WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

BIO-ECOLOGICAL INSIGHTS INTO EARTHWORM DIVERSITY AND DISTRIBUTION ACROSS TALIPARAMBA, MANGALORE AND KARKALA TALUKS OF KERALA AND KARNATAKA

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ABSTRACT :

Earthworms are key to healthy soils they help recycle nutrients, break down organic matter, and improve soil structure. This study explores how earthworm species are distributed across Taliparamba (Kerala), and Mangalore and Karkala taluks (Karnataka), areas with varied soils, climates, and land uses. Field surveys across farms, forests, grasslands, and urban edges uncovered species and families, including both native and introduced earthworms. Study found that earthworm diversity is closely linked to soil characteristics and levels of human disturbance. Taliparamba showed richer and more unique species, likely thanks to its laterite soils and better-preserved habitats. Our analysis revealed clear patterns in how earthworm communities shift along land use and soil gradients. These insights highlight the importance of protecting diverse habitats to sustain soil biodiversity, and they offer useful guidance for managing soils more sustainably in this part of the Western Ghats.

Keywords: Earthworm diversity, Soil biodiversity, Species distribution

Introduction

Earthworms are important soil invertebrates belonging to the Phylum *Annelida* and Class *Oligochaeta*. Known as "the farmer's friend," these soil macroinvertebrates play a vital role in maintaining soil health and fertility. Their ecological significance has been recognized since ancient times. Cleopatra considered earthworms sacred as early as 50 BC. Aristotle (384–322 BC), the Greek philosopher, described them as the "intestine of the earth" for their ability to process and enrich soil. Sir Charles Darwin (1881), a pioneer in earthworm studies, remarked, "It may be doubted whether there are any other animals which have played so important a part in the history of the world as these lowly organized creatures." Stephenson (1923) compiled a detailed taxonomic account in the *Fauna of British India* series, further highlighting their biological importance.

Earthworms represent 60–80% of total soil biomass and significantly influence soil turnover, nutrient mineralization, humification of organic matter, and soil moisture content. Their presence improves soil texture, porosity, infiltration, and water retention, thereby enhancing plant growth and crop productivity. Through continuous burrowing, ingestion, mixing, and aeration, they renew soil fertility and are considered key biological indicators of soil health. A single acre of fertile land may contain more than 50,000 earthworms of various species.

The distribution of earthworms depends on the physico-chemical properties of the soil—such as temperature, pH, moisture, inorganic salts, organic content, texture, and aeration. Earthworms tend to avoid dry or drought-prone soil by migrating to deeper layers or entering a dormant state called diapause. Loose, well-aerated soils rich in organic matter support larger earthworm populations than compact, clayey, or poorly aerated soils. In subtropical regions like India, earthworm activity is largely seasonal, peaking during the monsoon months of July to September.

Vermiculture is the scientific practice of rearing specific species of earthworms under optimal conditions to accelerate their breeding and activity. Vermitechnology refers to the process of compost production through the decomposition of organic waste by earthworm activity. Under favorable conditions, earthworms and microorganisms act synergistically to rapidly decompose organic matter.

Although both epigeic (surface-dwelling) and anecic (deep-burrowing) species are used in vermiculture, not all species are equally effective under all conditions. Commonly used species include *Eisenia fetida* (Tiger worm), *Eudrilus eugeniae* (African nightcrawler), *Perionyx excavatus* (Indian blue worm), and *Pontoscolex corethrurus*. Other species occasionally used include *Megascolex konkanensis*, *Lampito mauritii*, *Metaphire houletti*, *Drawida* spp., *Amynthas corticis*, and *Dichogaster* spp.

Three orders, four suborders, seven superfamilies, twenty-seven families, and eight subfamilies make up the taxonomy of earthworms. Bouche (1977) classified terrestrial earthworms into three ecological groupings based on their functional characteristics: endogeic, anecic, and epigeic. Small and uniformly colored, epigeic (phytophagous) worms live on the surface and consume decomposing organic debris, such as leaf litter. Although they do not substantially change the structure of the soil, they are important for nutrient enrichment, have short life cycles, and have high rates of reproduction and regeneration. Perionyx excavatus, Eisenia fetida, and Eudrilus eugeniae are a few examples.

Worms classified as anecic (phytogeophagous) are larger, frequently have pigmented ends, and consume both soil and litter. They have a relatively modest rate of reproduction; examples include Lumbricus terrestris, Aporrectodea trapezoides, Pheretima spp., and Allolobophora chlorotica. They also

make surface castings, dig deep vertical burrows, and aid in pedogenesis and soil profile development. Worms that are endogeic (geophagous) reside in the soil and consume organic matter. They form horizontal burrows, vary in size from small to huge, and have little pigmentation. They are frequently found in agricultural areas and woodlands, and even in nutrient-poor soils, they show great energy efficiency and enhance soil structure. Drawida ampullacea, Metaphire houletti, Megascolex konkanensis, Pontoscolex corethrurus, and Lampito mauritii are a few examples.

Life Cycle of the Earthworm

Although self-fertilization is uncommon, earthworms are hermaphrodites, meaning they have both male and female reproductive organs. Throughout their lives, they can reproduce constantly or semi-continuously. Two worms align head-to-tail during copulation, which occurs on the soil's surface or underground, with the male genital apertures of one worm positioned opposite the spermathecal pores of the other. Copulation typically lasts less than an hour, during which genital cups and papillae aid in sperm exchange and penial setae enter into the partner's spermathecal pores to transfer sperm. After mating, each worm releases a ring of mucus from its clitellum, which advances and collects eggs and stored sperm to create a lemon-shaped cocoon that is placed in the soil or on top of it around ten days later.

Up to three cocoons can be produced weekly by each worm. Environmental factors like soil temperature, moisture content, and the adult's nutritional state all affect cocoon growth. Depending on the species, cocoons can vary in size, shape, and color. They usually hatch in 18 days, releasing 2–20 juveniles, with an average of 4 per cocoon. Although some bigger species, such as Megascolides australis, may take two to three years to achieve maturity, the juveniles emerge via a tiny hole at the pointed end of the cocoon and mature into adults in about sixty days. In roughly 220 days, the majority of earthworms finish their life cycle, giving birth to 300–400 children during their lives. Sexual maturity typically occurs 8–12 weeks after hatching.

Reproduction in Earthworms

Earthworms are hermaphrodites, meaning each individual possesses both male and female reproductive organs. However, they typically *do not self-fertilize*. Each worm has *testes*, *seminal vesicles*, and *male pores* for sperm production, storage, and release, along with *ovaries* and *female (ovi) pores* for egg production.

During mating, earthworms align ventrally and exchange sperm via *spermathecae*—internal sacs that store sperm received from the mating partner. Notably, *copulation and fertilization are distinct events*.

After mating, the *clitellum* a glandular band located posterior to the spermathecae—secretes a mucous ring that forms the *cocoon*. The worm then backs out of this ring, depositing its *eggs and stored sperm* (from the partner) into the cocoon. This cocoon seals into a *lemon-shaped incubator* where embryos develop. Hatchlings emerge as miniature earthworms, lacking reproductive structures, which develop later. Some species exhibit *parthenogenesis*, wherein male structures and spermathecae may be absent or non-functional.

Taxonomy and Identification

Many earthworm species are identical on the outside, hence internal anatomy is important for classification; nonetheless, some exterior morphological features are still important for taxonomy. The bodies of earthworms are long, cylindrical, segmented, bilaterally symmetrical, and have a soft cuticle covering. Although tropical species are often larger (200 adults weigh around 1 kg, and 1 million weigh about 1 tonne), size is not a valid taxonomic identifier and can vary within species; measurements are typically made from contracted specimens. Only live specimens can accurately observe their pigmentation, which is darker on the dorsal side and typically red, pink, or brown due to blood hemoglobin. The peristomium, the first section of the body, and the pygomere, the final, are both usually devoid of setae. An essential taxonomic characteristic is the prostomium, a fleshy lobe that comes before the mouth: Zygolobus (no groove, proboscis-like), Tanylobo (groove extends over segment 1, e.g., Octochaetidae), Epilobus (partial groove on segment 1, e.g., Konkandrilus, Eudrilus), and Prolobus (distinct transverse groove, e.g., Moniligastridae). Perichaetine (>8 setae grouped in a circle), Anisochaetine (increasing setae toward posterior), and Lumbricine (eight per segment) are the different taxonomic groups that comprise the bristle-like locomotory structures known as setae (or chaetae), which are lacking in segment 1. Coelomic fluid is released via dorsal pores, which are found between segments and help in defense and moisture retention.

Families vary in the shape of the clitellum, a glandular band involved in cocoon production, which can be saddle-shaped or annular. Male (usually on segments 13, 15, or 18) and female (always on segment 14) genital pores vary in number and location (1–5 pairs), and they are essential categorization indicators. The shape, quantity, and placement of genital marks vary, such as the papillae on the ventral surface of sexually mature worms. Lastly, either ventro-lateral or dorso-lateral nephridiopores openings of the excretory nephridia, whether meganephridia or micronephridia also exhibit taxonomically significant location.

1. Internal Structure

- *Testes*: Usually paired in segments 10 and 11 (*holandric*), or only in 10 (*proandric*) or 11 (*metandric*). Connected to *vas deferentia* and *male pores*. *Seminal vesicles*, often in segments 9 and 12, store maturing sperm.
- *Ovaries*: Almost always *metagynous*, paired in segment 13. Eggs exit through segment 14. *Ovisacs* may be present in segment 14.
- *Spermathecae*: Consist of a *duct and sac (ampulla)*, which may have outgrowths (*diverticula*) for sperm storage:
    - *Adiverticulate*: No outgrowths (e.g., *Drawida*)

- *Bidiverticulate*: Two diverticula (e.g., *Megascolex mauritii*, *Amynthas minimus*)
- *Polydiverticulate*: Multiple diverticula (e.g., *Hoplochaetella*)

Study Area

The present study was conducted across three distinct taluks: Taliparamba (Kerala), Mangalore, and Karkala (Karnataka)—each exhibiting unique geographical and ecological characteristics that influence earthworm diversity.

2. Taliparamba (12.05°N, 75.35°E)

Located in Kannur district of Kerala, Taliparamba spans an area of 1330.56 sq. km and includes 47 villages. The terrain extends from the coastal region of Ramanthali to the forested villages of Nuchyard and Vayathur near the Karnataka border. The average elevation is 56 meters above mean sea level. Five locations were selected for sampling: Vadavanthur, Annur, Kankol, Kandoth, and Vellur. The area features thick vegetation composed mainly of mango, jackfruit, and teak trees, alongside numerous shrubs. Portions of the forest are regarded as sacred groves. The agricultural landscape comprises plantations of coconut, areca nut, and banana.

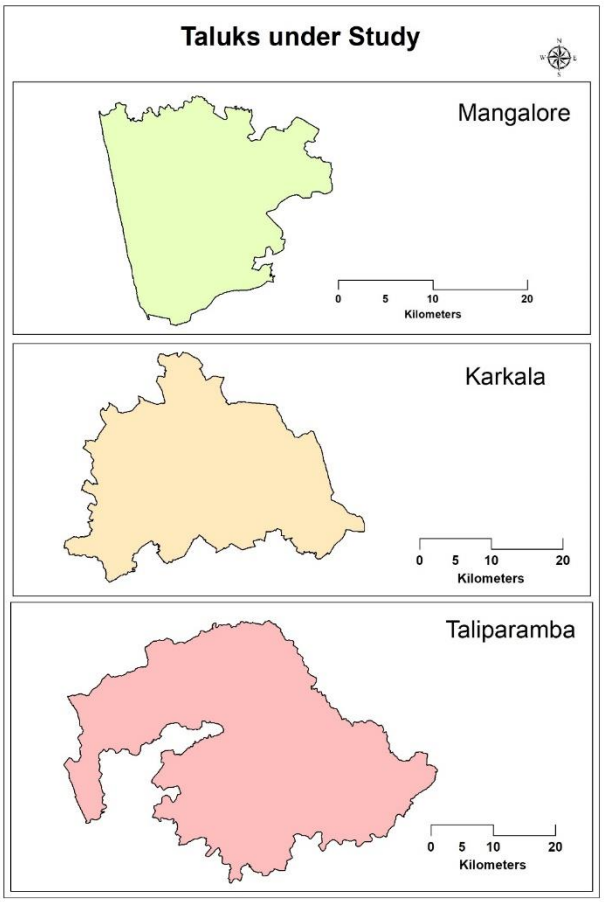


Figure 1. Study Areas

3. Mangalore (12.87°N, 74.88°E)

Situated along the western coast of India, Mangalore is the administrative center of the Dakshina Kannada district and covers an area of 132.45 sq. km. The region is bounded by the Arabian Sea to the west and the Western Ghats to the east, with elevations averaging 22 meters above sea level. The city exhibits a varied topography of plains, undulating terrain, hills, and valleys. Geologically, the hilly areas are dominated by laterite while coastal regions contain sandy soils. Vegetation is semi-evergreen with coconut, areca nut, and banana plantations dominating. Eleven localities were selected: Kannur, Adyar, Panambur, Kolya, Konaje, Thokottu, Attavar, Kottara, Muger, Kodical, and Kulur.

4. Karkala (13.2°N, 74.9°E)

Karkala taluk lies in Udupi district, Karnataka, at an elevation of 81 meters. The area is characterized by black rocky outcrops and dense forest cover. This region forms part of the Western Ghats, renowned for their biodiversity. Eight sampling locations were chosen: Nakre, Parappu, Renjala, Nallur, Borkatte, Kadari, and the edges of Anekere pond.

Methodology

5. Earthworm Collection:

Sampling was carried out using two standard methods:

- Digging and hand sorting method
- Quadrate method

At each sampling site, earthworms were collected in triplicate using a 30 x 30 cm quadrat, with soil excavated up to a depth of 30 cm. Collected earthworms were first anesthetized in 30% alcohol for two minutes, then preserved in 10% formalin. Dissection was carried out immediately post-anesthetization for anatomical study and identification using standard taxonomic keys by Blakemore (2006) and Julka (1998). All specimens were deposited in the department museum.

6. Soil Analysis:

Soil samples from three habitat types (agricultural, forest, and residential) in each taluk were analyzed for physical parameters including moisture content, pH, temperature, and electrical conductivity.

- Moisture content was estimated by oven-drying soil at 100°C for 8 hours. The percentage was calculated using the formula:

  Moisture content(%)=Wet weight - Dry weightTotal weight×100\text{Moisture content} (\%) = \frac{\text{Wet weight - Dry weight}}{\text{Total weight}} \times 100Moisture content(%)=Total weightWet weight - Dry weight×100

- pH was measured using a calibrated digital pH meter.
- Temperature was recorded at a soil depth of 10 cm at the time of collection.
- Electrical conductivity was measured by dissolving 1g of soil in 40ml distilled water using a Systronic water analyzer.

Results Summary

A total of 14 earthworm species were recorded from the study areas, belonging to five families:

- Moniligastridae: *Drawida barwelli*, *D. sp.1*, *D. sp.2*, *D. sp.3*, *D. sp.4*
- Glossoscolecidae: *Pontoscolex corethrurus*
- Eudrilidae: *Eudrilus eugeniae*
- Megascolecidae: *Pheretima houletti*, *Pheretima sp.*, *Metaphire houletti*, *Perionyx excavatus*
- Octochaetidae: *Konkadrilus stephensoni*, *Dichogaster affinis*, *D. sp.*

The agricultural habitats exhibited the highest species richness (10 species), followed by residential (5 species), and forest habitats (3 species). *Pontoscolex corethrurus* was the most widespread species, occurring in all three taluks across all habitat types. Other species showed restricted distribution:

- *Pheretima houletti* was limited to Mangalore and Taliparamba, in agricultural habitats.
- *Konkadrilus stephensoni* was recorded only in Karkala agricultural habitats.
- *Drawida sp.4*, *Dichogaster affinis*, and *Pheretima sp.* were exclusive to Taliparamba's agricultural areas.
- *Perionyx excavatus* was found in Mangalore and Karkala, in both agricultural and residential areas.

The findings are consistent with previous studies reporting these species from various regions including Australia, Taiwan, Bangladesh, Singapore, and different parts of India (Julka, 1988; Annapooma & Jothipriya, 1999; Hariprasad et al., 2005; Blakemore, 2006; Kathireshwari et al., 2008; Anushree et al., 2009; Siddaraju et al., 2010).

1. Soil Characteristics

Soil parameter values varied significantly across localities and habitat types:

- Moisture Content: Highest in Karkala across all habitats; lowest in Mangalore forest and Taliparamba agricultural and residential areas.
- pH: Highest in Mangalore forest, lowest in Karkala agricultural and residential habitats.
- Temperature: Highest in Mangalore, lowest in Karkala across all habitats.
- Electrical Conductivity: Highest in Karkala, lowest in Mangalore.

Table 1. Systematics of megadrile earthworms studied in taliparamba, mangalore & karkala taluks

SYSTEMATICS OF MEGADRILE EARTHWORMS STUDIED IN TALIPARAMBA, MANGALORE & KARKALA TALUKS		
SYSTEMATICS	**GENERA**	**SPECIES**
I. ORD: MONILIGASTRIDA		
1. Fam. Moniligastridae	1. *Drawida*	1. *D. barwelli* Beddard, 1886
		2. *D.* sp.1
		3. *D.* sp.2
		4. *D.* sp.3
		5. *D.* sp.4
II. ORD: HAPLOTAXIDA		
2. Fam. Glossoscolecidae	2. *Pontoscolex*	6. *P. corethrurus* Müller, 1856
	3. *Eudrilus*	7. *E. eugeniae* Kinberg, 1867
3. Fam. Eudrilidae		
4. Fam. Megascolecidae	4. *Perionyx*	8. *P. houletti* Gates, 1926
	5. *Pheretima*	9. *Pheretima* sp.
	6. *Metaphire*	10. *M. houletti* Perrier, 1872
	7. *Perionyx*	11. *P. excavatus* Perrier, 1872
5. Fam. Octochaetidae	8. *Konkadrilus*	12. *Konkadrilus stephensoni*
	9. *Dichogaster*	13. *D. affinis* Michaelsen, 1890
		14. *Dichogaster* sp.1

The systematics of megadrile earthworms investigated in the taluks of Taliparamba, Mangalore, and Karkala are shown in Table 1, where they are categorized under the two main orders Moniligastrida and Haplotaxida. The genus Drawida, which has five species, including the known Drawida barwelli (Beddard, 1886) and four unnamed species designated as D. sp.1 to D. sp.4, is the only member of the family Moniligastridae within the order Moniligastrida. The order Haplotaxida comprises several families: Glossoscolecidae, which includes the genus Pontoscolex with P. corethrurus (Müller, 1856); Eudrilidae, which includes Eudrilus eugeniae (Kinberg, 1867); Megascolecidae, which includes the genera Perionyx (P. houletti Gates, 1926 and P. excavatus Perrier, 1872), Pheretima (one unidentified species), and Metaphire houletti (Perrier, 1872); and Octochaetidae, which includes Konkadrilus stephensoni, Dichogaster affinis (Michaelsen, 1890), and one unknown Dichogaster species (Dichogaster sp.1).

The distribution and abundance of several earthworm species in the three taluks of Mangalore, Karkala, and Thaliparamba are compiled in Table 2 for the forest, agricultural, and residential habitats. With high abundance (marked +++) in all habitat categories across all three taluks, Pontoscolex corethrurus emerged as the most prevalent and abundant species, demonstrating its ecological flexibility. While other Drawida species (sp1–sp4) demonstrated restricted and habitat-specific presence, mostly in the forest and agricultural regions of Karkala, Drawida barwelli was found only in the forest habitat of Thaliparamba. In Karkala's forest habitat, Konkadrilus stephensoni and Drawida sp2 & sp3 were infrequently observed.

Only Thaliparamba's residential and agricultural environments were found to harbor Dichogaster affinis and Dichogaster sp., respectively. In Mangalore's agricultural and residential habitats as well as Karkala's residential regions, Perionyx excavatus was moderately to highly numerous. Metaphire houletti were found in Mangalore's agricultural and wooded regions. Pheretima sp. was widely distributed in Mangalore and Thaliparamba's agricultural areas. While Eudrilus eugeniae was only found in small numbers in Mangalore's residential and agricultural areas, an unnamed Perierima sp. was found only in Thaliparamba's residential sector. Overall, the distribution of species among the earthworms in the area shows both habitat specificity and a range of ecological tolerance.

Table 2. Species of Earthworm Collected in Different Habitat of Three Taluks

SPECIES OF EARTHWORM COLLECTED IN DIFFERENT HABITAT OF THREE TALUKS									
Location	**Mangalore**			**Karkala**			**Thaliparamba**		
Habitat Species	**Forest**	**Agriculture**	**Residential**	**Forest**	**Agriculture**	**Residential**	**Forest**	**Agriculture**	**Residential**
1. Drawida barwelli						+++			
2. Drawida sp1				++					
3. Drawida sp2					+				
4. Drawida sp3					++				
5. Drawida sp4								+	
6. Pontoscolex corethrurus	+++	+++	+++	+++	+++	+++	+++	+++	+++
7. Kohkardilus stephensoni					+				
8. Dichogaster affinis								+	+
9. Dichogaster sp						+			
10. Perionyx excavatus		++	+++			++			
11. Metaphire houletti	++		+++						
12. Pheretima sp		+++						+++	
13. Perierima sp								+++	
14. Eutrilus eugeniae		+	++						0
□ +++ = More Abundant □ ++ = Moderately Abundant □ + = Rare									

Table 3. Morphometric and Ecological Features of Earthworm Species

MORPHOMETRIC AND ECOLOGICAL FEATURES OF EARTHWORM SPECIES										
Family	**Species**	**Length (mm)**	**Diameter (mm)**	**No. of Segments**	**Clitellum Segments**	**Type of Clitellum**	**Prostomium**	**Male Pore Segments**	**Female Pore**	**Ecological Feature**
Moniligastridae	1. Drawida barwelly	70	10	111	10–14	Annular	Prolobic	10th	–	Endogeic
	2. Drawida sp1	80	10	229	10–13	"	"	11th	–	–
	3. Drawida sp2	85	10	180	10–14	"	"	11th	–	–
	4. Drawida sp3	93	10	254	12–16	"	"	–	–	–
	5. Drawida sp4	84	13	120	6–10	"	"	10th & 11th	11th	–
Glossoscolecidae	6.Pontoscolex corethrurus	100	5	181	14–21	Saddle-shaped	–	10th	–	–
Eudrilidae	7. Eudrilus eugeniae	102	11	154	15–14	Annular	Open epilobic	14th & 18th	14th	–
	8.Konkadrilus stephenson	155	8	225	14–17	Saddle-shaped	Prolobic	18th	19th–20th	–

	i									
Octochaetidae	9.Dichogaster affinis	89	12	93	15–21	–	Epilobic	13th	13th	–
	10.Dichogaster sp1	155	10	258	–	–	–	–	–	–
Megascolecidae	11. Perionyx excavatus	150	8	210	12–17	Saddle-shaped	Zygolobic	8th	–	–
	12. Metaphire houletti	72	8	100	5–9	Annular	Open epilobic	16th	14th	–
	13. Pheretima houletti	125	16	165	14–18	"	Closed epilobic	16th	6th, 7th, 8th	–
	14. Pheretima sp	96	12	113	14–17	"	Prolobic	16th	–	–

Significant variation in anatomical characteristics and ecological roles can be seen in the morphometric and ecological characteristics (Table 3.) of the earthworm species that were collected from Taliparamba, Mangalore, and Karkala. Drawida species, which belong to the Moniligastridae, with segment counts between 111 and 254 and lengths between 70 and 93 mm and diameters between 10 and 13 mm. Each has a prolobic prostomium and an annular clitellum, primarily between segments 10 and 16. While female pores are frequently unrecorded, male pores are usually found on the tenth or eleventh segment. Other Drawida species have unclear ecological roles, but Drawida barwelli is recognized as endogeic.

With 181 segments and a saddle-shaped clitellum, the widely dispersed Pontoscolex corethrurus (Glossoscolecidae) is slender (5 mm in diameter) (14–21). Eudrilus eugeniae (Eudrilidae) has an annular clitellum, a longer length of 102 mm, and a wider diameter of 11 mm. Its prostomium is open epilobic, with the female pore on the 14th segment and the male pores on the 14th and 18th segments. Larger (155 mm, 225 segments), Konkadrilus stephensoni has a prolobic prostomium and a saddle-shaped clitellum. Dichogaster affinis, a member of the Octochaetidae, has a clitellum that spans segments 15–21, a relatively short body (89 mm), a thick diameter (12 mm), and an epilobic prostomium. The 13th segment has both male and female pores. Despite its notable size, Dichogaster sp1 has no comprehensive anatomical records. The size and structure of the Megascolecidae family exhibit diversity. Perionyx excavatus has a saddle-shaped clitellum with a zygolobic prostomium. It is long (150 mm) and thin (8 mm) (12–17). The prostomial kinds and pore placements of Metaphire and Pheretima houletti are different; the former have open epilobic features, while the latter have closed epilobic features. Pheretima sp. has a well-developed clitellum and a prolobic prostomium (14–17). Overall, differences in body sizes, pore locations, prostomium form, and clitellum type serve as important taxonomic and ecological markers; nevertheless, ecological roles are still mostly unknown, with the exception of Drawida barwelli.

Table 4. Data of Soil Qualities in Different Habitats in the Study Area

DATA OF SOIL QUALITIES IN DIFFERENT HABITATS IN THE STUDY AREA					
Habitat	**Location**	**Moisture**	**pH**	**Temperature (°C)**	**Electric Conductance (µS)**
Forest	Taliparamba	31.2 ± 0.26	6.2 ± 0.047	23.17 ± 0.11	37.27 ± 11.59
	Mangalore	28.6 ± 0.23	6.26 ± 0.018	22.3 ± 0.345	34.57 ± 13.67
	Karkala	35 ± 1.54	6.23 ± 0.008	22.2 ± 0.29	61.05 ± 20.39
Residential	Taliparamba	23.4 ± 0.34	6.244 ± 0.01	23.25 ± 0.75	77.55 ± 26.31
	Mangalore	24.6 ± 0.11	6.23 ± 0.009	23.3 ± 0.415	68.77 ± 19.85
	Karkala	25.2 ± 0.08	6.16 ± 0.06	22.77 ± 0.19	75.17 ± 19.83
Agricultural	Taliparamba	28.6 ± 0.23	6.17 ± 0.006	24.07 ± 0.91	45.87 ± 2.35
	Mangalore	31.4 ± 0.11	6.16 ± 0.05	24.42 ± 0.39	44.67 ± 11.05

	Karkala	32.2 ± 0.08	6.16 ± 0.036	22.5 ± 0.145	49.42 ± 14.34

Significant differences in moisture content, pH, temperature, and electrical conductivity are found in the soil quality investigation of forest, residential, and agricultural habitats in the Taliparamba, Mangalore, and Karkala regions (Table 4.). The forest soils have superior water retention, with the highest moisture levels, particularly in Karkala (35%), followed by Taliparamba (31.2%) and Mangalore (28.6%). With a limited range of 6.16 to 6.26, the pH readings are slightly acidic in all habitats and sites, indicating a consistently moderately acidic soil character throughout the area. Forest soils are colder, particularly in Karkala (22.2°C), while agricultural habitats have the greatest soil temperatures (up to 24.42°C in Mangalore), probably as a result of open exposure and tillage techniques. Residential areas, especially Taliparamba, had the highest electrical conductance (77.55 µS), which indicates potential anthropogenic inputs or waste accumulation. Electrical conductance is a measure of soil salinity and nutrient content. On the other hand, conductivity is typically lower in forest soils; Mangalore has the lowest conductance (34.57 µS). These differences imply that land use has a major impact on soil conditions, with residential areas displaying indicators of environmental stress through greater conductance and forest habitats sustaining higher moisture but lower conductivity.

Taxonomy

2. Family: Moniligastridae (Claus, 1880)

3. *Drawida barwelli (Beddard, 1886) (Fig. 7)*

This species is distributed in the Karkala region and is commonly found in residential habitats. Individuals typically measure around 70 mm in length (ranging between 80–120 mm) and 10 mm in width (with a minimum width of 5 mm). The number of body segments ranges from 111 to 115 (generally between 90–120). Anterior secondary annulation begins after the 14th segment. The prostomium is prolobous, and each segment contains eight small setae. The segments have a wider anterior flange, while post-clitellar segments have a wider posterior flange. The clitellum is thin, indistinct, and occupies segments 10–14 (commonly from 9, 10 to 13 or 14). A pair of male pores are found at the furrowed tips of eversible pores on segment 10 (or between segments 10/11), while the female pores are located on the anterior margin of segment 12. Spermathecal pores are seen between segments 8–9 (7/8). No genital markings are observed.

4. *Drawida sp.1 (Fig. 14)*

Found in the forest habitats of Karkala, this species reaches a length of 80 mm and a width of 10 mm, with a total of 229 body segments. The prostomium is prolobous. The clitellum is present from segments 10 to 13. Male pores are located on the 11th segment. Spermathecal pores are situated between segments 7/8. Genital markings are absent.

5. *Drawida sp.2 (Fig. 9)*

This species is distributed in agricultural habitats of Karkala. It has a body length of about 85 mm and a width of 10 mm, with a segment count ranging from 180 to 182. The prostomium is prolobous. The clitellum spans segments 10 to 14. Male pores are located on the 11th segment, and genital markings are not visible.

6. Drawida sp.3 (Fig. 4)

Also recorded from agricultural habitats in Karkala, this species measures approximately 93 mm in length and 10 mm in width, with a total of 254 segments. The prostomium is prolobous. The clitellum occupies segments 12 to 14. Genital markings were not observed.

7. Prima sp. (Fig. 13)

This species is distributed in Taliparamba and is typically found in agricultural land. It measures about 96 mm in length and 12 mm in width, with 113–120 body segments. The prostomium is prolobous in form. The clitellum is located from the 14th to 17th segments. Male pores are found on the 16th segment, and no genital markings are observed.

8. 6. Perionyx excavatus (Perrier, 1872) (Fig. 10)

Perionyx excavatus is found in Mangalore and Karkala, inhabiting moist sandy soil, kitchen waste areas, and agricultural lands. The species shows variability in size, with lengths ranging from 50 to 180 mm (commonly around 150 mm) and widths between 2 and 3.5 mm (typically 13 mm). Segment count ranges from 115 to 155 (or up to 205–210). The anterior dorsum is violet-red with a distinctive blue iridescence, while the ventrum is pale cream. The prostomium is zygolobous. The annular clitellum spans segments 12–17 (sometimes noted as 13–17). Male pores are situated on the 18th segment (or at the junction of 18th/19th), while a single central female pore is present on the 14th segment. Two pairs of spermathecal pores are located between segments 7/8 and 8/9. Spermathecae are found in segments 8 and 9 and feature large tapering or bilobed ampullae. Genital markings are not present.

9. 7. Metaphire houletti (Perrier, 1972) (Fig. 1)

Reported from Mangalore, Metaphire houletti inhabits forested regions and garden soil. The body length is typically around 100–120 mm (recorded minimum: 72 mm), with a width ranging from 3 to 7 mm (typically 8 mm). The body is reddish-brown in color, and the total number of segments varies from 92 to 200 (commonly 100–105). The prostomium is of the open epilobous type. The clitellum is annular and located between segments 5–9 (alternatively cited as 14–16). Male pores are found on the 16th or 18th segment, and a medio-ventral female pore is situated on the 14th segment. No genital markings are observed.

10. 8. Dichogaster affinis (Michelson, 1890) (Fig. 11)

This species is distributed in the Taliparamba region, where it is found in both agricultural and residential habitats. It measures approximately 89 mm in length (sometimes noted as 84 mm) and 12 mm in width. The number of segments ranges from 93–100 (can extend to 110–150). Although the body is generally pigmentless, the anterior region appears pinkish-red. The prostomium is closed epibolous. The clitellum is saddle-shaped and spans segments 15–21 (sometimes 13–21). Male pores are located in tumid seminal grooves on the 13th segment (occasionally reported as 18th). Genital markings are absent.

Family: Glossoscolecidae

11. 9. Drawida sp. 4 (Fig. 2)

This species is distributed in Taliparamba and found predominantly in agricultural habitats. The average length is about 84 mm, with a width of 13 mm and 120–123 body segments. The prostomium is prolobous. The clitellum spans segments 6–11. Male pores are present on the 10th and 11th segments, while a single female pore is located on the 11th segment. No genital markings are observed.

12. Family: Eudrilidae (Claus, 1880)

1. Pontoscolex corethrurus (Müller, 1856) (Fig. 12)

This species is widely distributed across Karkala, Mangalore, and Taliparamba. It thrives in moist soils and is commonly found in sacred groves, gardens, and agricultural land. The length ranges from 70 to 120 mm (typically around 100 mm) with a width of about 5–6 mm. The worm has 166–200 segments (commonly 181–184). It is unpigmented, with a yellow anterior and orangish-yellow clitellum. The prostomium is prolobous. The clitellum is saddle-shaped and spans segments 14–21 (sometimes 15–23). Male pores are minute and located at the 10th (sometimes noted as 17th) segment; female pores are possibly present on the 14th. Spermathecal pores are minute and found between segments 6/7, 7/8, and 8/9. No genital markings are seen.

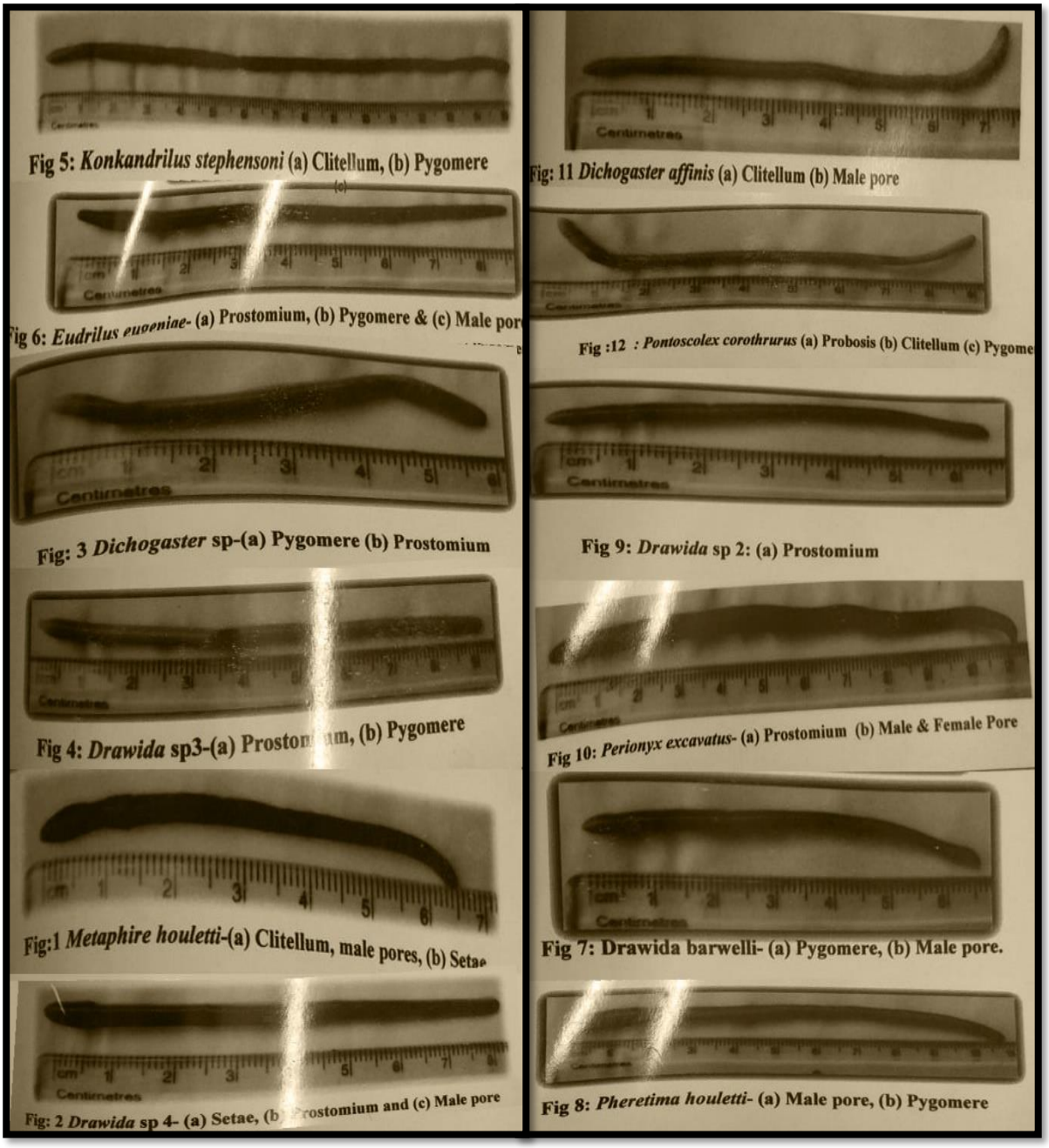
2. Eudrilus eugeniae (Kinberg, 1867) (Fig. 6)

Found in Mangalore and Taliparamba, Eudrilus eugeniae typically inhabits areas with residential waste. It measures around 102 mm in length (ranging from 90 to 185 mm), with a width between 5–8 mm (commonly 11 mm). The species has 145–196 segments (typically 153–155). Its coloration ranges from red-brown to dark violet. The prostomium is small and open epilobous. The clitellum is found between segments 14–18 (usually 15–18). Male pores are on the 14th and 18th segments (sometimes 17/18), and female pores are merged with spermathecal pores on the 14th segment. Genital markings are not observed.

13. Family: Megascolecidae (Rosa, 1891)

1. Pheretima houletti (Gates, 1926) (Fig. 8)

This species is found in Mangalore and Taliparamba, particularly in coconut and areca plantations. Individuals measure between 75 and 180 mm in length (commonly 125 mm) and have a width of 3–5 mm (up to 15 mm). The total number of segments ranges around 160–165. The prostomium is of the open epilobous type. The clitellum is annular and extends from the 14th to 18th segments (sometimes noted as 14–16). Male pores are found in copulatory pouches on the 16th segment (also recorded as 18th), while a single female pore is located on the 14th segment. Spermathecal pores appear as four pairs between segments 5/6 and 8/9. Genital markings are absent.



14. Family: Octochaetidae

1. Konkandrilus stephensoni (Fig. 5)

This species is found in the agricultural soils of Karkala. It has a total body length of approximately 155 mm and a width of 8 mm, with 225 segments. The prostomium is prolobic, and the clitellum is located between segments 14 and 17. Male pores are situated on the 18th segment, and female pores are observed between the 19th and 20th segments. No genital markings are evident.

2. Dichogaster sp. (Fig. 3)

Also recorded from Karkala, this species is found in both agricultural and residential habitats. It reaches a length of 155 mm and a width of 10 mm, comprising 258 body segments. The prostomium is epilobic. The clitellum is not clearly defined in the specimen, and genital markings are not observed.

Conclusion

Numerous species from families such as Moniligastridae, Glossoscolecidae, Eudrilidae, Megascolecidae, and Octochaetidae were found in a research on earthworm diversity in the Karkala, Mangalore, and Taliparamba regions. Among the common species are Eudrilus eugeniae, Pheretima houletti, Konkandrilus stephensoni, Metaphire houletti, Dichogaster affinis, Pontoscolex corethrurus, Drawida barwelli, Drawida spp., Prima sp., and Perionyx excavatus. These earthworms were found in a variety of settings, including residential areas, woodlands, agricultural lands, and sacred groves. In addition to having an annular or saddle-shaped clitellum and a prolobous or epilobous prostomium, the majority of species differ greatly in length (50–185 mm), breadth (2–15 mm), and segment count (90–258). The majority of genital markings are lacking, and species identification is aided by pore locations and clitellum position. This diversity is a reflection of the region's habitat variation and biological richness.

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