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A New Genus and Species of Earthworm (Oligochaeta: Megascolecidae) from Semi-Arid Australia

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Abstract. A new genus and species of terrestrial oligochaete, *Aridulodrilus molesworthae* (Megascolecidae) is described from a new species found in a semi-arid habitat in New South Wales, Australia. The location of this species provides additional evidence that localized landscape and pedologic factors have allowed isolated populations of native earthworms to persist in areas where low rainfall averages were previously thought to preclude their occurrence. The genus has a combination of morphological features that distinguish it from all other Australian genera. While it shares some features with genera in Western Australia, the wide geographic gap (some 2300 km) appears to preclude any close phylogenetic affinity with these taxa.

Introduction

Genomic studies currently support a Pangaean origin for earthworms, with vicariance into distinct Northern and Southern Hemisphere clades following its breakup (Anderson *et al.,* 2017). The Megascolecidae is one of the largest earthworm families in the Southern Hemisphere and the zoogeographic affinities of members of the family in disparate Gondwanan fragments (Jamieson, 1981) suggests that they have existed in Australia well before the dismemberment of that supercontinent, persisting and diversifying throughout the many subsequent climatic and geological shifts.

The lack of fossil records notwithstanding, it is a reasonable assumption that earthworm populations were more widespread across the Australian continent when more mesic habitats were prevalent. The last significant drying period in Australia during the late Miocene likely precipitated a retreat of earthworms to wetter coastal areas and the major river systems of the continent, but the climatic shift may have been sufficiently gradual to allow earthworm populations to persist and vicariate within drier habitats where critical soil, topographic and groundwater factors intersect. The new taxon described herein may be an example of such a survival.

The earliest studies of the Australian earthworm fauna were centred on New South Wales, with J. J. Fletcher of the Australian Museum publishing several papers (e.g., Fletcher, 1886) and predicting that "the earthworms of this Colony… as regards both individuals and species, will compare favourably in point of numbers with earthworms in other parts of the world." More than a century of subsequent research has revealed a remarkable biodiversity in the Australian earthworm fauna, with nearly 800 endemic species in 55 genera having now been described. The anatomical features and taxonomy of Australian earthworms have been summarized in Jamieson (2001), Blakemore (2000a) and Dyne & Jamieson (2004). Molecular analysis has shown that the Megascolecidae is monophyletic, with acanthodrile earthworms, once considered a separate family, to be an included clade (James & Davidson, 2012). Unique combinations of anatomical features clearly define many Australian earthworm genera, but the taxonomic distinctions between others are less clear, because a very long evolutionary history in Australia has likely included

Keywords: *Oligochaeta; Megascolecidae; Aridulodrilus; semi-arid Australia; earthworm taxonomy; climate adaptation; microhabitat*
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character reversals or even homoplasies. Genomic work may ultimately be required to elucidate the nature of the more ambiguous generic relationships.

While Australian earthworms have been found in many habitats, including rainforest, coastal dune systems, wetlands and alpine woodlands, the drier interior parts of the continent have had only intermittent sampling, with the poor results yielded by earlier attempts (e.g., Spencer, 1896) having perhaps discouraged systematic survey. The new species, from semi-arid pastoral land in western New South Wales, has only come to light due to the interest of the property manager, without whose diligence it would have remained unknown.

Oligochaeta

Megascolecidae Rosa, 1891

Aridulodrilus gen. nov.

urn:lsid:zoobank.org:act:AFB3B6BE-1F0C-41D3-9CE0-12CF7B8AEDCE

Diagnosis. Large worms (over 250 mm in length). Setae more than 15 per segment throughout. Dorsal pores present. Male pores from racemose prostates paired on XVIII. Firm oesophageal gizzard in V; calciferous glands and oesophageal caeca absent; intestinal gizzards and typhlosole lacking. Nephridia meronephric, avesiculate, and astomate, tufted anteriorly. Caudal modifications of the excretory system (e.g., ureters) absent. Spermathecae three pairs, spermathecal diverticula clavate and single; several internal chambers (i.e., multiloculate but not sessile). Penial and genital setae absent.

Etymology. From the Latin *aridulo-drilus*—semi-desert worm.

Type-species. *Aridulodrilus molesworthae* gen. et sp. nov., monotypic.

Distribution. Western New South Wales, Australia (restricted).

Remarks. The closest generic relative appears to be *Austrohoplochaetella* Jamieson, 1971, differentiated by the lack, in *Aridulodrilus* gen. nov., of any caudal excretory system elaboration (such as megameronephridia, nephrostomes, bladders or ureters). Also *Aridulodrilus* gen. nov. lacks an intestinal typhlosole.

Aridulodrilus molesworthae sp. nov.

urn:lsid:zoobank.org:act:5FF63606-B904-463E-B5B6-932C25EDCD7B

Figs 1–4

Holotype: Rupee Station, 10 km NE from Broken Hill, Western New South Wales. Habitat is the outwash plain of the Mount Darling Range adjacent to Willa Willyong Creek, 31.9080°S 141.5683°E. Sandy silt to loamy clay, vegetation predominantly saltbush (*Atriplex nummularia*) (Fig. 5). Individual worms up to 1.5 m (extended) have been observed; the collected specimen was 80 cm in length prior to preservation. Material lodged in Australian Museum, W

Figure 1. Live extended specimen of *Aridulodrilus molesworthae* gen. et sp. nov.

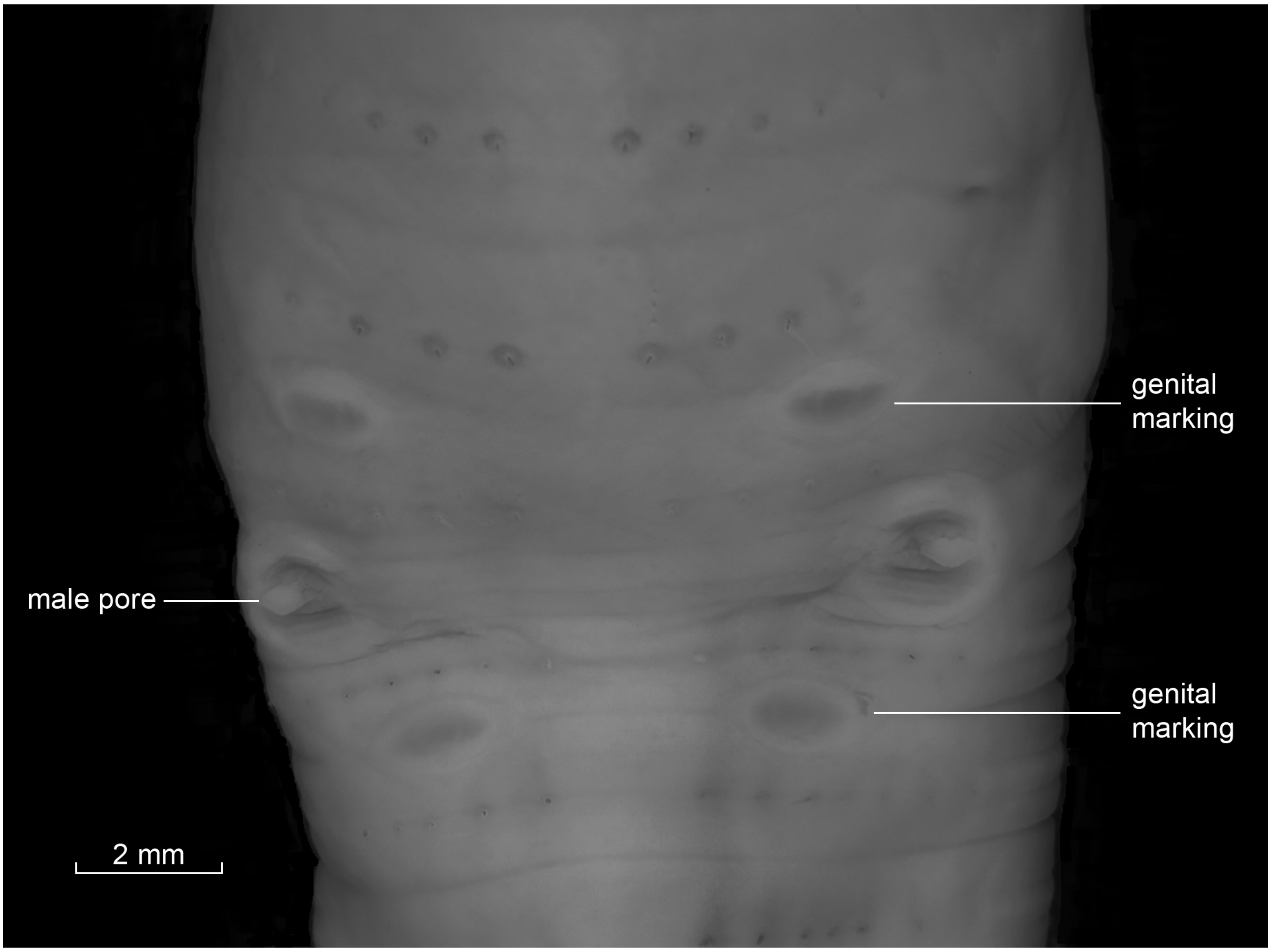

Figure 2. Male field of holotype of *Aridulodrilus molesworthae* gen. et sp. nov.

36906; presented to the AM by Keith Leggett of the NSW Arid Zone Research Station, 23 September 2010. **Paratypes** 2 (numbered 1 and 2 in discussion below): same general location, 31.9092°S 141.5690°E, collector R. Molesworth, 13 August 2020, following heavy rain. Material lodged in Australian Museum, W 53200.

Description

External anatomy

Holotype: length = 481 mm; width (midclitellar) = 12.3 mm; segment count = 275. Body pale, with diffuse brownish dorsal pigmentation. In life, the worms have a dark reddish-brown colour, especially dorsally (Fig. 1). Paratype 1: length = 286 mm, width (midclitellar) = 9.8 mm; segment count = 238. Paratype 2: a small, immature individual.

Prostomium prolobous. First perforate dorsal pore 4/5. Three pairs of widely lateral (*g*-lines) puckered spermathecal pores in 6/7–8/9, the posterior-most pair with protruding whitish matter (H only, possibly seminal material).

Perichaetine; setae generally follow distinct longitudinal setal lines (*vide* Fig. 2), but can be somewhat irregular in disposition, ranging in number from 16–20 per segment throughout. The ventral setal gap is narrow and fluctuates in width. Setae are not present between the male pores.

Male pores are widely separated (*e*-lines) on papillae within lunettes in XVIII. Clearly defined, paired oculate genital markings are intersegmental in 16/17 and 19/20, slightly more ventral than the male pores, their width approximately within the setal arc *bd* (Fig. 2); P1 has an additional set of identical markings in 20/21. Female pore is single, within a distinct slightly tumescent areola, midventral in XIV. A small, single unpaired genital marking aligned with the left 8/9 spermathecal pores occurs in 9/10 (H only).

Clitellum is tumescent and complete, encompassing the posterior half of XIII to the posterior edge of XVII, with a slight ventral gap in XVII (H, P1).

Internal anatomy

Septa in the oesophageal region are muscularized and thickened from 5/6 posteriad, those in 10/11–12/13 possibly the most robust. A large, firm gizzard, with muscular sheen, is present in VI, tapering in width as it meets the oesophagus. The oesophagus is well vascularized and densely rugose internally but lacks any obvious pouching or calciferous glands. The intestine commences with abrupt expansion in XVII. No typhlosole, caeca or other structures are present. Intestinal contents are primarily fine soil particles, with occasional small pieces of organic matter.

Last hearts are present in XIII.

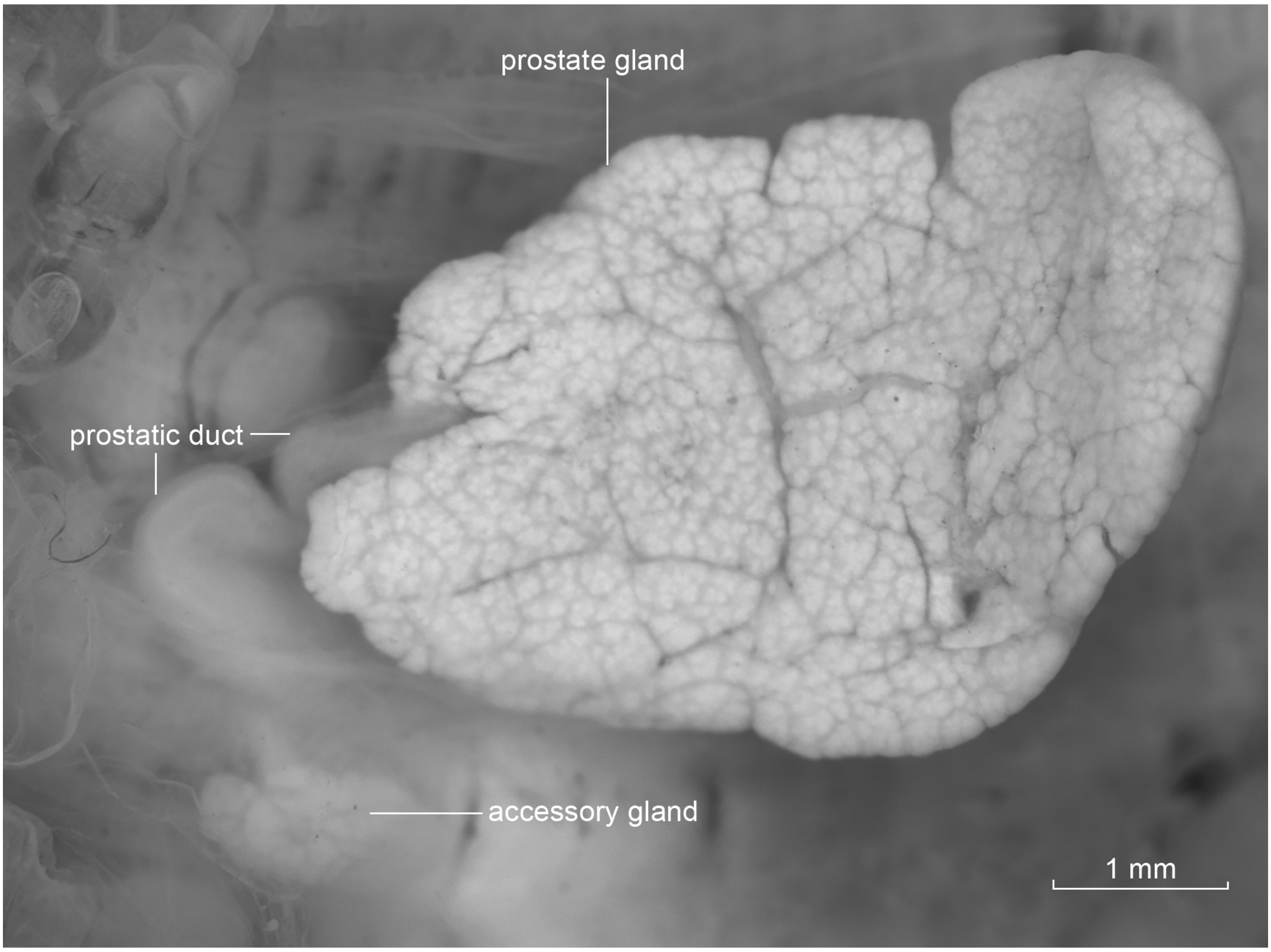

Figure 3. Right prostate gland of holotype.

Male funnels occur in X and XI and show some iridescence but are disproportionately small in relation the overall body size; 2 pairs of racemose seminal vesicles are attached to septa in XI and XII, the latter pair is slightly the larger. Finely racemose prostates, flattened and broadly leaf-like in appearance, are restricted to XVIII and clasp the intestine *in situ* (Fig. 3). The duct is sinuous and muscular, its distal end much dilated as if to form a chamber. Paired vasa deferentia lack conspicuous iridescence and discretely enter the duct ventrally just prior to its final distal bend. Penial setae are absent. Finely loculate ovoid accessory glands (apparently associated with the external genital markings) are present in XVII and XIX and XX (P1 only). A further pair, more ventrally located, is present in XX (H) and XXI (P1) without any corresponding external manifestation.

Ovaries in XIII consist of a membranous fan containing many individual ovules (H); in P1 ovules are embedded in large white flocculent masses, with a filamentous attachment to the preceding septum. Small and diaphanous ventrally situated oviducal funnels have ducts that enter the body wall separately, ventrally, in XIV. Small glandular masses attached to the posterior face of septum 13/14 are possibly ovisacs. Spermathecae lie in segments VI, VII and VIII, subequal in size, each organ consisting of a large, spheroidal ampulla, short thick duct and small clavate diverticulum. In all cases, the diverticulum joins the duct within the body wall, though the bulk of each organ is free within the body cavity (Fig. 4).

Meronephric; the nephridia consist of numerous small, simple tubular coils of variable size lining the body wall, with no pre- or post-septal nephrostomes or bladders visible. The nephridia are smaller and more numerous in the forebody and in places appear to consist of 2 distinct bands within each segment. Large tufts of nephridial tubules are present in segments II-V with composite ducts leading to the pharynx. Caudally, the meronephridia are larger and less numerous but still lack nephrostomes (as elsewhere in the body), or elaborations such as bladders or ureters.

Etymology

The species is named for the manager of the property on which the species was detected—Ms Rosalind Molesworth.

Behaviour

Following infrequent heavy rainfall events, worms have been observed emerging from burrows and being active on the soil surface, including engaging in reproductive coupling (R. Molesworth, *pers. comm.* and video). This emergence phenomenon (the only means of obtaining specimens to date) appears to be restricted to a 10 ha area within the property. The species likely survives at or above the capillary fringe of the water table and its behaviour is governed by fluctuations in the level of the latter and by rainfall events that temporarily saturate the upper soil layers. There is no

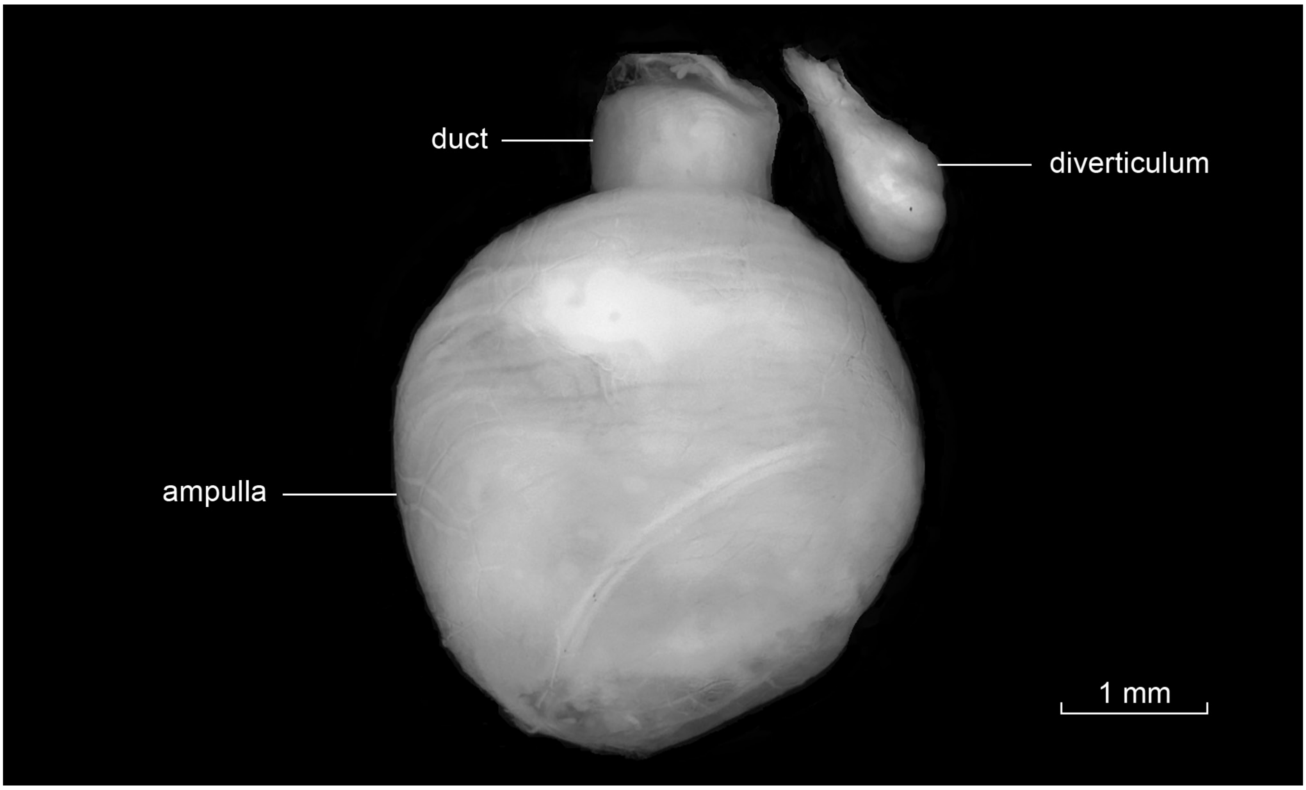

Figure 4. Right IX spermatheca, diverticulum dissected from body wall of *Aridulodrilus molesworthae* gen. et sp. nov.

obvious sign of surface castings associated with this species during such events.

The phenomenon of aestivation or diapause in earthworms has been researched for various species (e.g., Jiménez *et al*., 2000; Cosín *et al*., 2006). This behaviour involves a dramatic slowing in metabolic activity or even the production of a mucous-lined chamber to impede water loss, and is usually the result of deteriorating soil conditions, especially during prolonged dry periods. It is not known whether *Aridulodrilus* has adopted such a mechanism in order to cope with extended periods of drought.

Taxonomic affinities

The newly erected taxon shares some features with the genus *Austrohoplochaetella* (which is restricted to Western Australia), by virtue of the expansion that genus to include perichaetine species as well as those with racemose prostates (Jamieson, 2001). This emended definition of *Austrohoplochaetella* gave priority to the possession of a highly modified caudal excretory system as a unifying apomorphic characteristic. The new genus is clearly distinguishable through the absence of any such caudal nephridial elaboration. The monotypic *Pseudonotoscolex* Jamieson, 1971 also restricted to Western Australia, lacks ureters but has stomate megameronephridia caudally. In addition, unlike *Aridulodrilus*, it possesses the lumbricine setal arrangement.

Importantly, however, the geographic gap between the new taxon and species with which it shares some morphological features is so wide (some 2300 km), there is unlikely to be any close phylogenetic affinity.

Aridulodrilus is also quite distinct from earthworm genera known to be associated with the geographically proximate Murray-Darling River system, such as *Heteroporodrilus* Jamieson, 1970 (*vide* distribution map in Blakemore, 2000b).

Given its isolated occurrence, any future augmentation to this currently monotypic new genus is far from certain.

Discussion

This species adds to the number of earthworms now known to occur in areas in Australia more arid than previously deemed habitable for Oligochaetes (e.g., Dyne, 2019). The mean annual rainfall for the district in which the new species was found is approximately 260 mm, far below that which was previously accepted as being the minimal requirement for the survival of earthworm populations in Australia. Rainfall in the district is also erratic, with prolonged periods of drought significantly reducing the annual total. In 2019, for example, the total rainfall was less than 70 mm (Bureau of Meteorology climate statistics for Broken Hill, www.bom.gov.au).

Abbott (1994) reviewed some 2000 Australian earthworm records, finding that only 0.15% of these occurred outside the 400 mm isohyet. This correlation seems to hold true even accounting for the seasonality of rainfall, with some regions having extended periods of dryness through the year. Baker *et al*. (1997) noted that in the case of Northern Hemisphere earthworms present in Australia as exotics, intolerance of lower rainfall levels was even more pronounced, with 600 mm being an indicative lower limit.

The apparent relationship between rainfall averages and earthworm occurrence is not confined to Australia. Pickford (1937) considered average rainfall as one of the

Figure 5. Habitat of *Aridulodrilus molesworthae* gen. et sp. nov.

most important factors delimiting earthworm distribution in South Africa, noting that few endemic acanthodrile species had been recorded outside the 630 mm isohyet and only one beyond the 500 mm boundary. Kobayashi (1940) found that in Northeast China (formerly Manchuria), 400 mm was a reliable limit to the occurrence of endemic species.

While there are records of earthworms occurring in regions having markedly less rainfall, these tend to comprise peregrine species whose tolerance to a wide range of environmental variables is well established. Tripathi & Panwar (2012) for example, recorded eight introduced earthworm species in cultivated lands of the Thar desert region of India, which has a rainfall mean of 200–300 mm.

While these rainfall-correlated distribution patterns seem to have a generalized validity, there is increasing evidence that local peculiarities of landscape and/or edaphic variables, including the position of the water table, can create moisture refugia and permit native earthworms to survive extended dry intervals and reproduce irrespective of the limitations suggested by consideration of rainfall statistics alone. Gates (1967), for example, proposed that the only records of worms in lower rainfall areas of the Great Plains east of the Rocky Mountains in North America were due to factors such as proximity to streams or other semi-permanent moisture sources.

In Australia, anomalous habitat occurrences may favour those species whose diet largely consists of soil microbiota, rather than those heavily reliant on humic materials present on the ground surface or in upper soil layers (epigeic species), because prolonged dry spells would preclude access to these food sources.

Isolated populations of species such as the one described herein, are likely relicts from more pluvial periods in Australia's past, able to persist where there is a conjunction of favourable groundwater and edaphic factors. Because such circumstances are relatively rare, these earthworm populations will be non-contiguous and only encountered through serendipitous collection, rather than through systematic survey.

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