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Zoological Record

An Update of Species in the *Metaphire genus* along with *Metaphire inclara* (Gates, 1932) (Oligochaeta: Megascolecidae): A New Record in India

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ABSTRACT

This study was conducted to contribute to the understanding of Asian biodiversity in terms of earthworms. Specimens were collected from the soil, fixed in 5% formalin, transferred to ethanol for preservation, and examined using a stereomicroscope with taxonomic characteristics. This study presents the initial documentation of *Metaphire inclara* (Gates, 1932) in India. This increased the number of species in the genus of *Metaphire* from 11 to 12 for India. As updated, the species in the genus of *Metaphire* in India are *Metaphire andamanensis* (Michaelsen, 1907), *Metaphire anomala* (Michaelsen, 1907), *Metaphire bahli* (Gates, 1945), *Metaphire birmanica* (Rosa, 1888), *Metaphire californica* (Kinberg, 1867), *Metaphire harrietensis* (Stephenson, 1925), *Metaphire houlleti* (Perrier, 1872), *Metaphire peguana* (Rosa, 1890), *Metaphire planata* (Gates, 1926), *Metaphire posthuma* (Vaillant, 1868), and *Metaphire scitula* (Gates, 1936). We offer a concise description, distribution data, an identification key, and a comprehensive species list for the taxa under investigation.

Keywords: Earthworms, India, *Metaphire*, new record, taxonomy

INTRODUCTION

Earthworms are widely recognized as ecosystem engineers. Their burrowing and feeding activities significantly impact soil quality, contributing to a healthy and productive environment (Lavelle et al., 2006). Due to their sensitivity to environmental changes, earthworms serve as critical bioindicators, frequently employed in environmental assessments and contaminant studies (Howmiller & Beeton, 1971; Julka, 1988; Weber, 2007; Martins et al., 2008; Ozdemir et al., 2011; Pelosi & Röembke, 2016; Velki & Ecimović, 2017). Additionally, earthworms facilitate the breakdown of various organic wastes, transforming them into readily usable micronutrients and natural fertilizers, thereby enhancing

soil fertility (Dash & Senapat, 1986; Reynolds & Eggen, 1993).

Earthworms, particularly those of the *Metaphire* genus, play crucial roles in various ecosystems due to their ecological functions and medicinal value. Some species in this genus have significant importance in both ecological and medicinal contexts (Yu et al., 2021). Potential impact on soil properties and role in influencing N2O emissions, highlighting their contributions to greenhouse gas dynamics in soil environments (Luo et al., 2013; Singh et al., 2020). The genetic diversity and population structure of *Metaphire* species have been research subjects, shedding light on the evolutionary relationships within this genus. Studies on the molecular systematics and phylogeography of *Metaphire* earthworms have provided insights into their evolutionary history and geographic distribution (Chang et al., 2008). Furthermore, the high-quality genome assembly of some species of the genus *Metaphire* has facilitated a deeper understanding of the genetic makeup and potential traits of this earthworm species (Jin et al., 2020).

India boasts an impressive earthworm fauna, encompassing 453 species distributed across ten families: Moniligastridae, Lumbricidae, Almidae, Rhinodrilidae, Acanthodrilidae, Eudrilidae, Ocnerodrilidae, Benhamiidae, Octochaetdae, and Megascolecidae (Narayanan et al., 2020, 2021, 2022; Ahmed et al., 2022). While occupying only roughly 2% of the world's landmass, India remarkably harbors 10.5% of the planet's known earthworm species (Julka et al., 2009). This translates to one of the highest earthworm biodiversity levels globally, with a striking level of endemism at both genus and species levels. Approximately 71% of genera and 85% of earthworm species found in India are unique to the country (Julka & Paliwal, 2005). Within India, the Western Ghats biodiversity hotspot and the western coastal plains emerge as the regions with the richest earthworm diversity, accounting for nearly 53% of the nation's earthworm species diversity.

The genus *Metaphire* Sims and Easton, 1972, ranks among the largest within the earthworm family Megascolecidae and dominates East and Southeast Asian earthworm communities. Currently, it encompasses about 200 nominal species, primarily distributed across 22 informal species groups. Distinctive morphological features include copulatory pockets housing the male pores, gut uvulae originating from the 27th segment, and the absence of nephridia on the vas deferens (Sims & Easton, 1972; Blakemore, 2012).

Globally, over 6,000 earthworm species have been described, of which 3,000-3,500 are considered valid (Csuzdi, 2012; Reynolds & Wetzel, 2024). Among these, approximately 150 species exhibit peregrine distribution (Blakemore, 2006, 2012). Extensive research efforts have shed light on global earthworm

diversity (Mısırlıoğlu et al., 2023; Sautter et al., 2006; Razafindrakoto et al., 2010).

Understanding Indian earthworm taxonomy has significantly benefited from the contributions of numerous researchers, including Michaelsen (1907, 1909), Stephenson (1914, 1916, 1923, 1925), Gates (1926, 1932, 1933, 1936, 1937, 1945, 1955, 1958, 1959, 1972, 1976), Halder (1998, 1999, 2003), Halder and Julka (1967), Julka (2014, 1976, 1988), Julka and Senapati (1987), Julka et al. (2009), Halder and Dhani (2005), Halder and Gosh (1997), Halder et al. (2004, 2007), Soota and Halder (1980, 1981), Soota and Julka (1970), Hasan et al. (2018a, 2018b, 2019, 2022, 2023), Ghosh et al. (2019, 2020), Bora et al. (2021), Beddard (1900), Dash and Senapat (1986), Verma and Yadav (2011), Verma et al. (2010). Additionally, international experts like Blakemore (2006, 2012), Görres and Melnichuk (2012), Gorsuch and Owen (2014), Howmiller and Beeton (1971), Hatai (1930, 1931), Shen et al. (2005), Thai (1984), Thai et al. (1992), Shen and Yeo (2005), Tsai et al. (2004), Nguyen et al. (2017), Kobayashi (1936a, 1936b), Perrier (1872), Reynolds (1978, 1994a, 1994b, 2009, 2014, 2018, 2022), Rosa (1888, 1890), Razafindrakoto et al. (2010), Vaillant (1868) and Weber (2007) have provided valuable insights on Indian earthworm species.

OBJECTIVES OF THE STUDY

The objective of the study is to contribute to Asian biodiversity by reporting *Metaphire inclara*, which is naturally distributed in India but has not been reported yet, and creating a key for the genus *Metaphire*.

MATERIALS AND METHODS

Earthworms were collected from the soil through manual excavation and physical sorting, focusing on typical microhabitats such as fallen logs and leaf litter. Specimens were then fixed in 5% formalin before being transferred to ethanol for preservation. Morphological observations were conducted using a stereomicroscope (Leica EZ4HD) with outlines drawn using an attached drawing tube. Following preservation, species identification was confirmed using caliper measurements. Voucher specimens have been deposited at the Zoological Survey of India.

Materials Examined

01ex. Tirap district, Arunachal Pradesh. Coll. S. Biswas and Party, the date of the collected specimen was 28. xii. 1984. Reg. No. ZSI-An7512/2.

RESULTS AND DISCUSSION

The species belonging to the genus *Metaphire* recorded so far in India are described below.

Systematics

Class Clitellata Michaelsen, 1919
Subclass Oligochaeta Grube, 1850
Order Crassiclitellata Jamieson, 1988
Family Megascolecidae Rosa, 1891
Genus *Metaphire* Sims and Easton, 1972

Type species. *Rhodopis javanica* Kinberg, 1867, by monotype.

Diagnosis. Clitellum annular on 14-16. Prostomium epilobic. Male pore, usually single or paired in 18. Female pore, single or paired in 14. Setae perichaetin. Intestinal origin in 15. Prostate glands racemose.

3.1. *Metaphire andamanensis* (Michaelsen, 1907)

1907. *Pheretima andamanensis* Michaelsen, Mitt. Naturhist. Mus. Hamburg 24: 164; Type: ZMUH 7169, ZSIC 2823. (Reynolds and Wetzel 2024).
1972. *Pheritima andamanensis*-Gates, Trans. American Philos. Soc. 62: 157.
1972. *Metaphire andamanensis*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 217.

Distribution

India (Andaman and Nicobar Islands: North Cinque Island) (Michaelsen 1907, 1909).

3.2. *Metaphire anomala* (Michaelsen, 1907)

1907. *Pheretima anomala* Michaelsen, J. Hamburg wiss. Anst. 24(2): 167; Type: MNHU 4273, ZMUH 7185 (Reynolds and Wetzel, 2024).
1972. *Metaphire anomala*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 237.

Distribution

India (West Bengal, Madhya Pradesh; Uttar Pradesh) (Halder, 1999). Elsewhere. Myanmar, Thailand (Halder, 1999).

3.3. *Metaphire bahli* (Gates, 1945)

1945. *Pheretima bahli* Gates, Spol. Zeyl. 24: 85; Type: missing (Reynolds and Wetzel 2024).
1972. *Metaphire bahli*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 239.

Distribution

India (Kerala) (Narayanan et al., 2020).

3.4. *Metaphire birmanica* (Rosa, 1888)

1888. *Perichaeta birmanica* Rosa, Ann. Mus. Genova (2), 26: 164; Type: MGDG 44041, MNHU 2274 (Reynolds and Wetzel, 2024).
1900. *Pheretima birmanica* Michaelsen, Das Tierreich, 10: 255.
1972. *Metaphire birmanica*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 238.

Distribution

India (West Bengal, Himachal Pradesh, Uttar Pradesh) (Halder, 1999).

3.5. *Metaphire californica* (Kinberg, 1867)

1867. *Pheretima californica* Kinberg, Öfv. Akad. Förh. 23: 102; Type: NHRS 160 (Reynolds and Wetzel, 2024).
1972. *Metaphire californica*-Sims and Easton,. J. Linn. Soc. 4(3): 238.

Distribution

India (West Bengal). **Elsewhere**. South Africa, Greece, Egypt, Lebanon. China, Japan: Bunna, Malay Peninsula, Indonesia, Hong Kong; Australia; U.S.A., Mexico, some islands in the Pacific and Atlantic Ocean; South America (Halder, 1999).

3.6. *Metaphire harrietensis* (Stephenson, 1925)

1925. *Pheretima harrietensis* Stephenson, Rec. Indian mus. 27: 59; Type: ZSIC 1222 (Reynolds and Wetzel, 2024).
1972. *Metaphire harrietensis*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 238.
Distribution

India (Andaman & Nicobar Islands: Mount Harriet) (Stephenson, 1925).

3.7. *Metaphire houlleti* (Perrier, 1872)

1872. *Perichaeta houllet* Perrier, Nouv. Arch. Mus. Hist. Nat. Paris 8: 99: Type: MNHN (Reynolds and Wetzel, 2024). .
1972. *Pheretima houletti*-Gates, Trans. American Philos. Soc. 62: 190.
1972. *Metaphire houletti*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 238.

Distribution

India (Andaman and Nicobar Island, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal).

Elsewhere

Australia, Bahamas, Cambodia, China, Cuba, El Salvador, Fiji, France, French Guiana, Guadeloupe, Indonesia, Laos, Madagascar, Malaysia, Mexico, Myanmar, Nepal, Papua New Guinea, Philippines, Sierra Leone, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam (Hasan et al., 2023).

3.8. *Metaphire peguana* (Rosa, 1890)

1890. *Perichaeta peguana* Rosa, Ann. Mus. Genova (2), 30: 113; Type: MGDG 44037 (Reynolds and Wetzel, 2024).
1900. *Pheretima peguana*-Michaelsen, Das Tierreich, 10: 292.
1972. *Metaphire peguana*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 239.

Distribution

India (Kerala, Andaman and Nicobar Islands, Tamil Nadu, Tripura, West Bengal).

Elsewhere

Indonesia, Malaysia, Myanmar, Singapore, Thailand, Vietnam (Halder, 1999).

3.9. *Metaphire planata* (Gates, 1926)

1926. *Pheretma planata* Gates, Ann. Mag. Nat. Hist., 9: 411; Type: USNM 19312, BMNH 1928:4:2:1, ZSIC 3084 (Reynolds and Wetzel, 2024).
1972. *Metaphire planata*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 239.

Distribution

India (Andaman and Nicobar islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Puducherry, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, and West Bengal).

Elsewhere

Australia, Barbados, China, Jamaica, Fiji, Indonesia, Japan, Korea, Madagascar, Malaysia, Mexico, Mozambique, Myanmar, New Zealand, Philippines, Reunion, Samoa, South Africa, Sri Lanka, Taiwan, Trinidad and Tobago, United Kingdom, United States and Vietnam (Hasan et al., 2023).

3.10. *Metaphire posthuma* (Vaillant, 1868)

1868. *Perichaeta posthuma* Vaillant, Mém. Acad. Montpellier 7: 146; Type: Cat. No MNHN 656-71. (Reynolds and Wetzel, 2024)
1972. *Pheretima posthuma*-Gates, Trans. American Philos. Soc. 62: 212.
1972. *Metaphire posthuma*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 217.

Distribution

India (Andaman and Nicobar Island, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh (Solan: Nalagarh), Jammu and Kashmir, Jharkhand, Karnataka, Meghalaya, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttarakhand, Uttar Pradesh, West Bengal).

Elsewhere

Bangladesh, Cambodia, China, Indonesia, Mexico, Myanmar, Northern Mariana Island, Pakistan, Philippines, Taiwan, Thailand, United States, United Kingdom, Vanuatu and Vietnam (Halder, 1999).

3.11. *Metaphire scitula* (Gates, 1936)

1936. *Pheretima scitula* Gates, Rec. Indian Mus. 36: 457; Type: ZSIC 3308 (Reynolds and Wetzel, 2024).
1972. *Metaphire scitula*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 238.

Distribution

India (Andaman & Nicobar Islands: Port Blair) (Gates, 1936).

3.12. *Metaphire inclara* (Gates, 1932)

1932. *Pheretima inclara* Gates, Rec. Indian Mus. 34: 439, 444; 1 specimen from the young collections without indication as to locality; Type: missing (Reynolds and Wetzel, 2024).
1972. *Metaphire inclara*-Sims and Easton, Biol. J. Linn. Soc. 4(3): 239.

Brief Description

Length 211 mm. Greatest diameter 6 mm. Number of segments 123. The dorsum anterior to the clitellum is a light bluish grey; the clitellum is brownish grey. The setae begin, apparently, only on segment 3 and are small and closely crowded; the setal circles without dorsal or ventral breaks. The spermathecal setae on 6 are 30; on 7, 30; the male setae on 17 are 27; on 18, 24; on 19, 31; there are about 125 setae on segment 20. The first dorsal pore is in 12/13. The clitellum is annular, extending from 13/14-16/17; intersegmental furrows, dorsal pores and setae lacking. The spermathecal pores are minute; three pairs in 5/6-7/8. There is a single female pore on 14. The male pores are minute, each at the end of a tiny cone which probably represents a protuberance from a very small, male-pore disc; the disc surrounded by five complete or nearly complete concentric, circular furrows, external to which are additional shorter furrows. There are no genital markings. Internal anatomy. Septa 5/6-7/8 are muscular, 6/7-7/8 thicker than 5/6; 8/9 is present ventrally; 9/10 is lacking; 10/11 and 11/12 are thickly muscular; 12/13-13/14 are strengthened and translucent. There is a small, post-gizzard, glandular, oesophageal collar; lobulated. On this collar are ovoid, whitish, parasitic bodies, each of which is nearly surrounded by a reddish coagulum (blood). The intestinal caeca are simple, extending from 27 into 23. There are masses of nephridia in 5 and 6 segments and blood glands in 5. The single commissure of 9 is on the right side. There is probably a single median testis sac for each of segments 10 and 11. The seminal vesicles of 11 are small, flattened, leaf-like bodies, each with a well-developed, ovoid, mid-dorsal, primary ampulla. The vesicles of 12 are also small but are slightly more elongated in a vertical direction; each vesicle is also provided with a well-developed primary ampulla. The prostates

are large, extending through 16-20. The prostatic ducts are about 7 mm. in length, looped, the ectal half slightly thicker than the ental half. The spermathecal duct is shorter than the ampulla, the diverticulum is tubular and passes into the anterior face of the duct within the parities (Figure 1).

Distribution

India (Arunachal Pradesh) (This study)

Elsewhere

Burma (Gates, 1932)

Key to species of the genus *Metaphire* Sims & Easton, 1972 in India is given below.

1. Male pores on xx……..…..... *Metaphire anamola*
1'. Male pores on xvii……..…….…….……2
2. Spermathecal pores four pairs……..…..…….. *Metaphire posthuma*
2'. -Spermathecal pores less than four pairs…….....….3
3. Two pairs of spermathecal pores…….....4
3'. -Three pairs of spermathecal pores…….....…5
4. Spermathecal pores at 6/7-7/8…….….... *Metaphire planata*
4'. Spermathecal pores at 7/8-8/9……...….... *Metaphire californica*
4". Spermathecal pores intersegmental, in 7/8, 8/9…....*Metaphire andamanensis*
5. Spermathecal pores 3 pairs at 5/6-7/8…..……...….*Metaphire birmaniaca*
5'. Spermathecal pore three pairs, in furrows 6/7/8/9….....*Metaphire bahli*
5". Genital markings, when present.....6
5"'. Genital markings, when absent….....……7
6. Genital marking two pairs across 17/18 and 18/19.....*Metaphire peguana*
6'. Genital markings, in the vicinity of spermathecal pore.....*Metaphire houlleti*
6". Genital markings in two median patches of ca. 9 irregular transverse rows each, on 18.....*Metaphire harrietensis*
7. Prostate gland in 16-20 segment.....*Metaphire iclara*
7'. Prostate gland in 17-19 segment.....*Metaphire scitula*

The taxonomic characters of all Metaphire species are presented in Table 1. Their state-wise distribution within India is further illustrated in Table 2 and Figure 2, while Figure 3 depicts the state-wise species diversity. Notably, the genus's known range currently extends primarily to Myanmar, as reported by Gates (1932). However, vast unexplored regions within India, coupled with its historical role as a trading hub for millennia, suggest the potential for further intensive studies to reveal the presence of numerous hitherto unknown exotic species within the country.

Table 1

Character comparison among the Metaphire species found in Arunachal Pradesh State, India

Character	*M. andamanensis*	*M. anomala*	*M. bahli*	*M. birmanica*	*M. californica*	*M. harrietensis*	*M. houlleti*	*M. peguana*	*M. planata*	*M. posthuma*	*M. scitula*	*M. inclara*
Length (mm)	108-120	134-154	76–121	85-210	56-132	200	40–240	115–240	64-176	60-140	100-200	211
Diameter (mm)	6-6.5	4.6-6.6	4–5	5.8-6.7	3-5	11.5	2.6–7	4.2–8	4-7	3-8	5	6
Segments	110	77-118	79–119	105-111	85-115	123	73–200	97–125	115-142	91-140	?	123
Prostomium	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open	Epilobous open
First dorsal pore	12/13	12/13	12/13	12/13	12/13	12/13	Often in 9/10 or11/12, sometimes in 7/8–12/13	12/13	10/11	12/13	12/13	12/13
Spermathecal pore	6/7/8/9	5/6-7/8	6/7/8/9	5/6-7/8	7/8/9	6/7-8/9	6/7/8/9	6/7/8/9	6-8	5/6-8/9	6/7, 7/8, 8/9	5/6-7/8
Genital markings	On 18, median to copulatory pouches.	17-19, or 17-23, or absent	17/18 and 18/19, invaginate	Absent	Absent	presetal and postsetal in 18	Usually absent, when present near spermathecal pores	17/18 and 18/19, nearly elliptical pads with slit-like central apertures	Absent	on 14-30, but usually on 17and 19.	Absent	Absent
Clitellum	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	13/14-16/17
Male pore	18	20	18	18	18	18	18	18	18	18	18	18
Female pore	14	14	14	14	14	14	14	14	14	14	14	14
Morphology of male region	Strongly concave	Strongly concave	Strongly concave	Strongly concave	Strongly concave	Strongly concave	Not concave	Not concave	Not concave	Strongly concave	Strongly concave	Strongly concave
Spermathecal diverticula origin	Entally	Entally	Entally	Entally	Entally	Entally	Entally	Entally	Entally	Entally	Entally	Entally
Intestinal caeca	18-23	**17-23**	27-24	**27-25**	**15-22**	**27-?**	27–22	27–22	**27-20**	**26-24**	**26-?**	15-18
Gizzard	between septa 7/8 and 10/11	large within 9-10	in segment 8	within 9-10	within 9-10	between septa 7/8 and 10/11	within 9-10	within 9-10	in segment 8	within 9-10	between septa 7/8 and 10/11	between septa 7/8 and 10/11
Last pair of heart	13	13	13	13	13	13	13	13	13	13	13	13
Prostate	Racemose in 17–20	Racemose in 17–22	Racemose in 17–20	Racemose in 17–21	Racemose in 16–22	Racemose in 17–21	Racemose in 16,17–20, 21.	Racemose in 16–21	Racemose in 16–21	Racemose in 15–21	Racemose in 17–19	Racemose in 16–20

Table 2

Metaphire species list in India

Species	**Zoogeographical distribution**	**Ecological category**	**Habitats**
M. andamanensis (Michaelsen, 1907)	Endemic	Epi-endogeic	Cultivation, grassland
M. anomala (Michaelsen, 1907)	Non-native	Epi-endogeic	Natural forest and anthropogenic areas.
M. bahli (Gates, 1945)	Non-native	Epi-endogeic	Natural forest and anthropogenic areas.
M. birmanica (Rosa, 1888)	Non-native	Epi-endogeic	Deep clay substrates.
M. californica (Kinberg, 1867)	Non-native	Epi-endogeic	Residential gardens and natural forests
M. harrietensis (Stephenson, 1925)	Endemic	Epi-endogeic	Cultivation, grassland
M. houlleti (Perrier, 1872)	Non-native	Epi-endogeic	Cultivation, grassland
M. peguana (Rosa, 1890)	Non-native	Epi-endogeic	Forest, wastewater saturated soil from households.
M. planata (Gates, 1926)	Non-native	Epi-endogeic	Cultivation, grassland
M. posthuma (Vaillant, 1868)	Non-native	Epi-endogeic	Cultivation, grassland
M. scitula (Gates, 1936)	Non-native	Epi-endogeic	Cultivation, grassland
M. inclara Gates, 1932	Native	Epi-endogeic	Cultivation, grassland

Figure 1

Metaphire inclara (A)-DBV-Dorsal blood vesicle, SV-Seminal vesicle, GZ-Gizzard, PH-Pharynx; (B)-PG-Prostate gland (C)-PM-Prostomium, PE-Peristomium, AN-Anus; (D)-CLR-Clitellar region, PSA- Perichaetin setal arrangement

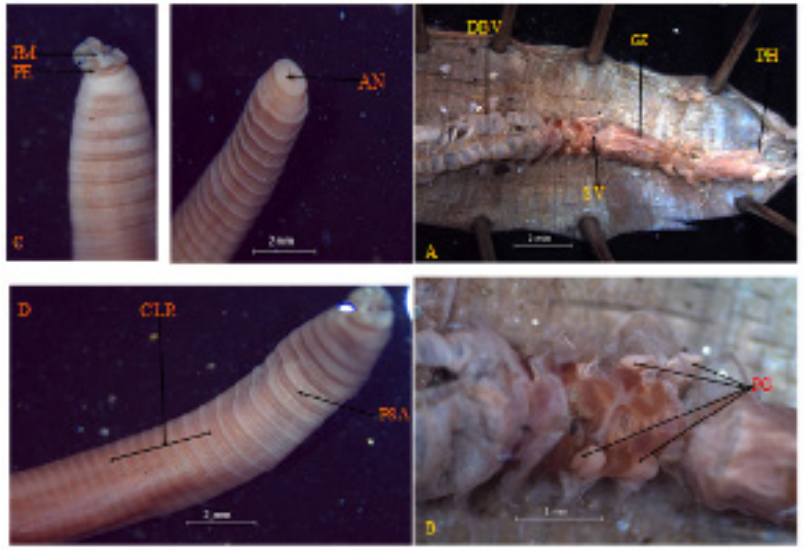


Figure 2

State wise distribution of genus Metaphire species in India

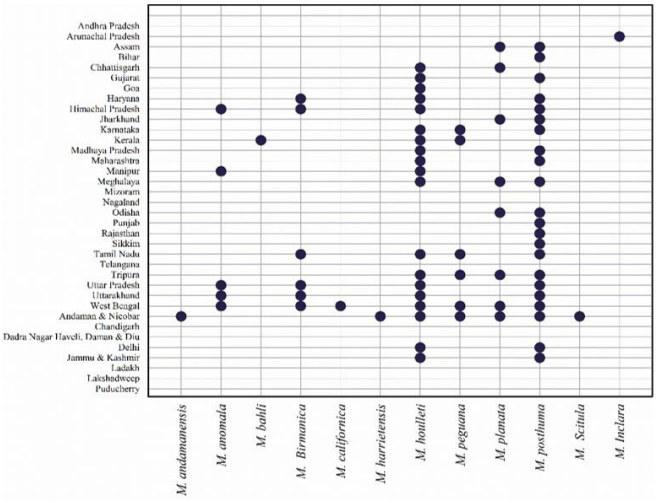
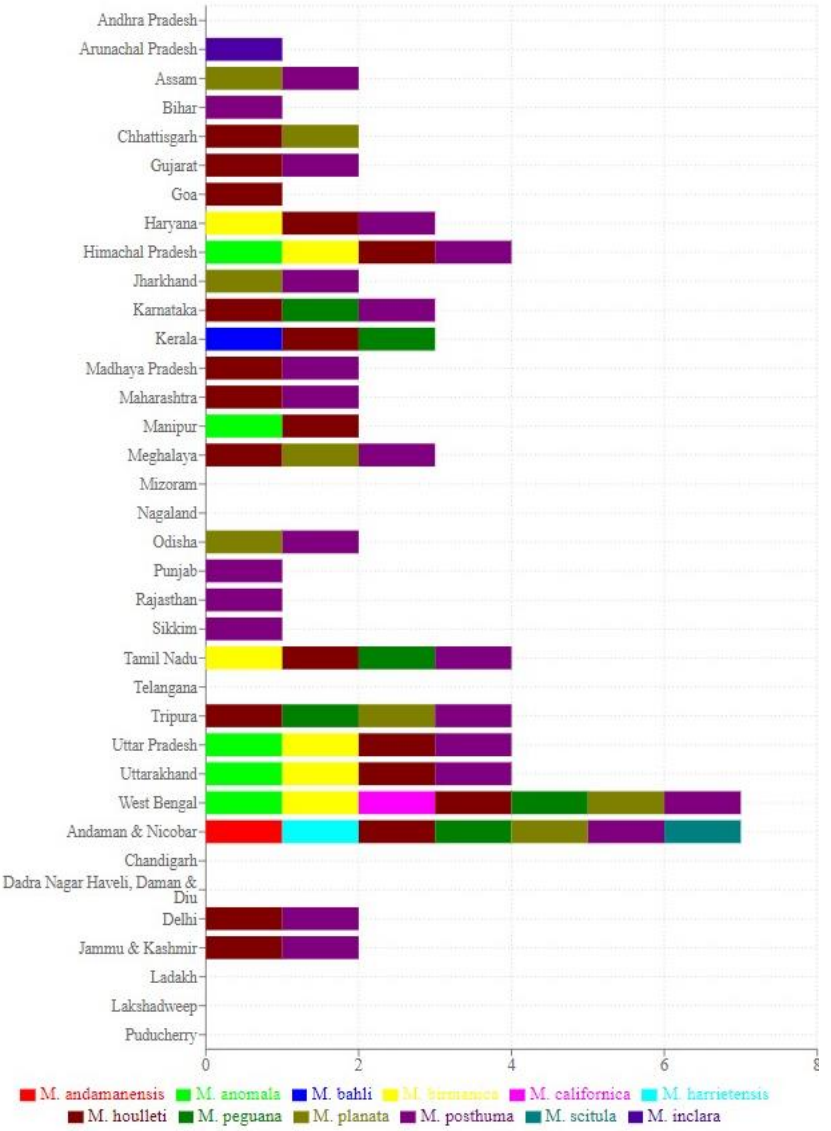


Figure 3

State wise species diversity of genus Metaphire in India



Metaphire inclara falls morphologically within the *M. peguana* species group, joining fellow members *M. peguana peguana* (Rosa, 1890), *M. peguana laisonensis* (Nguyen & Nguyen, 2017), and *M. doiphamon* (Bantaowong & Panha, 2016). This group shares similarities in spermathecal spore number and position, genital markings, and male region morphology (Bantaowong et al., 2016; Blakemore, 2016; Nguyen et al., 2017). However, species differentiation occurs in size, male region genital marking shape, spermathecal diverticula origin, and prostate shape (Bantaowong et al., 2016; Nguyen et al., 2017). Notably, *M. inclara's* initial description stemmed from Burma (Gates, 1932), making this present record from Arunachal Pradesh its first documented occurrence in India.

India harbors 12 species within the genus *Metaphire*, as detailed in the preceding tables and figures. Notably, this marks the first record of *M. inclara* since its original description by Gates in 1932, based on eleven specimens collected from dense jungle soil in Myanmar. The species name itself references the absence of a clearly defined margin surrounding the male pores.

Recent advancements in earthworm taxonomy and ecology have been significantly influenced by molecular phylogenetic techniques, leading to notable progress in understanding earthworm diversity and relationships (Marchán et al., 2022). DNA barcoding has emerged as a powerful tool for identifying earthworm species, complementing traditional morphology-based taxonomy (Hijam et al., 2022). These molecular approaches have enabled researchers to more accurately differentiate between earthworm species, contributing to a deeper comprehension of their genetic variance and population structures (Heimburger et al., 2022). Studies have emphasized the significance of earthworm casting activity in soil ecosystems, highlighting how the chemical composition of earthworm casts can offer insights into their ecological contributions and habitat sustainability (Iordache, 2023). However, the molecular methods could not be used in this study due to budgetary constraints. We think that it would be useful to consider this issue in future studies.

CONCLUSIONS

The presence of 12 *Metaphire* species in India, including globally widespread members, suggests India as a favorable habitat for this genus. Among these, *Metaphire inclara* exemplifies this adaptability, thriving in forest soils yet demonstrating tolerance for diverse environments. Given the multifaceted impacts of climate change, targeted surveys in additional Indian states, like Arunachal Pradesh, and neighboring countries like Bangladesh in Southeast Asia

are likely to reveal further occurrences of *M. inclara*. This broadened distribution knowledge would be crucial for effective conservation strategies in the face of environmental challenges.

Emerging trends and future directions in earthworm research encompass a wide array of topics that are shaping the field. One significant trend is the increasing use of DNA barcoding for earthworm species determination, which is crucial for ecological research, especially in studies focusing on earthworm diversity and species distributions (Torppa, 2023). This technological advancement allows for more precise and efficient identification of earthworm species, aiding in monitoring and conservation efforts. Bioremediation using earthworms to address pesticide-contaminated agricultural soil is another area that requires further research to develop site-specific and sustainable technologies for better remediation outcomes (Mishra et al., 2022). Understanding the potential of earthworms in remediation processes can lead to innovative solutions for managing pesticide contamination in agricultural settings.

RECOMMENDATIONS

Due to the scarcity of recorded specimens, significant gaps remain in our understanding of this species' habitat preferences and life cycle. While Gates (1932) suggested a biparental reproductive mode, which deviates from the predominantly parthenogenetic genus, this hypothesis requires further investigation. Additionally, elucidating the ecological role of this species within the earthworm fauna of India and neighboring regions presents a crucial avenue for future research.

It is increasingly important to establish long-term monitoring programs to track changes in earthworm diversity and abundance over time, particularly in response to environmental degradation or climate change. Such programs can inform evidence-based conservation strategies for earthworms and their associated ecosystems. Furthermore, collaboration with local stakeholders, academic institutions, and government agencies should be encouraged to facilitate data sharing, capacity building, and conservation initiatives related to earthworm biodiversity. These collaborative research efforts can significantly increase the impact and sustainability of biodiversity studies.

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