment.

**Keywords:** Distribution, diversity, earthworm, morphology, Nepal

## Introduction

Growing population and excessively high waste production has put pressure on researcher to find more significant and immediate decomposer for fast and effective management of waste mostly in city areas (Pant and Yami, 2008; Mazumdar, 2012; Dhimal, 2013). Furthermore, food quality and human health has come to the forefront rising organic farming and rooftop gardening concept, intensifying the further search of suitable decomposers (Brussaard, 2007; Adhikari, 2017; Blakemore, 2018). Earthworms are major decomposer with multiple significance on improving soil properties, repairing and running biogeochemical cycles (Darwin, 1881; Barrios, 2007). It acts as the bridge linking from waste to the best. Role and importance of earthworms has been explained since 1881 by Darwin exploring their activities (Brown, 2000; Mishra and Samal, 2021). Away from its exploration for role and importance, taxonomic consideration and distribution mapping is an immense need prior to any other examinations for their conservation (Phillips, 2019; Phillips, 2021). Expedition for the earthworm collection, identification and its classification has rarely been considered in Nepal, whereas, detail taxonomic and molecular databases are even available in

the case of European, many Asian countries and global scale (Orgiazzi, 2016; Phillips, 2019; Mishra and Samal, 2021; Marchan, 2022). Knowing exact earthworm species diversity in the community, provides better alternatives according to need and accessibility of organism in particular area for particular waste types (Mishra and Samal, 2021).

Earthworms, also known as creepy crawlies, *Gadyaula* (Nepali), *Danbi* (Newari) are most abundant worms residing on soil and feed upon dead and decaying organic matter are organic decomposers. They are also known as 'friend of farmers' and 'soil engineers', providing healthy habitat for the growth of plants and other soil organisms (Barrios, 2007; Shipitalo and Korucu, 2017; Bora, 2021). Its movement in search of food and moisture, waste feeding habit, digestive alimentary canal, casting mechanism and cleaning property are of ecological significance that keep balance on soil environment and make it suitable for further ecological interactions (Darwin, 1881; Barrios, 2007; Jaikishun, 2015). Earthworm belongs to Phylum Annelida for having truly segmented body with internal body cavity called coelom (Orgiazzi, 2016). Further it comprises species from class Clitellata and subclass Oligochaeta having nearly 11000 species under 800 genera and 38 families with about 7000 species of earthworms under 20 families (Orgiazzi, 2016; Mishra and Samal, 2021). Based on the habitat preference, earthworms were classified into three ecological groups as; Epigeic (litter inhabitants), Anecic (vertical soil inhabitants) and Endogeic (soil inhabitants) (Bouche, 1972; Jimenez and Decaens, 2000; Neilson, 2000; Orgiazzi, 2016; Shipitalo and Korucu, 2017). Their body size varies from few centimeters to meters long and are cosmopolitan in distribution except in cold dry deserts (Orgiazzi, 2016; Shipitalo and Korucu, 2017; Mishra and Samal, 2021).

Various study related to earthworm, vermicomposting, comparative ability of different earthworm species on organic waste conversion, suitability, efficiency and commercial production to market analyzing has been carried out in Kathmandu and other agricultural area (Pant and Yami, 2008; Devkota, 2014; Tripathi, 2016; Dhimal, 2013). However, diversity and distribution of earthworm species in Nepal or its any particular region has not been updated later than Michaelsen (1909) and Gates (1972) as associated area of India and Burmese fauna. He had collected and described 31 species from Himalayan region, with proper location of Nepal for 4 species from present Airport, Chitlang and Pharping areas and all of them were endemic. Later on, Pandey (2012) has worked on 12 earthworm species for understanding toxic metal accumulation and transfer through earthworm species to predators and other. Earthworms' diversity has declined with intensified agriculture using chemical inputs, that slightly improved with organic manuring (Blakemore, 2018). Such a significant group of species lack intense taxonomic study on their diversity and distribution in Nepal (https://www.ksabmagar.com.np/2019/08/earthworms-of-nepal-brief-information.html). Marchan, (2022) has also emphasized on need of taxonomic proper delimitation of each taxon under the earthworm group along with number of unsolved contradictions among and in between the taxa (Ansari and Saywack, 2011). Thus, present study aimed to identify the local earthworm species along the northern and southern parts of Kathmandu district based on morphological features and figure out their distribution in different habitat.

## Materials and Methods

Study was carried out in Machhegaun area of Chandragiri municipality ward-9 and ward-2 and ward-7 of Tokha municipality with area of 4.66, 4.41 and 0.65 sq. km respectively (CBS, 2018). Former lies in 27° 40' 15" N and 85° 15' 10" E, southern part of Kathmandu and later in 27° 45' 0" N, 85° 20' 0" E, at North. Altitude lies around 1300 to 2500 m above sea level. The vegetation type was nearly similar at both sites with forest dominated by subtropical and temperate species such as Pine (Salla), *Schima wallichi* (Chilaune), *Myrica esculenta* (Kaphal), *Castanopsis indica* (Katus), *Zizyphus mauritiana* (Bayar), and *Prunus cerasoides* (Painyu). Soil type sandy loam, Clay loam and silty loam with pH range between 5.5 to 6.5. Temperature ranges from 3°C in winter (Dec-Feb) to 31°C in summer (April to August) with rainfall starting from March to October with maximum rainfall in the month of July and August and average annual rainfall 1433.75 mm (CBS, 2020).

### *Sampling and Collection*

Systematic Random sampling was used to decide the area for earthworm collection. All the possible habitats were listed and located in study area during preliminary visit, then randomly sample were collected in the field using hand sorting method digging 20cm×20cm×20cm hole (Edwards and Lofty, 1997). Collected specimen were examined immediately in the field for its body color and color of clitellum before preserved in 80% ethanol for further study in laboratory (Ansari and Saywack, 2011; Brown, 2017). Photographs of specimens were taken in field fixing as possible clear back ground as well as in its natural habitat using Samsung M-31 micro-camera (**Photoplate 1**). For each study site, collections were made separately to document species distribution in different habitat with proper tagging. Further in lab, morphological features were noted and excluded the study of internal morphology and anatomy due to lab constrains. Based on morphological features, specimens were identified using different online databases and literatures (Gates, 1972; Joshi and Dabral, 2008; Csuzdi, 2018; Chang, 2016; Brown, 2017; Podolak, 2020). Obtained information were arranged in table using Microsoft excel, 2010 and morphology based taxonomic key was presented in hierarchical chart using Microsoft word, 2010.

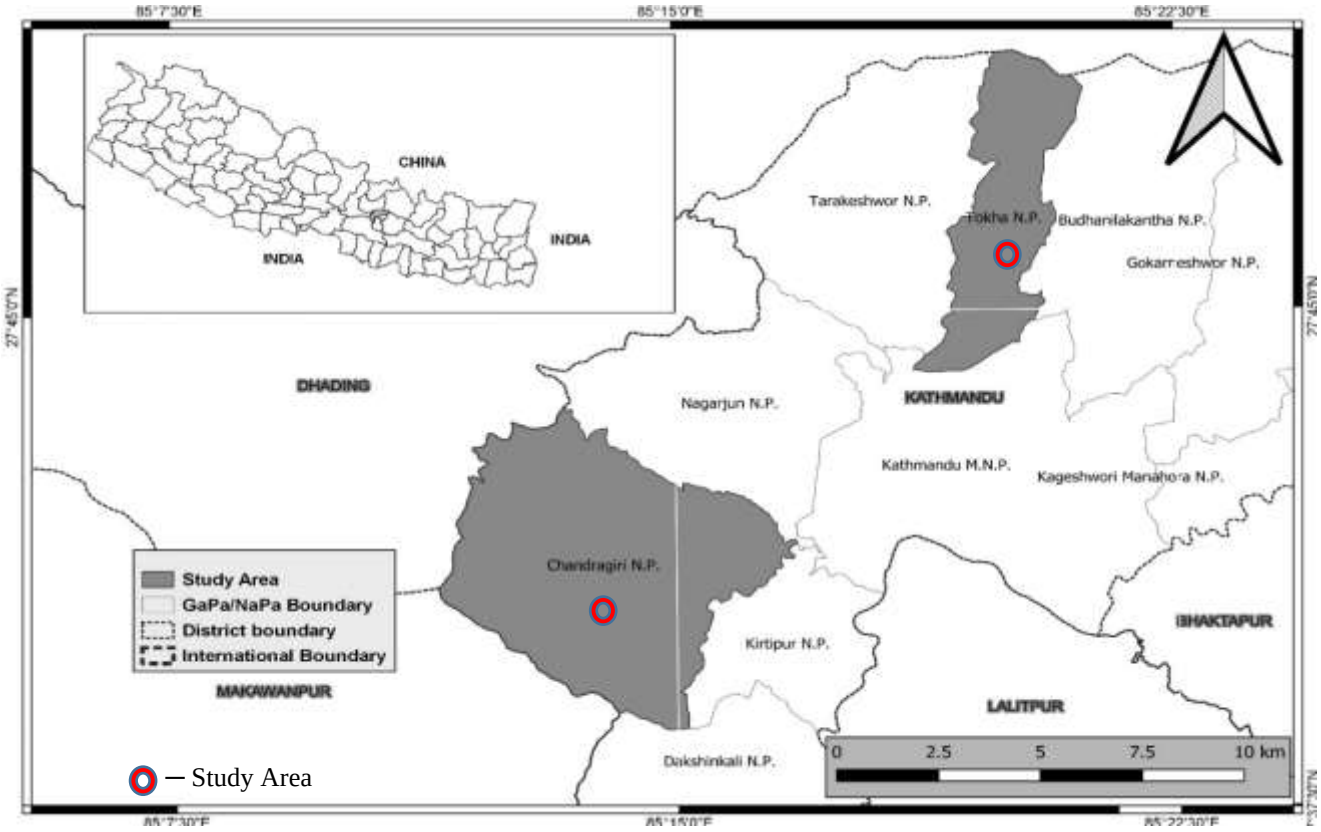


**Fig. 1**: Map of study area showing municipalities.


**Photoplate 1**

## Result and Discussion

Altogether Eight species of Earthworm were recorded belonging to two families; Lumbricidae including four genera *Aporrectodea*, *Dendrobaena*, *Eisenia* and *Lumbricus* and family Megascolecidae including two genera *Perichaeta* and *Perionyx* (Table 1). Species richness found to be low however, global database including more than 9000 surveys also had mentioned about zero to only 12 species in each survey (Phillips, 2021). It makes some relief that the study area is not in worst for earthworm diversity, which might due to its temperate location known to more diverse for earthworm than tropics and its climatic condition being more suitable for their existence (Bora, 2021; Phhillips, 2021). Species richness and their density depends on soil temperature, soil pH, annual rainfall and litter (Potvin and Lilleskov, 2017; Phillips, 2021). Species identification was troublesome due to their synonymous names (Table 1) and its morphological and anatomical complexities; which implies the immediate need of extensive taxonomic treatment on earthworm species, before they disappear and misidentified for the use on commercial purpose (Jaikishun, 2015). Additionally, in another side, some invasive species of earthworm has created a great issue in European countries, which makes alert for the buying of earthworm as bait from foreign countries and checking of vermicompost if they were heat treated or not before use (Chang, 2016). Such study on invasive earthworm around the Nepal has not been reported during literature review for this study.

All the morphological characteristics were of taxonomic significance and were noted for each species including their habitat preference from each site (Table 2). Morphological characters as mentioned in the study such as body length, color, clitellum length and color were of significant use for species identification and further studies since they are user friendly and useful for field study (Ansari and Saywack, 2011). Taxonomic key based on external morphology was prepared for the reported species (Fig. 2). Taxonomic features included here might be significant for use in identification (Jaikishun, 2015).

Occurrence of different earthworm species in different habitat shows their feeding preference and distribution in Kathmandu (Table 3). Seven species reported from each side among which 6 were common to both sites and one in each were different and unreported from other site. Gates (1972) and Julka (1993) had also mentioned about distribution of these species in Nepal in their work on Burmese and Indian earthworms respectively. Half of the species have been previously included by Pandey (2012) as frequently occurring species of earthworm in Nepal. Four European and four Asian species recorded with saddle and annular clitellum respectively (Chang, 2016). Unreported species from one another place implies their habitat preference or nutrient specificity or effect of environmental determinants (Kumar, 2021). Some epigeic species reported from crop field might be due to recent use of manure for new crop or might be ploughing of lawn with former crop residues underside and similar types of species were reported from cultivated and non-cultivated abandoned land by Singh (2020). Animal dung was dominated by *Eisenia* species and its large population actively working on cow dung. Similar study has shown abundant distribution of these species from all types of selected collection habitats (Singh, 2016). Species- habitat preference was also claimed by Tripathi and Bhardwaj (2004). Very few species reported from the rocky and gravel filled lawns which might be due to dryness, less litter, and rough surrounding. However, presence of unique earthworms even in such a harsh condition claims their wide range of adaptive feature (Brun and Danieli, 2020). Diverse species were obtained from crop field and kitchen garbage composting which might be due to regular moist condition along the habitat by irrigation or kitchen waste water deposition making the environment suitable for earthworms. It might also be due to native species being more frequent (Fragoso., 1999). *Eisenia* species were abundantly reported from most of the habitat such as litter deposited crop fields, animal dung, and abandoned land, which shows their wide range of distribution which might be due to their voracious feeding habit and efficient vermicomposting nature with other species and can be recommended for easy culture in temperate region such as Kathmandu (Devkota, 2014; Tripathi, 2016). *Eisenia fetida* was known to be used regularly for the organic waste treatment in city area of Nepal (Dhimal, 2013).

In general talk with local farmers, animal dung was known to be in regular use for different crops as fertilizer with later added chemical fertilizers in the area (Pant and Yami, 2008). Concept of organic farming has been introduced but not regulated properly and continuously due to easy availability of chemical fertilizer in comparison to organic manure for large scale application. Pest and diseases were another reason claimed by farmers as reason behind the use of synthetic products. Crop land using organic manure and synthetic fertilizer may have different status of earthworm diversity, activity and density, which can be the objective for further study in this field.

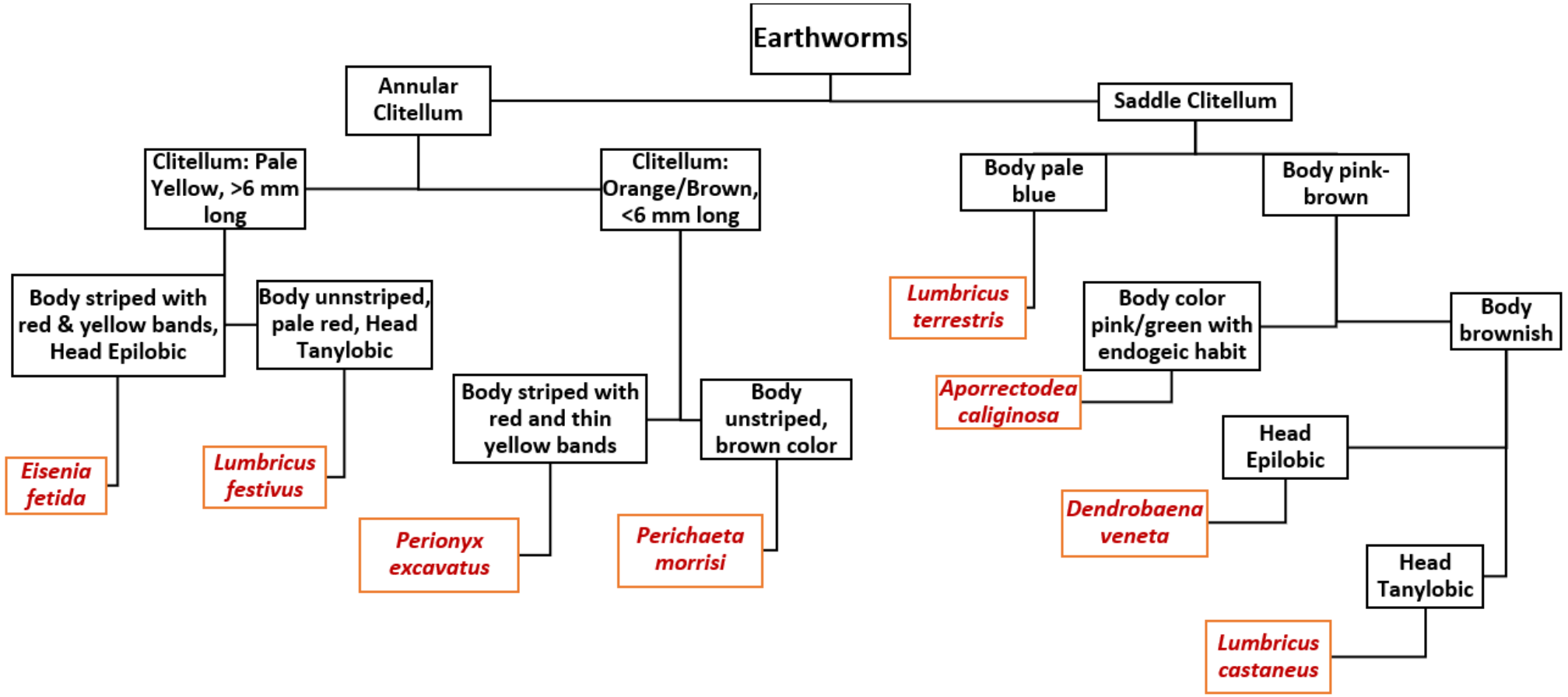


**Fig. 2:** Key to species based on external morphology
[Note: Black text presents characteristics and red text indicates. Species]

**Table 1**: Earthworm species and their synonyms with family

| Family | Name of Species | Synonyms* |
|---|---|---|
| Lumbricidae | *Aporrectodea caliginosa* | *Allolobophora caliginosa* Savigny, (1826); *Enterion caliginosum* Savigny, (1826); *Nicodrilus caliginosus* Savigny, (1826); *Lumbricus communis* subsp. *pellucidus* Eisen, (1871); *Allolobopora inflata* Michaelsen, (1899); *Nicodrilus caliginosus* var. *paratypicus* Bouche, (1972); *Aporrectodea caliginosus* subsp. *alternisetosus* Bouche (1972). |
| Lumbricidae | *Dendrobaena veneta* | *Allolobophora veneta* Pink, (1886); *Eisenia vene ta* Pink, (1886); *Eisenia zebra* Michaelsen, (1903) |
| Lumbricidae | *Eisenia fetida* | *Allolobophora foetida* Savigny, (1826); *Eisenia fasciata* Backlund, (1948); *Eisenia foetida* Savigny, (1826); *Enterion fetidum* Savigny, (1826); *Lumbricus annularis* Templeton, (1836) |
| Lumbricidae | *Lumbricus castaneus* | *Enterion castaneum* Savigny, (1826); *Lumbricus josephinae* Kinberg, (1866) |
| Lumbricidae | *Lumbricus festivus* | *Enterion festivum* Savigny, (1826) |
| Lumbricidae | *Lumbricus terrestris* | *Aporrectodea terrestris* Savigny, (1826); *Enterion terrestris* Savigny, (1826); *Lumbricus agricola* Hoffmeister, (1843) |
| Megascolecidae | *Perichaeta morrisi* | *Amynthas mauritiana* Beddard, (1892); *Amynthas morrisi* Beddard, (1892) |
| Megascolecidae | *Perionyx excavatus* | - |

*Synonyms were retrieved from gbif.org online database, Orgiazzi, 2016; and Shipitalo and Korucu, 2017.

**Table 2:** Morphological variation among Earthworm species including habitat preference

| Species Name | Ecological group | Body Color | BL (mm) | BW | Total Segment | Head shape | Clitellum color | Clitellum shape | CS | CL (mm) | CW (mm) | SS | TP | TP shape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aporrectodea caliginosa* Savigny | Endogeic | Pink/green | 60-100 | 2 | 70-100 | Epilobic | Pale Pink | Saddle | 23 | 5-7 | 3 | Close | 29-30 | Swelling |
| *Dendrobaena veneta* Rosa | Compost | Pinkish-reddish brown | 100-200 | 5 | 100-130 | Epilobic | Dark Brown | Saddle | 27 | 6-8 | 4 | Wide | 29-31 | Swelling |
| *Eisenia fetida* Savigny | Compost | Red with yellow band | 60-80 | 4 | 80-100 | Epilobic | Pale Yellow | Annular | 22 | 6-11 | 2 | Close | 27-31 | Thin band |
| *Lumbricus castaneus* Savigny | Epigeic | Dark brown | 80-130 | 4 | 100-120 | Tanylobic | Dark Red | Saddle | 27 | 4-6 | 3 | Close | 28-31 | Dark band |
| *Lumbricus festivus* Savigny | Epigeic | Pale red | 70-90 | 3 | 70-90 | Tanylobic | Pale Yellow | Annular | 30 | 6-7 | 3 | Close | 32-35 | Banded |
| *Lumbricus terrestris* Linn. | Epigeic | Pale blue | 70-130 | 4 | 90-120 | Epilobic | Orange | Saddle | 26 | 6-8 | 3 | Wide | 29-30 | Swelling |
| *Perichaeta morrisi* Bedd. | Endogeic | Brown | 80-100 | 3 | 80-90 | Epilobic | Brownish Grey | Annular | 23 | 5-6 | 3 | Close | 24-25 | Thin band |
| *Perionyx excavatus* Perr. | Compost | Red with yellow thin band | 70-100 | 3 | 80-100 | Epilobic | Orange | Annular | 23 | 4-5 | 2 | Close | 27-29 | Thin band |

(Note: BL- Body Length; BW- Body Width; CS- Clitellum Shape; CL- Clitellum Length; CW- Clitellum Width; SS- Setae Spacing; TP- Tubercula Pubertatis)

**Table 3:** Distribution of different earthworm species along the various habitat in both the Municipalities

| Name of species | Chandragiri Municipality | | | | | Tokha Municipality | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Animal dung** | **Kitchen garbage** | **Crop field** | **Abandoned land** | **Gravel and sandy lawn** | **Animal dung** | **Kitchen garbage** | **Crop field** | **Abandoned land** | **Gravel and sandy lawn** |
| ***Aporrectodea caliginosa*** | - | - | + | + | - | - | - | + | + | + |
| ***Dendrobaena veneta*** | + | + | - | - | - | + | + | + | | - |
| ***Eisenia fetida*** | + | + | + | + | - | + | + | + | - | - |
| ***Lumbricus castaneus*** | - | + | + | - | - | Unreported | | | | |
| ***Lumbricus festivus*** | - | - | + | + | + | - | - | + | - | + |
| ***Lumbricus terrestris*** | - | + | + | + | - | - | + | + | - | - |
| ***Perichaeta morrisi*** | - | - | - | - | + | - | - | - | + | + |
| ***Perionyx excavatus*** | Unreported | | | | | + | + | + | - | - |

(Note: "+" indicates presence of species; "-" indicates absence of species)

## Conclusion

Study revealed good number of earthworm species from small area and initiation of morphology based taxonomic key will be further helpful in species identification during similar work. Abundant distribution of most species along all types of habitats and unique distribution of some species in particular harsh environment showed diverse distribution and adaptive capability of earthworms.

## Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

## References


Adhikari J (2017) Organic Farming and its Prospects in Peri-urban Area of Pokhara, Nepal. *Journal of Forest and Livelihood* **15**(2): 13-31.

Ansari AA and Saywack P (2011) Identification and Classification of Earthworm Species in Guyana. *International Journal of Zoological Research* **7**(1): 93-99. DOI: /10.3923/ijzr.2011.93.99

Barrios E (2007) Soil Biota, Ecosystem Services and Land Productivity. *Ecological economics* **64**(2):269-285. DOI: 10.1016/j.ecolecon.2007.03.004

Blakemore RJ (2018) Critical Decline of Earthworms from Organic Origins under Intensive, Humic SOM-Depleting Agriculture. *Soil Syst.* **2** (33). DOI: 10.3390/soilsystems2020033

Bora S, Bisht SS and Reynolds WJ (2021) Global Diversity Earthworms in Various Countries and Continents: A Short Review. *Megadrilogica* **26** (9): 127-153.

Bouche MB (1972) Lombriciens de France: Ecologie et Systematique. Ann. Zool. **72**(2): 672.

Brown GG, Barois I and Lavelle P (2000) Regulation of Soil Organic Matter Dynamics and Microbial Activity in the Drilosphere and the Role of Interactions with Other Edaphic Functional Domains. *Eur.J.Soil Biol* **36:** 177-198. DOI: 10.1016/S1164-5563(00)01062-1

Brown KD (2017) Earthworm Recorder's Handbook. Earthworm Society of Britain.

Brun JJ and De Danieli S (2020) Earthworms: our partners for resilient, living soil in the mountains (Booklet). Interreg Alpine Space, European Union.

Brussaard L, De Ruiter PC and Brown GG (2007) Soil Biodiversity for Agricultural Sustainability. *Agriculture, Ecosystems and Environment* **121:** 233-244. DOI: 10.1016/j.agee.2006.12.013

CBS: Central bureau of statistics (2018) Municipal level district commodity details, Kathmandu. Ramshahpath, Thapathali Kathmandu, Nepal.

CBS: Central bureau of statistics (2020) Nepal statistical pocket book. Government of Nepal National Planning Commission. Ramshahpath, Thapathali Kathmandu, Nepal.

Chang CH, Snyder BA, and Szlavecz K (2016) Asian Pheretimoid Earthworms in North America North of Mexico: An illustrated key to the genera *Amynthas*, *Metaphire*, *Pithemera* and *Polypheretima* (Clitellata: Megascolecidae). *Zootaxa* **4179** (3): 495-529. DOI: 10.11646/zootaxa.4179.3.7

Csuzdi C, Szederjesi T, Sherlock E (2018) Annotated Checklist of Earthworm Species Described by András Zicsi (Clitellata: Megadrili). *Zootaxa* **4496** (1): 11-42. DOI: 10.11646/zootaxa.4496.1.4

Darwin C (1881) The formation of Vegetable Mould, through the Action of Worms, with Observations on their Habits. London:john murray, albemarle street. Translation right reserved. London, William Clowes and Sons limited, Stamford Street and Charging Cross. http://darwin-online.org.uk/content/frameset?pageseq=2&itemID=F1357&viewtype=side retrieved on 2nd May 2022

Devkota D, Dhakal SC, Dhakal DD, Dhakal D and Ojha RB (2014) Economic of Production and Marketing of Vermicompost in Chitwan, Nepal. *International Journal of Agricultural and Soil Science* **2**(7): 112-117.

Dhimal M, Gautam I and Tuladhar R (2013) Effectiveness of Vermicomposting in Management of Organic Wastes using *Eisenia foetida* and Perionyx favatus in Central Zoo Jawalakhel. *Nepal. J. Nat. Mus.* **27**: 92-106. 10.3126/jnhm.v27i0.14158

Edwards CA and Lofty JR (1977) Biology of Earthworms, II ed. Chapman and Hall Ltd., London. 10.1007/978-1-4613-3382-1

Fragoso C, Kanyonyo J, Moreno A, Senapati BK, Blanchart E and Rodriguez C (1999) A Survey of Tropical earthworms: Taxonomy, Biogeography and Environmental Plasticity. *In* P. Lavelle, L. Brussaard and P. Hendrix (eds) *Earthworm Management in Tropical Agroecosystems.*

Gates GE (1972) Burmese Earthworms: An Introduction to the Systematics and Biology of Megadrile Oligochaetes with Special Reference to Southeast Asia. *Transactions of the American Philosophical Society* **62**(7): 1–326. 10.2307/1006214

GBIF (2016) Backbone Taxonomy. GBIF Secretariat. Checklist Dataset. via GBIF.org http://doi.org/10.15468/39omei

Jaikishun S, Ansari A, Punu GP and Seecharran D (2015) Taxonomy of Earthworm Species Collected from East Coast of Guyana. *Annual Research & Review in Biology* **8**(6): 1-7. DOI: 10.9734/ARRB/2015/22573

Jimenez JJ and Decaens T (2000) Vertical distribution of earthworms in grassland soils of the Colombian Llanos. *Bio Fertil Soils* **32**: 463-473. 10.1007/s003740000277

Jimenez JJ, Rossi JP and Lavelle P (2001) Spatial Distribution of Earthworms in Acid-soil Savannas of the Eastern Plains of Colombia. *Applied Soil Ecology* **17**: 267-278. 10.1016/S0929-1393(01)00133-0

Joshi N, Darbal M, (2008) Life Cycle of Earthworms *Drawida nepalensis*, *Metaphire houlleti* and *Perionyx excavates*

under Laboratory-controlled Conditions. *Life Science Journal* **5**: (4).

Julka JM (1993) Earthworm Resources and Vermiculture: The Director, Zoological Survey of India, Calcutta.

Kumar S, Tripathi G and Mishra GV (2021) A comparative Study on Earthworm Biodiversity & Species Habitat-Relationship of Hilly and Plain Areas of Sirohi District of Rajasthan, India. *Applied Ecology and Environmental Sciences* **9**(4): 419-439. DOI: 10.1269/aees 9-4-2

Marchan DF, Decaens T, Dominguez J and Novo M (2022) Perspectives in Earthworm Molecular Phylogeny: Recent Advances in Lumbricoidea and Standing Questions. *Diversity* **14**: 30. 10.3390/dl4010030

Mazumdar BN (2012) Nepal: Capacity Building for Waste Management. Organic Composting.

Michaelson W (1909) The Oligochaeta of India, Nepal, Ceylon, Burma and the Andaman Islands. *In*: (Vol I: 1907-09) Memoirs of Indian Museum. Chapter 3, Baptist Mission Press, Calcutta, 103-281.

Mishra CSK and Samal S (2021) Rediscovering Earthworms. Lady Stephenson Library, Newcastle upon Tyne, NE62PA, UK.

Neilsona R, Boaga B and Smith M (2000) Earthworm δ13C and δ15N Analyses Suggest that Putative Functional Classifications of Earthworms are Site- Specific and may Also Indicate Habitat Diversity. *Soil Biology & Biochemistry* **32**: 1053-1061. 10.1016/S0038-0717(00)00013-4

Orgiazzi A, Bardgett RD, Barrios E, Behan-Pelletier V, Briones MJI, Chotte JL, De Deyn GB, Eggleton P, Fierer N, Fraser T, Hedlund K, Jeffery S, Johnson NC, Jones A, Kandeler E, Kaneko N, Lavelle P, Lemanceau P, Mik L, Montanarella L, Moreira FMS, Ramirez KS, Scheu S, Singh BK, Six J, van der Putten WH and Wall DH (2016) Global Soil Biodiversity Atlas. European Commission, Publication Office of the European Union, Luxembourg. 176. DOI: 10.2788/799182

Pandey R (2012) Analysis of Toxic Metals (Cd, Pb, Zn, Cu, Fe) in Earthworm Species (*Eisenia fetida, Perionyx excavates* and *Lampito mauritii)* and their vermiculture.

Pant SR and Yami KD (2008) Selective Utilization of Organic Solid Wastes by Earthworm (*Eisenia foetida*). *Nepal Journal of Science & Technology* **9**: 99-104. 10.3126/njst.v9i0.3172

Phillips HRP , Bach EM, Bartz MLC, Bennett JM, Beugnon R, Briones MJI, Brown GG , Ferlian O, Gongalsky KB, Guerra CA, Ries BK, Krebs JJ, Orgiazzi A, Ramirez KS, Russell DJ , Schwarz B, Wall DH, Brose U, Decaëns T, Lavelle P, Loreau M, Mathieu J, Mulder C, Putten WHVD, Rillig MC, Thakur MP, Vries FTD, WardleDA, Ammer C, Ammer S, Arai M, Ayuke FO, Baker GH, Baretta D, Barkusky D, Beauséjour R, Bedano JC, Birkhofer K, Blanchart E, Blossey B, Bolger T, Bradley RL, Brossard M, Burtis JC, Capowiez Y, Cavagnaro TR, Choi A, Clause J, Cluzeau D, Coors A, Crotty FV, Crumsey JM, Dávalos DJD, Cosín D, Dobson AM, Domínguez A, Duhour AS, EekerenNV, Emmerling C, Falco LB, Fernández R, Fonte ST, Fragoso C, Franco ALC, Fusilero A, Geraskina AP, Gholami S, González G, Gundale MJ , López MJ, Hackenberger BK, Hackenberger DK, Hernández LM,. Hirth JR, Hishi T, Holdsworth AD, Holmstrup M, Hopfensperger KN, Lwanga EH, Huhta V, Hurisso TT, Iannone III BIV, Iordache M, Irmler U, Ivask M, Jesús JB, Maynard JLJ, Joschko M, Kaneko N, Kanianska R, Keith AM, Kernecker ML, Koné AW, Kooch Y, Kukkonen ST, Lalthanzara H, Lammel DR , Lebedev L, Cadre EL, Lincoln NK, Hernández DL, Loss SR, Marichal R, Matula R, Minamiya Y, Moos JH, Moreno G, Ríos AM, Motohiro H, Muys B, Neirynck J, Norgrove L, Novo M, Nuutinen V, Nuzzo V, Rahman PM, Pansu J, Paudel S, Pérès G, Camacho LP, Ponge JF, Prietzel J, Rapoport IB, Rashid MI, Rebollo S, Rodríguez MA, Roth AM, Rousseau GX, Rozen A, Sayad E, Schaik LV, Scharenbroch B, Schirrmann M, Schmidt O, Schröder B, Seeber J, Shashkov MP, Singh J, Smith SM, Steinwandter M, Szlavecz K, Talavera JA, Trigo D, Tsukamoto J, López SU, ValençaAWD, Virto I, Wackett AA, Warren MW, Webster ER, Wehr NH, Whalen JK, Wironen MB, Wolters V, Wu P, Zenkova IV, Zhang W, Cameron EK and Eisenhauer N (2021) Global Data on Earthworm Abundance, Biomass, Diversity and Corresponding Environmental Properties. *Scientific data* **8**:136. DOI: 10.1038/s41597-021-00912-z

Phillips HRP, Guerra CA, Bartz MLC, Briones MJI, Brown G, Crowther, T W (2019) Global Distribution of Earthworm Diversity. *Science* 366:480. DOI: 10.1101/587394

Podolak A, Kostecka J, Paczka AM, Garczynska M, Paczka G and Szura R (2020) Life Cycle of the *Eisenia fetida* and *Dendrobaena veneta* Earthworms (Oligohaeta, Lumbricidae). *Journal of Ecological Engineering* **21:** 40-50. DOI: 10.12911/22998993/113410

Potvin LR and Lilleskov EA (2017) Introduced Earthworm Species Exhibited Unique Patterns of Seasonal Activity and Vertical Distribution, and *Lumbricus terrestris* Burrows Remained Usable for at Least 7 Years In Hardwood and Pine Stands. *Biol Fertil Soils.* **53**:187–198. DOI: 10.1007/s00374-016-1173

Shipitalo M and Korucu T (2017) Structure and Earthworms. *Encyclopedia of Soil Science* 3rdeds. 2012 -2015. DOI: 10.1081/E-ESS3-12005387

Singh S, Sharma A, Khajuria K, Singh J and Vig AP (2020) Soil Properties Change Earthworm Diversity Indices in Different Agro-Ecosystem. *BMC Ecology* **20:**27. DOI: 10.1186/s12898-020-00296-5

Singh S, Singh J and Vig AP (2016) Effect of Abiotic Factors on the Distribution of Earthworms in Different Land Use Patterns. *The Journal of Basic and Applied Zoology* 74: 41-50. DOI: 10.1016/j.jobaz.2016.06.001

Tripathi G and Bhardwaj P (2004) Earthworm Diversity and Habit Preferences in Arid of Regions Rajasthan. *Zoos Print Journal* **19** (7): 1515-1519. 10.11609/JoTT.ZPJ.1074.1515-9

Tripathi KM, Dhakal DD, Sah SC, Sharma MD and Baral DR (2016) Assessment of Earthworm Species for Organic Waste Conversion to Vermicompost Yield and Quality. International Journal of Research **03** (08)

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