A Comprehensive Examination of the Variety of Earthworm Species in Rajasthan A Critical Analysis

***Komal**

ABSTRACT

The main component of soil biota that offers a dynamic potential for sustainable agriculture is earthworms. These megadrili (Annelida: Clitellata) species are divided into many ecological groups that contribute to the pedoecosystem's viability. Fewer earthworm species from Rajasthan's varied ecological conditions have been documented. It starts the process of reviewing the biodiversity of earthworms. They are regarded as a crucial bio-indicator of the soil. Earthworm species number eighteen. The Megascolecidae, Ocnerodrilidae, Octochaetidae, Glossoscolecidae, and Lumbricidae are the five families to which they belong, out of fifteen genera. The Megascolecidae family has the greatest number of earthworm species among them, while the Glossoscolecidae family has the fewest. The distribution of earthworms is spotty; the highest percentage are exotic peregrine, at 55.56% (10) and the lowest, at 44.44% (8), are indigenous peregrine. The Octochaetidae and Megascolecidae families are home to all of the indigenous species of peregrine falcons. This thorough knowledge on Rajasthan's earthworm biodiversity may aid in future research on earthworm diversity.

Keywords: Megadrili, indigenous and exotic peregrine falcons, biodiversity, and bio-indicators.

1. INTRODUCTION

Rajasthan is the biggest state in India, making up 5.67 percent of the nation's total population and 10.4% of its total land area (Census, 2011). Large natural environments include the Indian Thar Desert, the Aravali and Vindhya mountain range, dry and semi-arid zones, freshwater and saltwater lakes, and wet areas are all part of the region's terrain. This significant bioregion is home to the nation's most ecologically and culturally diversified territory, as well as a variety of distinctive ecosystems, landscapes, flora, and wildlife. An place must manage its bioresources and practice sustainable land use patterns in order to meet its objectives for production, demand, and economics. A key component of organic farming that is sustainable is soil biodiversity. When it comes to symbiotic biomass, earthworms dominate the soil biota and are crucial to preserving soil fertility. Through their biological and physical activity, they serve a vital role in maintaining soil moisture and

improving soil nutrients. The diversity and number of earthworm species may be impacted by the intensification of agriculture and other disturbances. Extreme weather conditions, such as little moisture, high temperatures, and deteriorated soil systems in dry areas, are factors that restrict the dispersal of earthworms. Numerous factors contributing to climate change, such as rising temperatures, may raise metabolic demands, have an impact on the food and life cycle needs of soil organisms, and alter the availability of water in the soil. Because the quantity and quality of organic matter available to them as a food supply, as well as the existence of a suitably high level of soil moisture, dictate the number and biomass of earthworms, the diversity of earthworms is greatly impacted by global change. Better climatic conditions and vegetation in a given location may support the earthworm community's survival and dispersal, according to research by Kumar et al. The state of Rajasthan is renowned for its very significant biodiversity and ecological biome, and it has a diverse flora and fauna. Thus, in an effort to identify knowledge gaps that should be filled in further studies, a compilation of the information currently available on the variety and distribution of earthworms in the Indian state of Rajasthan has been prepared.

2. DISTINCTIVE LAND USE PATTERNS AND CLIMATIC CONDITIONS

The climate in Rajasthan varies, ranging from severely dry to humid. The eastern and southeast regions of the state are included in the humid zone. Everywhere else in the state has daily highs of 30 to 48°C throughout the summer, with the exception of the mountainous regions. The desert region deals with the issue of scorching winds and dust storms, particularly in the summer. Wintertime temperatures typically vary from 12 to 24°C, with occasional dips below 7°C in the middle of the season. The state's northern and western portions get the least amount of rain, averaging 170–312 mm yearly, while the south-eastern regions receive the most, ranging from 580–920 mm. The huge yearly rainfall in south-eastern Rajasthan is brought about by the southwestern (summer) monsoon winds from the Arabian Sea and the Bay of Bengal. In a given year, the amount of rain in Rajasthan varies greatly amongst its many districts.

Earthworm dispersal is mostly influenced by the physicochemical properties of the soil. The distribution of earthworm species in various pedoecosystems is shown by the presence of a species in one habitat and its exclusion from other habitats. Many biotic and abiotic factors, including soil characteristics, surface litter, vegetation type and dynamics, land use pattern, local or regional climate, and the pressure of human activities, generally control the diversity and distribution pattern of earthworms. The state is divided physiographically into four main regions: (i) the western desert, which consists of rocky plains, barren hills, and sandy plains; (ii) the Aravali hills, which stretch from Gujarat to Delhi and run from south-west to northeast; (iii) the eastern plains, which have rich alluvial soils; and (iv) the south-eastern plateau. The state's three principal rivers are the Mahi, Chambal, and Banas. For the purpose of broad agricultural planning and creating future plans, the areas have been divided into categories based on physiographic characteristics, various soil types, geological formation, climate, cropping patterns, irrigation system development, and mineral resources. Rajasthan is blessed with a varied soil composition and a range of agro-climatic zones, which enable the area to implement a flexible cropping schedule.

The landscape of Rajasthan often consists of rocky terrain, plateaus, ravines, rolling sand dunes, moist areas, arid areas or land covered with prickly bushes, plains that drain into rivers, plateaus, and forested areas. The complex and extremely varied soil types found in Rajasthan are a reflection of the diverse material and physiographic aspects of the region. While the soil in the eastern regions is heavy and has a clay texture, the soil in the western area is light and coarse in texture. The majority of Rajasthan's land area utilized for agriculture is modest, with the districts that border the Aravali mountain range—such as Ajmer, Banswara, Bundi, Chittorgarh, Pali, Sawai Madhopur, Sirohi, Udaipur, and Kota—having higher concentrations of forests. Low rainfall has resulted in a scarcity of desert forest lands in the arid zone districts of Jodhpur, Barmer, Bikaner, Churu, Sri Ganganagar, Jaisalmer, and Jalor. Other landforms including mountains and shifting dunes, as well as buildings, roads, and villages, are considered non-agricultural land. The state of the livestock economy in the areas is determined by the availability of permanent pasture and grazing land. These are areas known as cultural wastelands that might be farmed with irrigation. The areas with the most cultural wastelands are Ajmer, Alwar, and Jaisalmer, while the lowest are Hanumangarh, Jhunjhunu, and Bharatpur. A fallow field is one that has been plowed by a farmer but has not been farmed for one or more seasons in order to replenish its fertility. There are two categories of fallow land: long-fallow lands and present fallow fields. Lands that have not been farmed for more than a year are considered other fallow lands, while current year fallow refers to areas that have been left without crops for the current year. The amount of land that is not used for crops is relatively high in dry areas, with the exception of those where irrigation is used. Jodhpur, Jaisalmer, Bikaner, and Barmer are the leading districts in this category.

Based on the intensity of rainfall, the state of Rajasthan is commonly categorized into dry, semi-arid, sub-humid, humid, and extremely humid zones (Table 1). The soil's moisture content primarily determines earthworm activity and number, and estimations of the earthworm population and moisture content are positively associated. A significant portion of the distribution and presence of different earthworm species is influenced by soil moisture. The variety of earthworms depends on the temperature and moisture of the soil. There is a negative association between soil temperature and earthworm population, and soil temperature is crucial for maintaining earthworm populations in ecosystems. According to Turbe et al., the structure and texture of the soil have a significant impact on the activity of the soil biota. While fine-textured sandy soils with a lesser water-holding capacity are less suitable, medium-textured loam and clay soils encourage microbial and earthworm activity. The salt of the soil, which may rise close to the soil's surface, can also seriously stress soil organisms, hastening their desiccation.

Table 1: Rajasthan's agroclimatic zones

Zone	Average Rainfall (mm)	Temperature Range (°C)	Major Crops	Soil Type	Districts Covered
IA-Arid western plain	200-370	8-40	Bajra, kharif pulses, guar	Desert soil, sand dunes, aeolian soil	Barmer & part of Jodhpur
IB-Irrigated northwestern plain	100-350	4.7-42	Cotton, sugarcane, pulses, wheat, mustard, gram, vegetables, fruits	Alluvial deposits, calcareous, high soluble salt & exchangeable sodium	Sriganganagar, Hanumangarh, Kumar, and Tripathi
IC-Hyper arid partial irrigated zone	100-350	3-48	Bajra, kharif pulses, guar	Desert soil, sand dunes, aeolian soil	Bikaner, Jaisalmer, Churu
IIA-Internal drainage dry zone	300-500	5.3-39.7	Bajra, sesamum, kharif pulses, wheat, barley, mustard, gram	Sandy loam, shallow depth red soil in depressions	Nagaur, Sikar, Jhunjhunu, part of Churu
IIB-Transitional plain of Luni Basin	300-500	4.9-38	Bajra, maize, guar, sesamum, pulses, wheat, barley, mustard	Red desert soil, sierozem soil	Jalore, Pali, part of Sirohi, Jodhpur
IIIA-Semi arid eastern plain	500-700	8.3-40.6	Bajra, sorghum, pulses, wheat, barley, gram, mustard	Sierozem soil, alluvial, lithosols, brown soil	Jaipur, Ajmer, Dausa, Tonk
IIIB-Flood-prone eastern plain	500-700	8.2-40	Bajra, sorghum, maize, sugarcane, sesamum, pulses, wheat, barley, gram, mustard	Alluvial, prone to waterlogging	Alwar, Dholpur, Bharatpur, Karoli, Sawai Madhopur
IVA-Sub-humid southern plain	500-900	8.1-38.6	Maize, paddy, wheat, gram, oilseeds, cotton, opium	Lithosols, alluvial	Bhilwara, Sirohi, Udaipur, Chittorgarh
IVB-Humid southern plain	500-1100	7.2-39	Cotton, sugarcane, maize, sorghum, paddy, groundnut, mustard, sesamum, rapeseed	Reddish medium texture soil, well-drained calcareous, shallow on hills, deep soil in valleys	Dungarpur, Udaipur, Banswara, Chittorgarh
V-Humid southeastern plain	650-1000	10.6-42.6	Paddy, sorghum, soybean, wheat, barley, grain, mustard	Black alluvial, clay loam, groundwater salinity	Kota, Jhalawar, Bundi, Baran

Source: Directorate of Agriculture, Government of Rajasthan

The primary land use systems are: 8.05 acres under forest cover; 5.81 acres of non-agricultural land; 4.86 acres of permanent pasture and grazing land; 11.04 acres of culturable waste lands; 11.36 acres of fallow land; 6.95 acres of barren and uncultivated land; and 0.08 acres of various trees and grooves. A substantial portion of the state is not used by people for any kind of activity. The state of Rajasthan's net shown area is 51.85%. The patterns of land usage are altered by modern agricultural techniques, man-made canal projects, urbanization, and other irrigation systems. The number and variety of earthworm species are directly impacted by changes in the land use pattern of agroclimatic zones.

3. EARTHWORMS' DIVERSITY AND DISTRIBUTION

Numerous researchers have provided descriptions of earthworm variety and distribution around the globe. Reynolds characterized the worldwide distribution, movement hurdles, ecological requirements, and functional relevance of 3,627 terrestrial earthworm species that he had recorded. Compared to other regions, the Indian subcontinent has a high degree of variety, with 509 earthworm species from 67 genera and 10 families having been identified.Stephenson, Gates, Das, and Patra Senapati et al., Julka, Julka and Senapati, Bano, and Kale have all provided extensive documentation of the diversity and distribution patterns of earthworm fauna on the Indian subcontinent. Nevertheless, the research on Rajasthan's earthworm species is very incomplete and fragmented. Data on earthworm diversity from various regions of Rajasthan have only been given by a relatively small number of scientists (Table 2). Tripathi and Bhardwaj provided a description of the earthworm fauna of the Jodhpur district in Rajasthan.They identified nine earthworm species from various land use systems in these places, including Amynthas morrisi, Lampito mauritii, Metaphire posthuma, Perionyx sansibaricus, Ocnerodrilus occidentalis, Dichogaster bolaui, Octochaetona paliensis, Ramiella bishambari, and Pontoscolex corethrurus. Lampito mauritii was prevalent in both cultivated and sewage soils, but P. corethrurus and P. sansibaricus were only found in large quantities in sewage. Similarly, A. morrisi was only present in garden soil in large quantities. Only a minor amount of Octochaetona paliensis was found in non-cultivated soils. Metaphire posthumawas is abundant in gardens and has been documented in all pedoecosystems. Sewage soil included large amounts of Dichogaster bolaui.

Five earthworm species were identified by Suthar during his investigation of the earthworm fauna in the Jalore area of Rajasthan (Lampito mauritii, Metaphire posthuma, Ocnerodrilus occidentalis, Dichogaster bolaui, Malabaria sp.). The majority of earthworms have been shown to have erratic distribution and to be present in some limited areas. The two major species were O. occidentalis and M. posthuma. Suthar conducted a thorough survey in various regions of India's western and semi-arid regions to investigate the biodiversity of earthworms. The study identified a total of 11 earthworm species, including Amynthas morrisi, Lampito mauritii, Metaphire posthuma, Perionyx sansibaricus, Ocnerodrilus occidentalis, Dichogaster bolaui, Octochaetona paliensis, Ramiella bishambari, Pontoscolex corethrurus, Allolobophora parva, and Malabaria sp. in various land use patterns, including irrigated and non-irrigated areas of Rajasthan's Thar Desert. Eight species of earthworms were identified by Tripathi and Panwar from different locations in the Bikaner area. These species include Amynthas morrisi, Lampito mauritii, Metaphire posthuma, Perionyx sansibaricus,

Ocnerodrilus occidentalis, Dichogaster bolaui, Ramiella bishambari, and Pontoscolex corethrurus. Eight habitats were included in the survey: bare lands, natural plantations, wild, kitchen gardens, gardens, orchards, and non-cultivated areas. In each of these environments, the species L. mauritii and M. posthuma were discovered. The three types of earthwormsThere have been reports of Lampito mauritii, Eisenia fetida, and Perionyx excavatus from various parts of Kota city. These earthworms were all found in agricultural areas. Twelve earthworm species—Amynthas morrisi, Lampito mauritii, Metaphire posthuma, Megascolex konkanensis, Metaphire houlleti, Perionyx sansibaricus, Polypheretima elongata, Octerodrilus occidentalis, Octochaetona beatrix, Dichogaster bolaui, Pontoscolex corethrurus, and Gordiodrilus sp.—from various habitats were recently surveyed by Kumar et al. in the Sirohi district of Rajasthan. For the first time, they described five earthworm species from Rajasthan: M. konkanensis, M. houlleti, P. elongata, O. beatrix, and Gordiodrilus sp. A small number of earthworm species, including P. elongata, M. houlleti, Gordiodrilus sp., and M. konkanensis, were limited to a single location in the area, but L. mauritii, A. morrisi, P. corethrurus, and D. bolauishowed their presence in most of the locales.

Table 2: Reports of earthworm species from various regions of Rajasthan

S No.	Study Area/Region	Earthworm Species Recorded
1	Jodhpur	Amynthas morrisi, Lampito mauritii, Metaphire posthuman, Perionyx sansibaricus, Ocnerodrilus occidentalis, Dichogaster bolaui, Octochaetona paliensis, Ramiella bishambari, Pontoscolex corethrurus
2	Jalore	Lampito mauritii, Metaphire posthuman, Ocnerodrilus occidentalis, Malabariasp, Dichogaster bolaui
3	Western Arid and Semi-Arid Lands of India	Amynthas morrisi, Lampito mauritii, Metaphire posthuman, Perionyx sansibaricus, Ocnerodrilus occidentalis, Dichogaster bolaui, Octochaetona paliensis, Malabariasp, Ramiella bishambari , Pontoscolex corethrurus, Allolobophora parva
4	Bikaner	Amynthas morrisi , Lampito mauritii, Metaphire posthuman, Perionyx sansibaricus, Ocnerodrilus occidentalis, Dichogaster bolaui, Ramiella bishambari, Pontoscolex corethrurus
5	Kota City	Lampito mauritii, Perionyx excavates, Eisenia fetida
6	Sirohi	Pontoscolex corethrurus, Amynthas morrisi, Lampito mauritii, Metaphire posthuman, Megascolex konkanensis, Metaphire houlleti, Perionyx sansibaricus, Polypheretima elongate, Ocnerodrilus occidentalis, Dichogaster bolaui, Octochaetona Beatrix, Gordiodrilus sp.

A total of eighteen species of earthworms have been reported from Rajasthan; they are divided into fifteen genera and five families, which are the Megascolecidae, Ocnerodrilidae, Octochaetidae, Glossoscolecidae, and Lumbricidae (Table 3). The Megascolecidae family has the greatest number of earthworm species, while the Glossoscolecidae family contains the least amount. Based on a range of earthworm diversity data, the Megascolecidae family accounted for the majority of the eight species found in the Rajasthan region's earthworm fauna. This was followed by the Octochaetidae family with four species, the Ocnerodrilidae family with three species, the Lumbricidae family with two species, and the Glossoscolecidae family with one species. In terms of the uneven distribution of earthworms, the alien peregrine species has the greatest number, while the indigenous peregrine species has the lowest number (Table 4). All of the native species of peregrine falcons are members of the families Megascolecidae and Octochaetidae. According to Suthar, the majority of the earthworm variety in the dry and semi-arid regions of India is made up by members of the Megascolecidae family, who are dominant over other earthworm families and imported peregrine species.

4. EARTH-WORMS ECOSYSTEM SERVICES

The primary soil invertebrates that are sometimes referred to as "ecosystem engineers" are earthworms, since they profoundly alter the chemical, biological, and physical characteristics of the soil profile. The habitat and activity of various creatures within the soil ecosystem may be impacted by these adjustments. In an ecosystem, earthworms play the roles of consumer, decomposer, and modulator. The primary soil activities that earthworms affect include the breakdown of organic soil matter and the cycling of nutrients. They also have an impact on the chemical and physical qualities of the soil and interact with other animals, plants, and microbes. As garbage and soil managers, earthworms have approximately 600 million years of expertise. It makes sense why Darwin referred to them as "unheralded soldiers of mankind working day and night under the soil and friends of farmers."

By means of the decomposition process, earthworms recycle organic material in conjunction with bacteria and fungus. The majority of people are familiar with earthworms and compost, but earthworms also perform the same function in grazing soils, breaking down manure and planting litter, processing two to twenty tons of organic matter per hectare each year, and recycling leaf litter under orchards and in other forest areas. In only two months, they could turn 18–42% of the soil material into macro-aggregates. Kumar reported on the beneficial effects of using goat dung to compost earthworms (Eisenia fetida, Perionyx sansibaricus) for stabilizing leaf litter and kitchen trash.

By adding organic materials to the soil and liberating the nutrients stored in decomposing organisms and plant matter, the availability of nutrients is increased in two ways. Additionally, earthworms bring nutrients into closer contact with plant roots by carrying them down through the soil profile. According to their reports, breaking up soil organic matter (SOM) and combining it with mineral particles and microorganisms may improve mineralization by forming new surfaces where soil organic matter and microorganisms can interact. Researchers have seen increases in nitrogen availability in earthworm castings of up to five times that of undigested soil. Casts are a productive way to provide nutrients to plants. After being digested by earthworms and expelled in earthworm

casts, nutrients such as nitrogen and phosphorus are more easily absorbed by plants. In the experimental work conducted under controlled conditions by Kumar and Kumar et al., plant nutrient-rich vermicompost or biofertilizer was generated by vermicomposting by employing earthworm species: Eisenia fetidasansibaricus in the management and bioconversion of agro-waste.

Table 3 lists the species and genera of earthworms along with the names of the families that have been found in various regions of Rajasthan.

S. No.	Family	Genus (No.)	Species (No.)
1	Megascolecidae	6	8
2	Ocnerodrilidae	3	3
3	Octochaetidae	3	4
4	Glossoscolecidae	1	4
5	Lumbricidae	2	2
TOTAL		15	18

The physical structure of soil is changed by earthworm burrowing. They allow the soil's pores, which are tiny openings. When earthworms are added to soils that don't already have them, the rate at which water penetrates the soil may rise by up to ten times. As a result, water and soluble nutrients are delivered to the roots of plants. Additionally, burrowing increases plant root penetration and promotes soil aeration for both plants and other soil-dwelling species. Though mostly via their digging activities, earthworms have an impact on the availability of nutrients through their tissues. They create bio-structures and aggregates in the soil or on its surface, which have an impact on plant development, nutrient cycling, and the physical characteristics of the soil. The biological categories of earthworms—epigeic, anecic, and endogeic—have an impact on the properties of soil water, as shown by Ernst et al. All organisms are a component of food webs, much as earthworms. Predators like birds are widely recognized, but endemic and endangered land snails also eat native earthworms. Numerous bird and animal species feast on them. Earthworms are also a food source for centipedes, ants, carabid and staphylinid beetles, and their larvae. Upon establishment, earthworms provide a 25–30% boost in pastoral output. This corresponds to a carrying capacity of 2.5 stock units per hectare. Earthworms eliminate surface thatch, which may prevent water from penetrating the soil. Earthworms enhance the fertility of soil, recycle waste materials, and provide food for predators, all of which contribute to the restoration of both above- and below-ground ecosystem function. Earthworms are among the soil creatures that significantly enhance agricultural soil and promote the welfare of customers, farmers, and people in general.

5. ENDEMIC AND EXOTIC EARTH-WORMING

In the impacted areas of the nation, there is a greater likelihood of exotic and endemic fauna invading due to shifting land use patterns and different irrigation techniques. The majority of earthworms are found in exotic locations (55.56%), such as Amynthas morrisi, Metaphire posthuma, Polypheretima elongata, Ocnerodrilus occidentalis, Gordiodrilus sp., Dichogaster bolaui, Pontoscolex corethrurus,

Allolobophora parva, Octochaetona beatrix, Octochaetona paliensis, and Ramiella bishambari [Tables 2 & 4]. There have been reports of both local and foreign peregrine earthworm species from Rajasthan (Table 4). They are naturally able to adjust to various soil types. It is likely that these exotic species have spread around the globe as a result of human activity moving them through the soil surrounding exotic plant roots. It is well known that native species often predominate when invasive species exist. While the density of human population in Rajasthan is much lower than in other regions of the nation, high population densities may also have an influence on the distribution of earthworms in certain places. All of the information currently available about Rajasthan's earthworm biodiversity has been put here. The variety of earthworms offers a broad picture of their dispersion across Rajasthan's many environments.

Table 4: Distribution of earthworm species across categories in various regions of Rajasthan

Family	Earthworm Species	Category	District-wise Distribution
Megascolecidae	Amynthas morrisi (Beddard, 1892)	Exotic peregrine	Bikaner, Jodhpur, Sirohi
	Lampito mauritii (Kinberg, 1867)	Endemic peregrine	Barmer, Bikaner, Churu, Hanumangarh, Jalore, Jaisalmer, Jhunjhunu, Jodhpur, Kota city, Nagour, Pali, Sirohi, Sri Ganganagar
	Megascolex konkanensis (Fedard, 1898)	Endemic peregrine	Sirohi
	Metaphire houlleti (Perrier, 1872)	Endemic peregrine	Sirohi
	Metaphire posthuma (Vaillant, 1868)	Exotic peregrine	Barmer, Bikaner, Churu, Hanumangarh, Jalore, Jaisalmer, Jhunjhunu, Jodhpur, Nagour, Pali, Sirohi, Sri Ganganagar
	Perionyx sansibaricus (Michaelsen, 1891)	Endemic peregrine	Jodhpur, Hanumangarh, Sirohi
	Polypheretima elongata (Perrier, 1872)	Exotic peregrine	Sirohi
	Perionyx excavatus (Perrier, 1872)	Endemic peregrine	Kota city
Ocnerodrilidae	Ocnerodrilus occidentalis (Eisen, 1878)	Exotic peregrine	Barmer, Bikaner, Churu, Hanumangarh, Jalore, Jaisalmer, Jhunjhunu, Jodhpur, Nagour, Pali, Sirohi, Sri Ganganagar
	Gordiodrilus sp. (Beddard, 1892)	Exotic peregrine	Sirohi
	Malabaria sp.	Exotic peregrine	Jalore
Octochaetidae	Dichogaster bolaui (Michaelsen, 1891)	Exotic peregrine	Barmer, Bikaner, Churu, Hanumangarh, Jalore, Jodhpur, Nagour, Pali, Sirohi, Sri Ganganagar
	Octochaetona Beatrix (Beddard, 1902)	Endemic peregrine	Sirohi
	Octochaetona paliensis (Stephenson, 1920)	Endemic peregrine	Bikaner, Jodhpur
	Ramiella bishambari (Stephenson, 1914)	Endemic peregrine	Bikaner, Jodhpur, Pali, Shri Gangnagar
Glossoscolecidae	Pontoscolex corethrurus (Muller, 1857)	Exotic peregrine	Bikaner, Jodhpur, Sirohi
Lumbricidae	Allolobophora parva (Eisen, 1814)	Exotic peregrine	Hanumangarh, Shri Gangnagar
	Eisenia fetida (Savigny, 1826)	Exotic peregrine	Kota city

6. CONCLUSION

The variety and spread of earthworms may be attributed to changes in land use patterns and local climates. Numerous earthworm species have been found in abundance in various environments over the majority of Rajasthan, including Dichogaster bolaui, Oxydrilus occidentalis, Perionyx sansibaricus, Amynthas morrisi, Lampito mauritii, Metaphire posthuma, and Pontoscolex corethrurus. While earthworms including Octochaetona paliensis, Ramiella bishambari, and Allolobophora parva were found in a few state districts. However, some ecosystems in certain regions of the state are home to Malabaria sp., Perionyx excavatus, Eisenia fetida, Megascolex konkanensis, Metaphire houlleti, Polypheretima elongata, Octochaetona beatrix, and Gordiodrilus species. The districts of Sirohi, the southwest semi-arid area of Rajasthan, and the dry regions of Jodhpur and Bikaner are home to 12, 9, and 8 different species of earthworms, respectively. Additional research is required to examine the variety of earthworms in various regions of Rajasthan.

***Research Scholar**
Department of Zoology
Mohanlal Sukhadia University, Udaipur (Raj.)

REFERENCES

1. Ramakrishnan PS, Saxena KG, Swift MJ, Rao KS, Maikhuri RK. Soil biodiversity, ecological processes and landscapemanagement. Oxford and IBH Publishing Company Private Limited, New Delhi. 2005;302.
2. Julka JM, Paliwal R. Diversity and biogeography of Indian earthworms, In: proceedings of national level workshop on vermitechnology transfer to NSS programme officers, Department of Biochemistry and Zoology, Kongunadu Arts and Science College, Coimbatore, India. 2005a;5-21.
3. Julka JM, Paliwal R. Distribution of earthworms in different agro-climatic regions of India. In: Soil Biodiversity, Ecological Processes and Landscape Management. Ramakrishnan PS, Saxena KG, Swift MJ, Rao KS, and Maikhuri RK. (Eds), Oxford and IBH Publishing Company PrivateLimited, New Delhi. 2005b;3-13.
4. Dash MC, Saxena, KG, Giri S. Vermitechnology for Wasteland Reclamation, Plant Productivity and Composting: A Review in Indian Context. International J. Ecol. Environmental Science. 2009;35(2-3):163-185.
5. Bhadauria T, Kumar P, Kumar R, Maikhuri RK, Rao KS, Saxena, KG. Earthworm populations in a traditional village landscape in Central Himalaya, India. Applied Soil Ecol. 2012;53:83-93.
6. Dash MC. Charles Darwin's Plough. Tools for vermitechnology. I. K. International Publishing HousePvt. Ltd. New Delhi. 2012;185.

7. Curry JP, Byrne D, Schmidt O. Intensive cultivation can drastically reduce earthworm populations in arable land. Europ. J. Soil Biol. 2002;38:127-130.
8. Julka JM. Earthworms as bioindicators in conservation areas. In: National Seminar on vermitechnology and waste management, Patil R, Rao RC, (Eds.), Dept. Appl. Zool. Mangolore Univ. Mangolore, sponsored by DBT, New Delhi, 2005;28-29.
9. Suthar S. Earthworm biodiversity in western arid and semiarid lands ofIndia. Environmentalist. 2011;31:74-86.Available:https://doi.org/10.1007/s10669-011-9308-y
10. Thakur MP, Reich PB, Hobbie SE, Stefanski A, Rich R, Rice KE, Eddy WC, Eisenhauer, N. Reduced feeding activity of soil detritivores under warmer and drier conditions. Nature Climate Change. 2018;89 (1):75-78.
11. Hackenberger DK, Hackenberger BK. Earthworm community structure in grassland habitats differentiated by climate type during two consecutive seasons. Europ. J. Soil Biol. 2014;61:27-34.
12. Singh J, Schadler M, Demetrio W, Brown GG, Eisenhauer N. Climate change effects on earthworms-a review. Soil Organisms. 2019;91:114-138.
13. Amosse J, Turberg P, Kohler-Milleret R, Gobat JM, Le Bayon RC. Effects of endogeic earthworms on the soil organic matter dynamics and the soil structure in urban and alluvial soil materials. Geoderma. 2015;243-244:50-57.
14. Luscher G, Jeanneret P, Schneider MK, Hector A, Arndorfer M, Balazs K, Herzog F. Strikingly high effect of geographic location on fauna and flora of European agricultural grasslands. Basic and Applied Ecol. 2015;16:281-290.
15. Kumar S, Tripathi G, Mishra GV. A comparative study on earthworm biodiversity & species habitat-relationship of hilly and plain areas of Sirohi district of Rajasthan, India. Applied Ecol. Environmental Sciences. 2021;9 (4): 419-439. Available:http://pubs.sciepub.com/aees/9/4/2
16. Tripathi G, Bhardwaj P. Seasonal changes in population of some selected earthworm species and soil nutrients in cultivated agroecosystem. J. Environmental Biol. 2004;25 (2) :221-226.
17. Decaens T, Margerie P, Aubert M, Hedde M. Bureau F. Assembly rules within earthworm communities in north-western France a regional analysis. Applied Soil Ecology. 2008;39:321-335.
18. Tondoh EJ, Guei AM, Csuzdi C, Okoth P. Effect of land-use on the earthworm assemblages in semi-deciduous forest of Central-West Ivory Coast. Biodiversity and Conservation. 2011;20:169-184.
19. Hussain M. Agro-Climatic Zones and Economic Development of Rajasthan. International Journal of Humanities and Social Science Invention. 2015;4(2):50-57.
20. Lavelle P. Earthworm activities and the soil system. Biology and fertilityof soils. 1988; 6(3):237-251.

21. Bhadauria T, Ramakrishnan PS. Population dynamics of earthworms and their activity in forest ecosystems of north-eastIndia. J. Tropical Ecol. 1991;7(3):305-318.
22. Gonzalez G, Zon X, Borges S. Earthworm abundance and species composition in abandoned tropical croplands. Comparisons of tree plantations and secondary forests. Pedobiologia. 1996;40 (5):385-391.
23. Blakemore RJ, Chang CH, Chen JH, Chuang SC, Masamich T, Ito SJ, Sheng WH. Biodiversity of earthworms in Taiwan: A species checklist with the confirmation and new records of the exotic lumbricids Eisenia fetidaand Eiseniella tetraedra. Taiwania. 2006;51:226-236.
24. Karmegam N, Daniel T. Investigating efficiency of Lampito mauritii (Kinberg) and Perionyx ceylanensis(Michaelsen) for vermicomposting of different types of organic substrates. Environmentalist. 2009;29(3):287-300.
25. Turbe A, Toni A De, Benito P, Lavelle P, Ruiz N, Van der Putten WH, Labouze E, Mudgal S. Soil biodiversity: functions, threats, and tools for policy makers. Bio intelligence service, IRD, and NIOO. Report for European Commission (DG Environment). 2010;1-250.
26. Land use statistics 2018, 19. In: Economic review of Rajasthan 2020-21 published in February 2021.
27. Blanchart E, Julka JM. Influence of forest disturbance on earthworm (Oligochaeta) communities in the Western Ghats (South). Soil Biol. Biochem. 1997;29:303-306.
28. Bhaduaria T, Ramakrishnan PS, Shrivastava KN. Diversity and distribution of endemic and exotic earthworms in neutral and regeneration ecosystemin the central Himalaya, India. Soil Biol. Biochem. 2000;32:2045-2054.
29. Tsai CF, Shen HP, Tsai SC. On some new species of the Pheretimoid earthworms (Oligochaeta: Megascolecidae, from Taiwan. J. Nat. Taiwan, Museum. 1999;52:33-46.
30. Tsai CF, Shen HP, Tsai SC. Native and exotic species of terrestrial earthworms (Oligochaeta) in Taiwan with reference to northeast Asia. Zool Stud.2000;39:285-294.
31. Blakemore, RJ. Tasmanian earthworms, CD ROM Monograph with Review of world families. Verm Ecology. POBOX414 Kippax (Canberra, Astralia); 2000.
32. Blakemore RJ. Verm Ecol. POBOX414 Kippax (Canberra, Astralia); 2002.33.Blakemore RJ. Japanese earthworms (Annelida: Oligochaeta): A review and checklist of species. Org. Diver. Evol. 2003;11:1-43.
33. Chang CH, Chen JH. A new speciesof earthworm belonging to the genus Metaphire Sims and Easton (Oligochaeta:Megascolecidae) from southern Taiwan. Taiwania. 2004;49:219-224.
34. Chang CH, Chen JH. Three new species of Octothecate Pheretimoid earthworms from Taiwan with discussion on the biogeography of related species. J. Nat. Hist. 2005a;39:1469-1482.

35. Chang CH, Chen JH. Taxonomic status and intraspecific phylogeography of two sibling sps. of Metaphire (Oligochaeta:Megascolecies), in Taiwan. Pedobiologia. 2005b;49:591-600.
36. Blakemore RJ. A series of searchable texts on earthworm biodiversity, Ecology and systematic from various regions of the world (2nd Eds.), Kaneko, N. and Ito. M.T. COE Soil Ecology Research Group, Yokohama National University, Japan;2006.
37. Sautter KD, Brown GG, James SW, Pasini A, Nunes DH, Benito NP. Present knowledge on earthworm biodiversity on the state of Parana, Brazil. Europ. J. Soil Biol. 2006;42:296-300.
38. Reynolds JW. The distribution of the earthworms (Oligochaeta) of Indiana: A case