

**An Annotated Key Separating Foreign Earthworm Species from the Indigenous South African taxa (Oligochaeta: Acanthodrilidae, Eudrilidae, Glossoscolecidae, Lumbricidae, Megascolecidae, Microchaetidae, Ocnerodrilidae and Tritogeniidae)**

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## **An annotated key separating foreign earthworm species from the indigenous South African taxa (Oligochaeta: Acanthodrilidae, Eudrilidae, Glossoscolecidae, Lumbricidae, Megascolecidae, Microchaetidae, Ocnerodrilidae and Tritogeniidae)**

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### **ABSTRACT**

A functional guide for the separation of foreign earthworm taxa (intentionally or coincidentally recorded in South African soils) from native South African taxa is provided. Forty-four earthworm species recorded from South African soils, known as 'exotics' or introduced, which were under secondary attention for many years, are placed in the annotated keys. The family characters for the indigenous Acanthodrilinae, Microchaetidae and Tritogeniidae, and generic/specific foreign taxa of the Benhamiinae, Eudrilidae, Glossoscolecidae, Lumbricidae, Megascolecidae and Ocnerodrilidae are highlighted, keyed and illustrated. An expansive glossary covering terminologies used in earthworm taxonomy is provided and a broad bibliography of South African earthworms is included in the references.

**KEY WORDS:** Afrotropical Region, South Africa, earthworms, identification key, foreign species, indigenous taxa.

### **INTRODUCTION**

Amongst whole soil-dwelling organisms the earthworms (megadrile) are known to be the most important contributors to the soil profile formation. From the time of their evolutionary existence, subterranean armies of earthworms have regularly ploughed, fertilised, enriched and cultivated the land surface of the entire globe. Thanks to their continuous underground work, the surface of the earth has been covered by green grasses, bushes, trees, forests and productive fields, all of which produce food for other living organisms. Consequently, humans have been able to thrive, prosper and create civilisations, and have found in fertile soil a greater wealth than in gold mines. The beneficial role of earthworms in soil fertility has been well researched and recognised, but in recent years these studies have been intensifying. Global food production depends on intensive agricultural growth, and requires a better understanding of biodiversity and the biophysical regulations of soil fertility. This involves further study and observation of a complex range of environmental indicators. Proper knowledge of the soil organisms is therefore essential for understanding the complexities of soil ecosystems (Cortet *et al.* 1999; Fragoso *et al.* 1999).

South African soils are usually ranked as biologically diverse, such diversity having been triggered by countless factors in geology, climate, landscape and many other aspects. Therefore, the associated biodiversity of the soils is highly variable and generates significant interest, which in past years has focused on variable soil life forms, including earthworms, as an important ecological component. The earthworm fauna has to some extent been under investigation for many years and about 300 species of the nine families/subfamilies have been recorded, although it is important to emphasise that these species and the new taxa (still awaiting discovery) need greater attention.

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South African earthworms can be separated into two groups: species accepted as indigenous to South African soils, and species introduced to South African soils, either intentionally through anthropogenic means or coincidentally by natural means. Species that belong to the second group are usually termed 'exotics', 'foreign', 'peregrine' or 'introduced', and because they are well known from many parts of the world they have been subjected to various positive or negative ecological evaluations (Burtelow *et al.* 1998; Lavelle *et al.* 1999, 2006; Dlamini *et al.* 2001; Hendrix *et al.* 2008; Bhadauria & Saxena 2010; Avendaño-Yáñez *et al.* 2014). However, sometimes the selection of the species was not clearly indicated, and some of the conclusions should be tested against correctly identified selected species. The South African introduced species may be included also in some study, but if a correct identification at the species level is erroneously presented or omitted, it shall lead to invalid conclusions.

At present, with the development of ecological research there is an increasing awareness and understanding of the role of earthworms in soil fertility, and there is an urgent need for a reliable and comprehensive guide to the earthworms living in South African soil. It is important that this additional information be accessible to soil researchers, ecologists, earthworm producers, vermiculturists, farmers and non-specialists interested in gardening. A lack of identifiers for introduced beneficial species occurring in agriculture may lead to them being mistakenly evaluated as invasive foreign species that compete with indigenous organisms and thus damage the environment. Earthworms are often included in various environmental and agricultural studies, but when identification at species level (often based on the external characters of juvenile specimens) is erroneously presented or omitted, erroneous economic or ecological conclusions may be drawn.

It must be noted that in the body of research on megadrile in South Africa, it is mostly the indigenous microchaetids and acanthodrilids that have receive attention. Only a few papers present information on the occurrence of foreign taxa (Michaelsen 1910a, 1913; Jamieson 1967; Ljungström 1972; Van Bruggen 1978; Zicsi 1998; Plisko 2010), and this information is often limited to a species name and the place where it was found. Some of the papers are committed rather to common foreign species living in composting heaps, vermiculture production, or species used in workshops and laboratories as experimental objects (Reinecke & Ljungström 1969; Venter & Reinecke 1987; Mallett *et al.* 1987; Hallatt *et al.* 1990, 1992; Reinecke *et al.* 1990; Viljoen *et al.* 1991; Reinecke *et al.* 1992; Reinecke & Alberts 1994; Viljoen & Reinecke 1994; Reinecke & Pieters 1997, 1998; Maleri *et al.* 2007; Maleri *et al.* 2008). In many publications only a name (often currently accepted only as a synonym and thus not suitable for any further analysis) with limited description is given. No specific key with the important external and internal characters necessary for the identification of the foreign taxa has ever been produced. Forty-four earthworm species recorded from South African soils, known as the 'exotics' have been neglected for many years.

Following a request from the Soil Ecosystem Research Group (SERG), a group of South African researchers involved in soil biology, who concentrate on experimental ecological research at the sites where introduced species mostly occur, the necessity of producing a key for the earthworms living in these areas became clear. Due to the apparent lack of basic taxonomic knowledge of earthworms amongst specialists in other fields, this current paper was written with as many explanations as possible in order to be accessible to a wide audience.

The purpose of this paper is to provide basic information on the general categorisation of earthworms, and to produce simple keys that allow researchers to distinguish indigenous species from the introduced taxa. However, it must be noted that the identification of earthworms is not an easy task, even for qualified specialists. Examination of the compulsory characters required in earthworm taxonomy includes the external inspection of adult specimens and the study of their anatomy. In addition, such studies should be based on adequately preserved mature specimens and with specific knowledge of distinctive characters. Unfortunately, no juvenile specimens have been identified to species level; sometimes it is possible to identify them to family or genus level, but even that is not reliable. Only mature specimens develop characters leading to their proper identification. Even if mature/clitellate specimens are found together with juveniles, it does not follow that the juveniles belong to the same species, because they could be juveniles of another species of which no mature individuals were detected. Therefore, only adults can be reliably identified to a genus/species level and used for environmental assessment. Considering some of the external features observed in the individuals of various families recorded in South Africa and their preferences of biotopes, only some preliminary identifications on family/genus level could be suggested.

An introductory key is provided below to separate species accredited to eight families (with two subfamilies) of the earthworms living in South African soils, and keys for each family that allow the identification of genera and species. Special attention was paid to indicate characters separating the indigenous Acanthodrilinae, Microchaetidae and Tritogeniidae from these introduced species belonging to the Acanthodrilinae (two species), Benhamiinae (five species), Eudrilidae and Glossoscolecidae (each with only one species), Lumbricidae (18 species), Megascolecidae (11 species group and two species) and Ocnerodrilidae (four species).

#### MATERIAL AND METHODS

The diagnostic species descriptions were based on references informing on the species occurrence in this country. However, some of the earlier records and information on species occurrence were rather short and indistinct. When the report produced only the species name, with no species description, the species identification was accepted, although the presently known characters of this species were included in the current description. The descriptions of families and genera are based on their recent taxonomic status, compared with these given by Michaelsen (1900), Jamieson (1967), Brinkhurst and Jamieson (1971), Gates (1972), Sims and Easton (1972), Easton (1979), Sims (1987), Csuzdi (1996, 2010), Csuzdi and Zicsi (2003), Moreno (2004), Brown and Fragoso (2007), Blakemore (2008*a, b, c*; 2010) and Plisko (2004, 2013). Though this is not a revision of the recorded species, meticulous attention has been paid to synonymic names and to the correct characterisation of features at the family, genus and species level.

Individuals can be identified to the family level, as well as to the genus and species, using the separate keys, in conjunction with the glossary herein. It is advisable to compare the descriptions of characteristic features included in the keys with the drawings. The list of references, which consists of a comprehensive bibliography covering the original descriptions of species and genera, may be consulted for clarity of identification. The systematic record of families, genera and species is presented in alphabetical order. A short introduction provides information on family status, followed by the generic

and species description. The general information on the species' occurrence and their distribution in South Africa are placed in notes. Distinctive generic characters are repeated in the key to the species. These are provided before the species descriptions, and are followed by descriptions of the external characters and then of the internal features observed in dissected specimens. The names of provinces are updated to those currently used and are abbreviated.

Data given in this paper refer only to the genera and species recorded to present in South Africa (RSA). Freshwater Oligochaetes species or those accredited to microdriles are not included. In the case of uncertainty at the species or higher taxonomic level, the comprehensive information in the attached references may be consulted.

The glossary, abbreviations, codens, acronyms and definitions of terms used in the text are given in alphabetical order and compiled from Gates (1972), Reynolds (1977), Sims and Gerard (1985), Plisko (2004, 2010), and Blakemore (2010). In the description of species, the numbers refer to segment numbers. These may be presented as standalone numbers or, for example, 13–18, meaning from segment 13 to segment 18; they may also be presented as, for example, 13–18, 19, meaning from segment 13 to segment 18 with some part in segment 19. Segments may also be presented as, for example, 1/n13–1/n18, which also means from some part in segment 13 to some part in segment 18. Numbers separated by / denote septum (internal) or intersegmental furrow (external), e.g. 7/8 or 12/13–15/16 means septum separating segment 7 and 8, or it may refer to the intersegmental furrow on the external characters.

*Abbreviations used in text and figure captions:*

A – ampulla ; Cl – clitellum; Dv – diverticulum; EC – Eastern Cape; Fp – female pore; FS – Free State; GP – Gauteng; KNP – Kruger National Park; KZN – KwaZulu-Natal; LP – Limpopo; MP – Mpumalanga; Mp – male pore/s; NC – Northern Cape; NMSA – KwaZulu-Natal Museum, Pietermaritzburg, South Africa; NMSAD – KwaZulu-Natal Museum Oligochaeta Database; NMSA/Olig. – Oligochaeta collection code of the KwaZulu-Natal Museum; Np – nephridial pore; NW – North West; Pp – prostatic pores; RSA – Republic of South Africa; SERG – Soil Ecosystem Research Group, South Africa; SPp – spermathecal pores; S/Ss – simple segment; Tp – tubecula pubertatis; WC – Western Cape.

*Glossary:*

**Acanthodrilidae:** a family name.

**acanthodrilids:** a shortened name for the individuals of the Acanthodrilidae.

**Acanthodrilinae:** subfamily of the Acanthodrilidae.

**acanthodriline:** refers to a state of acanthodriline arrangement of the male, prostatic and spermathecae pores, in acanthodrilids (Fig. 1A, 1B ).

**acanthodriline arrangement:** refers to the location of two pairs of prostatic pores in segments 17 and 19 respectively, and male pores present in segment 18. This condition is usually associated with two pairs of spermathecae and their pores occurring in intersegmental furrows 7/8 and 8/9 respectively; cf. balantine (Fig. 2A, 2B), microscolece (Fig. 3), and megascolece (Fig. 4A, 4B).

**acanthodrilins:** a shortened name for the individuals of the Acanthodrilinae.

**aclitellate:** individuals with no clitellum.

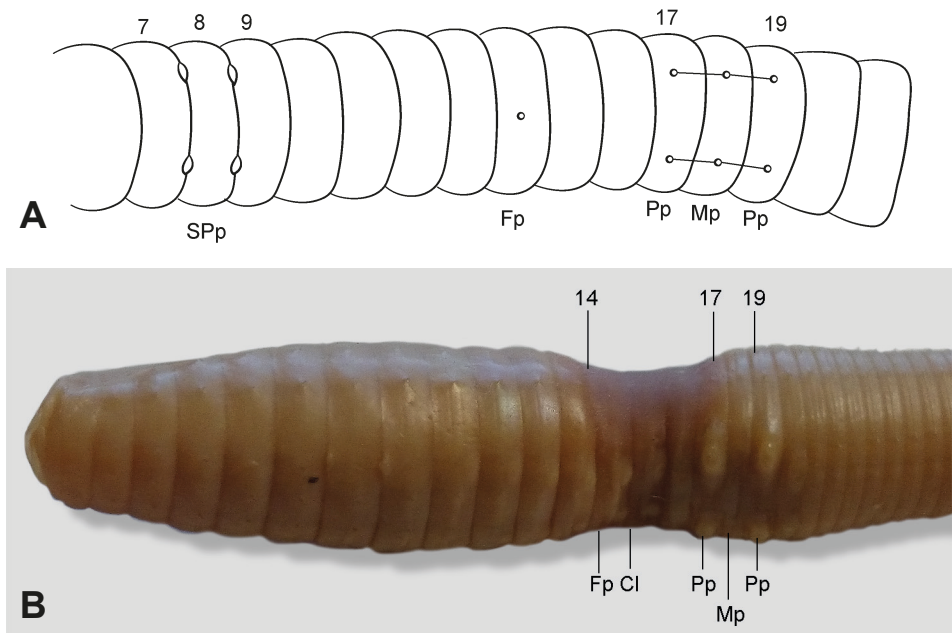


Fig. 1. (A) Acanthodrilinae arrangement (schematic); (B) *Parachilota timothyi* (Acanthodrilinae).

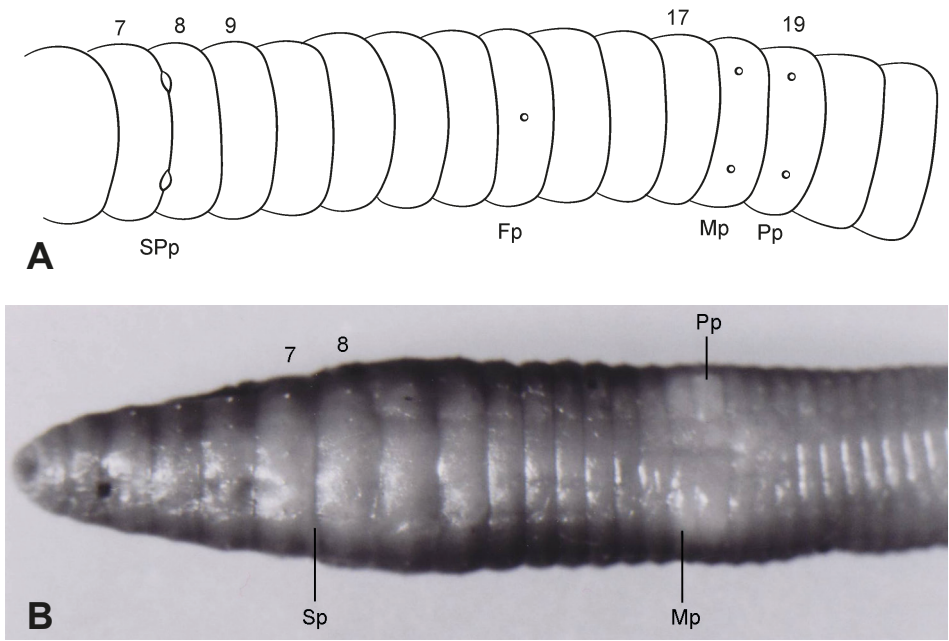


Fig. 2. (A) Balantine arrangement (schematic); (B) *Udeina quedeni* (Acanthodrilinae).



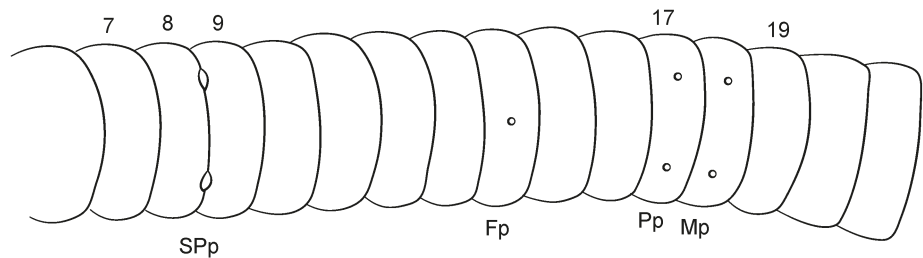


Fig. 3. Microscolece arrangement, schematic: one pair of prostatic pores in 17 or 19, male pores may occur in segment 17 or 18, or be absent; spermathecal pores may be single pair with pores in 7/8 or 8/9, or two pairs in 7/8 and 8/9, or absent.

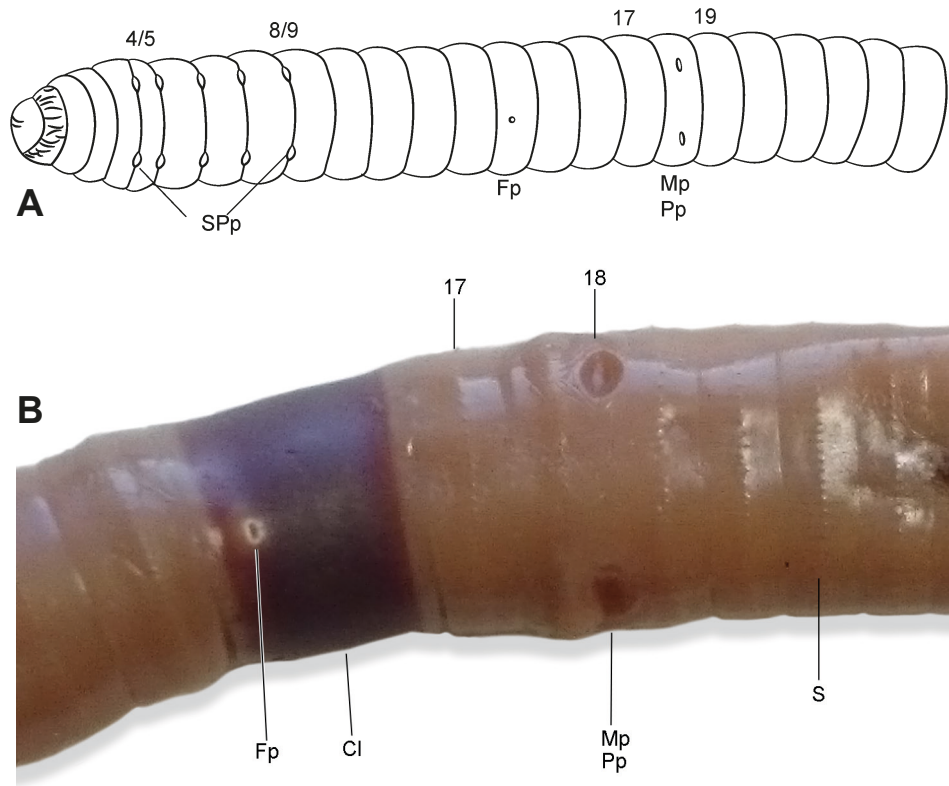


Fig. 4. (A) Megascolece arrangement (schematic): one pair of prostatic pores (tubular or lobular = racemose) in segment 18 and male pores in 18. Spermathecal pores may occur in some of the intersegmental furrows 4/5 – 8/9; (B) *Amynthus* sp. (Megascolecidae).

**aestivation:** a period of inactivity, or dormancy resulting from unfavourable environmental conditions (usually a lack of moisture).

**ampulla** (pl. ampullae): dilated ental end of spermatheca, forming a distal chamber.

**anal segment:** the last part of the body with no coelomic cavity and no setae; not counted as “a segment” in the whole number of the body segments.

**anecic:** refers to the deep burrowing earthworms.

**annular:** refers to the clitellum; the clitellar tissues are encircling the body. In some species a short distance between the clitellar borders not covered by clitellar tissues may be observed (cf. saddle-shaped).

**anthropochorous:** transported by humans, usually unintentionally.

**asetal:** with no setae (peristomium and anal segment do not have setae).

**autochthonous:** native.

**autotomy:** autotomisation, e.g. self-amputation; shedding the caudal region occurs in many earthworm species.

**balantine:** refers to a state of balantine arrangement of the male, prostatic and spermathecae pores in acanthodrilids.

**balantine arrangement:** refers to a reduction of a pair of tubular prostates and a pair of spermathecae, in Acanthodrilidae; the classical balantine condition refers to the occurrence of one pair of prostatic pores in segment 19, and male pores in 17 or 17/18 or 18, and one pair of spermathecae with its pores in intersegmental furrow 7/8 (Fig. 2A, 2B).

**Benhamiinae:** a subfamily name of Acanthodrilidae.

**caecum** (pl. caeca): intestinal pouch from the alimentary canal; may be simple, smooth or manicate (in Megascolecidae). In some older literature refers to the spermathecal ampulla (Beddard 1895a).

**calciferous glands:** glands located at the gut (oesophageal or intestinal), and serving various functions (e.g. controlling pH balance of the digestive system and secreting calcium carbonate). Their size, shape and position are important characters in Microchaetidae, Glossoscolecidae, Lumbricidae and Benhamiinae. May be absent in Megascolecidae and Acanthodrilinae in South African species. In earlier literature often named ‘Glands of Morren’.

**caudal zone:** an external mark in the area of segment 135 (in the caudal part of the body) in some specimens of *Pontoscolex corethrurus*. Its morphology and function are under investigation.

**coelom:** a body cavity between the body wall and internal organs, accommodating the alimentary canal, vascular and excretory systems, and other organs.

**clitellum:** a part of the body wall that is formed from glandular cells at maturity and that is involved with forming a cocoon. In the final state of its formation it can be annular (Fig. 5A) or saddle-shaped (Fig. 5B), but the shape varies according to the state of maturity of the individual. The shape and setting on the segments are significant at family, genus and species level. Appears in full capacity on mature individuals. Two types are recognised:

1. **saddle-shaped:** covering only the dorso-lateral part of the body (as it is in the majority of microchaetids, glossoscolecids, lumbricids and some acanthodrilids) (Fig. 5B).
2. **annular:** ring-shaped, encircling the body; occurs in megascolecids, in some species of acanthodrilids, eudrilids and ocnodrilids (Fig. 5A).



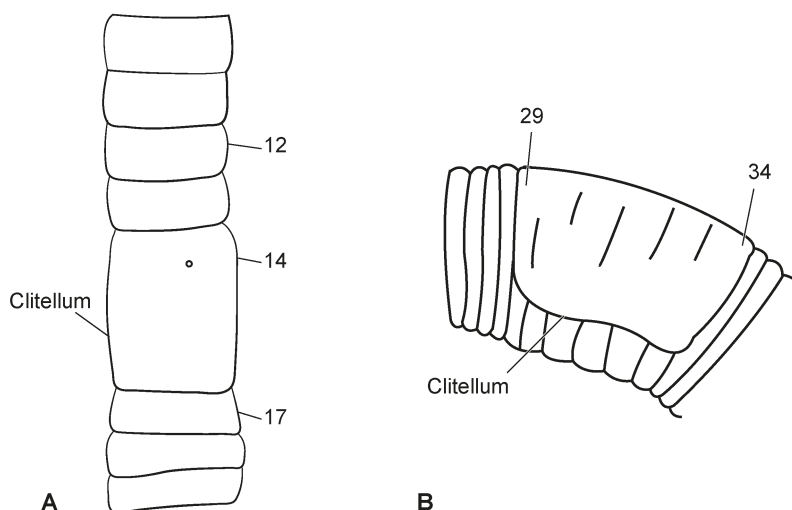


Fig. 5. Clitellum: (A) annular (schematic); (B) saddle-shaped (schematic).

**cocoon:** sometimes termed ‘capsule’; it is the egg case secreted by the clitellum, in which embryonic development takes place. Shape and size are species specific.

**dorsal pore** (pl. dorsal pores): intersegmental apertures in the mid-dorsal line, leading to coelomic cavity. Important character in lumbricids.

**dorsal vessel:** blood vessel located above the alimentary canal.

**endemic:** restricted to a certain region or part of region, native.

**endogeic:** refers to earthworms feeding on organic matter in the soil, coming to the surface for organic matter and breeding.

**epigeic:** refers to earthworms living and feeding on soil surface (litter eaters).

**epilobous:** a shape of prostomium with a tongue partly dividing the peristomium, may be open or closed (cf. prolobous, tanylobous, zygotobous).

**Eudrilidae:** a family name.

**female pores** (sing. female pore): the external pores of the oviducts; may be paired or singular. Their position is characteristic to families and genera (singular in megascolecids).

**genital field:** a space, at the ventral side of an individual, between the seminal grooves; an important species character in Benhamiinae species.

**genital glands:** internal glandular swellings, located in the separated segments, usually around the tips of the setae.

**genital markings:** glandular swellings, pits or grooves. In megascolecids variously arranged external sucker-like discs, pits, grooves, often correlated with position of spermathecal pores; are of great value for species identification. Characteristic for the microchaetids and lumbricids.

**gizzard** (crop): a part of the digestive system, usually muscularised; however, in some species may be weakly muscularised or not at all. Its location in segments is an important generic and species character.

**Glossoscolecidae:** a family name.

**hearts:** the enlarged segmental pulsating connectives of the blood system between the ventral and dorsal trunks (or sometimes between ventral and supraoesophageal vessels).

**hermaphrodite:** having both male and female reproductive organs in one individual. Earthworms are hermaphroditic.

**holandric:** a condition characterised by the presence of two pairs of testes and their funnels occurring successively in segments 10 and 11 (cf. proandric and metandric).

**holandric condition:** when testes and male funnels occur in segments 10 and 11.

**holandry:** a state of being holandric.

**holoic:** refers to the excretory system when the nephridia (stomate, exoic) are paired in segments (with the exception of the first and last segment, and in some species also omitting some of the segments). A state of the excretory system. A replacement for a term 'meganephridial' or shortened for 'holonephridial' (used in some papers) (cf. meroic).

**indigenous:** belonging naturally to the area; native, endemic; not imported or introduced.

**intersegmental furrow:** a division of segments; a border between two following segments where the epidermis is thinnest.

**intestine:** part of a digestive system. Commencement of intestine is an important character in all earthworm groups. In some species a folding occurs (named the caecum) on the dorsal part of the intestine.

**introduced:** brought from a place other than the native area; foreign, exotic, alien.

**juveniles:** not mature; individuals with no recognisable external feature indicating maturity, such as clitellum or tubercula pubertatis.

**Lumbricidae:** a family name.

**lumbricine arrangement** or '**setae lumbricine**': refers to eight setae per segment.

**male funnels:** the ental ends of the sperm ducts initiated at testes. Sometimes in older papers named 'spermiducal funnels'. Temporarily aggregated sperm in male pores may reveal its presence by iridescence (very useful observation for the funnels' location).

**male pores** (sing. male pore): the external openings of vasa deferentia through which the sperm are discharged during mating; may be simple opening, or with some glandular swellings (tumescens) around pores, or expanding on neighbouring segments. Important generic and species character.

**megadrile:** the term used for the description of terrestrial Oligochaeta larger than 20 mm, as opposed to the description of microdrile (smaller than 20 mm).

**Megascolecidae:** a family name.

**megascolecine** (Fig. 4A, 4B): the term indicates that the single pair of prostates, tubular or racemose, open their pores in segment 18 together with the ducts of male pores. In South Africa megascolecid species the prostates are of 'racemose' structure; the lobulation may be not be obvious superficially; however, within glands a prostate duct branches repeatedly.

**meroic:** refers to the excretory system when the nephridia are minute, multiple in one segment, and formed by fragmentation of the embryonic original single nephridial pair. Their number and shape are some of the most important characters in earthworm taxonomy (cf. holoic).

**metandric:** refers to a condition characterised by the presence of a single pair of testes and their funnels in segment 11 (cf. holandric and proandric).

**metandric condition:** when testes and male funnels occur in segment 11.

**metandry:** a state of being metandric.

**microdrile:** the term used for the description of small, usually limnic or aquatic Oligochaeta smaller than 20 mm (or slightly larger), in opposition to description of megadrile (larger than 20 mm, terrestrial).

**microscolece:** refers to a state of microscolece arrangement of the male, prostatic and spermathecae pores in acanthodrilids.

**microscolece arrangement:** refers to a reduction of a pair of prostatic pores, some of the spermathecal pores, with the presence of male pores in segment 17 or 18, or they may be absent. The reduction is observed in the species with acanthodriline male reproductive organs. In various species prostates may be one pair with opening in 17 or 19, or may be absent; spermathecae may be single pair, with pores in 7/8 or 8/9, or 7/8 and 8/9 or may be absent; male pores may occur in segment 17 or 18, or may be absent (Fig. 3).

**nephridium** – (pl. nephridia): excretory organs: large, paired in one segment are referred to as holoic; small, multiple in segment are meroic. Their shapes are one of the most important characters in earthworm taxonomy.

**nephropore:** the external opening of a nephridium.

**Ocnerodrilidae:** a family name.

**oesophagus:** a portion of the digestive organ between pharynx and crop, ending in an oesophageal valve.

**ovaries:** the organs producing ova (eggs). In megadrile usually in segment 13.

**oviduct:** the duct carrying the ova (eggs) from the coelomic funnel to the exterior (female pores).

**papillae:** occurring on various segments as swollen, raised areas; circular, oval or of other various shapes. It is of different taxonomic value in different families, and is often a problematic character.

**penial setae:** specialised setae, associated with male or prostatic pores.

**perichaetine arrangement** or ‘**setae perichaetine**’: refers to numerous setae occurring on one segment. Characteristic for Megascolecidae.

**peristomium:** the first part of the body supporting the prostomium and the mouth; first segment containing mouth; it is asetal.

**proandric:** refers to a condition characterised by the presence of a single pair of testes and their funnels in segment 10 (cf. holandric and metandric).

**proandric condition:** testes and male funnels occur only in segment 10.

**prolobous:** a shape of prostomium with tongue not dividing peristomium (see other shapes of prostomium: epilobous, tanylobous, zygalobous).

**prostates** (sing. prostate): the paired glands, producing fluid supporting the transport of sperm during copulation; associated with vasa deferentia that extend to the exterior through male pores; each consists of a prostatic gland, muscular prostatic duct and prostatic pores (Fig. 6A, 6B). Prostates are absent in indigenous Microchaetidae and Tritogeniidae and in introduced Lumbricidae and Glossoscolecidae. In Acanthodrilinae, Benhamiinae, Ocnerodrilidae and Eudrilidae they are of a tubular structure (Fig. 6B). In Megascolecidae they are of a lobular structure, i.e. ‘racemose’ (Fig. 6A).

**prostatic duct:** extended part of prostatic gland, usually muscular; its ectal part opens into the prostatic pore.

**prostatic gland:** glandular part of prostate; may be confined to one segment or extended through several segments.

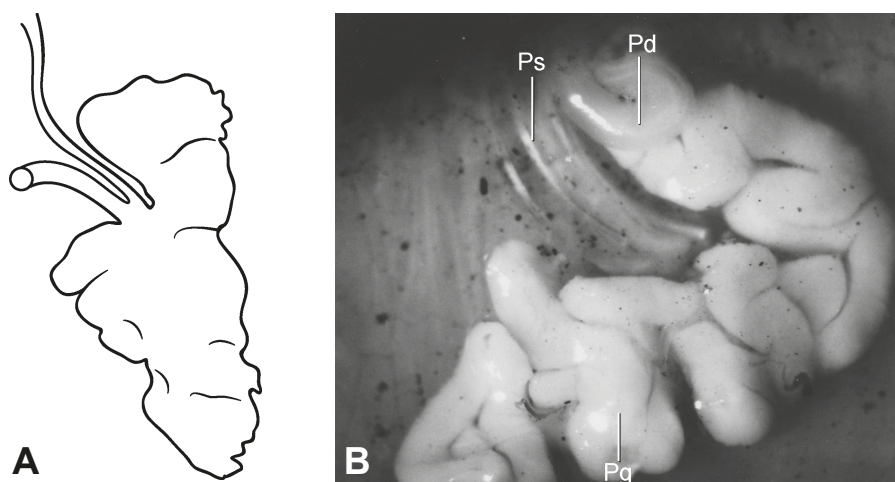


Fig. 6. Prostates: (A) (schematic) racemose=lobular (*Amyntas* sp.) Megascolecidae; (B) tubular (*Udeina adriani*) Acanthodrilinae.



Fig. 7. Prostomium: (A) zygalobous; (B) prolobous; (C) epilobous; (D) tanylobous.

**prostatic pores** (sing. prostatic pore): the ectal parts of prostatic ducts, open near male pores or fused with them; occur at ventral part of the body in the area of segments 17–19 (Acanthodrilinae, Benhamiinae and Ocnodrilidae), or are combined with male pores in front of intersegmental furrow 17/18 covered by ventral part of clitellar tissues (Eudrilidae).

**prostomium**: the anterior part of the body (a lobe) projecting above the mouth. The shape of the prostomium is species specific and used broadly for species classification. Types of prostomium:

1. **zygalobous**: when anterior lobe is just like extended little part of peristomium (Fig. 7A).
2. **prolobous**: a shape of prostomium with tongue not dividing peristomium (Fig. 7B).
3. **epilobous**: when a tongue partly divides the peristomium, may be open or closed (Fig. 7C).
4. **tanylobous**: when a tongue completely divides peristomium (Fig. 7D). There may not be clear lines dividing the peristomium, making the prostomium open or closed.

**quincunx**: a pattern involving the location of setae in a peculiar set-up; refers to species – *Pontoscolex corethrurus* (Müller, 1857) of the family Glossoscolecidae.

**racemose**: (Fig. 6A) the lobular kind of prostate with a central lumen from which short branches pass out. This type of prostate occurs in species accredited to Megascolecidae.

**regeneration**: a regrowth of an organ or part of the body that has been lost. Common in earthworms, although only the part of the body that does not consist of reproductive

organs may be fully regenerated. Partially injured reproductive organs may be regenerated.

**reproduction:** the biological process by which new individual organisms are produced. In earthworms the following types of reproduction may occur:

1. **biparental** (e.g. sexual reproduction, when the development of a new individual occurs after two mature individuals exchange sperm during mating).
2. **parthenogenetic** (e.g. when an individual develops from a female gamete (ovum) without being fertilised by a male gamete (sperm)).
3. **self-fertilisation:** the union of female and male gametes produced by the same individual.

**saddle-shaped:** refers to clitellum (Fig. 5B) when tissues cover the body only dorso-laterally, sometimes extending ventrally, although they are not connected.

**secondary annulation** (Fig. 8A): external demarcations of the segment occurring between intersegmental furrows and marking the segments. The term used to describe a loss of the uniformity in internal-external division in the preclitellar part of the body, something which occurs commonly in the two South African indigenous families: Microchaetidae and Tritogeniidae. Usually occurs on the anterior segments in front of the clitellum. The lack of uniformity creates difficulty in establishing the segment number and the position of internal and external characters, and special attention is therefore required during external observation and dissection.

**segment** (metamere): portion of the body externally divided by intersegmental furrows, internally separated by septa; a primary unit of segmentation. It may be a 'simple' part, internally divided by septa and externally demarcated by intersegmental furrows (as it is in acanthodrilids and megascolecids), or a primary unit superficially demarcated by shallow external furrows (as it is in microchaetids) when it is commonly termed 'secondary annulation' and sometimes a 'ringlet'.

**segmentation** (Figs 8A–8C): repeated transverse metameric internal and external divisions along the longitudinal axis, externally clearly marked by intersegmental furrows and internally by septa; simple (Fig. 8B). (See also a secondary segmentation (Fig. 8A)).  
**semimature:** an individual having partly developed some of the sexual characters in progress to maturity but with no external sexual features, such as clitellum, tubercula pubertatis or other maturity glands.

**seminal grooves:** external elongated depressions connecting prostatic pores and male pores.

**seminal vesicles:** the storage sacs for an individual earthworm's own sperm.

**septum** (pl. septa): an internal partition between segments, dividing and supporting internal organs; usually delicate, thin, although in some segments much thickened to varying degrees. It is an important specific character in all earthworm groups.

**seta** (pl. setae): small, solid bristles to aid locomotion located at each segment (excluding only peristomium and last segment with anus). They are of several types, shapes, and functions: simple, genital, penial, associated with male pores, or genital papillae or certain other parts of the body. Each state has a particular taxonomical value at family, genus and species level.

1. When there are only eight setae per segment (Acanthodrilidae, Eudrilidae, Glossoscolecidae, Lumbricidae, Microchaetidae, Ocnerodrilidae, Tritogeniidae,) this is usually termed a 'lumbricine arrangement', or 'setae lumbricine' (Figs 9A–9C).



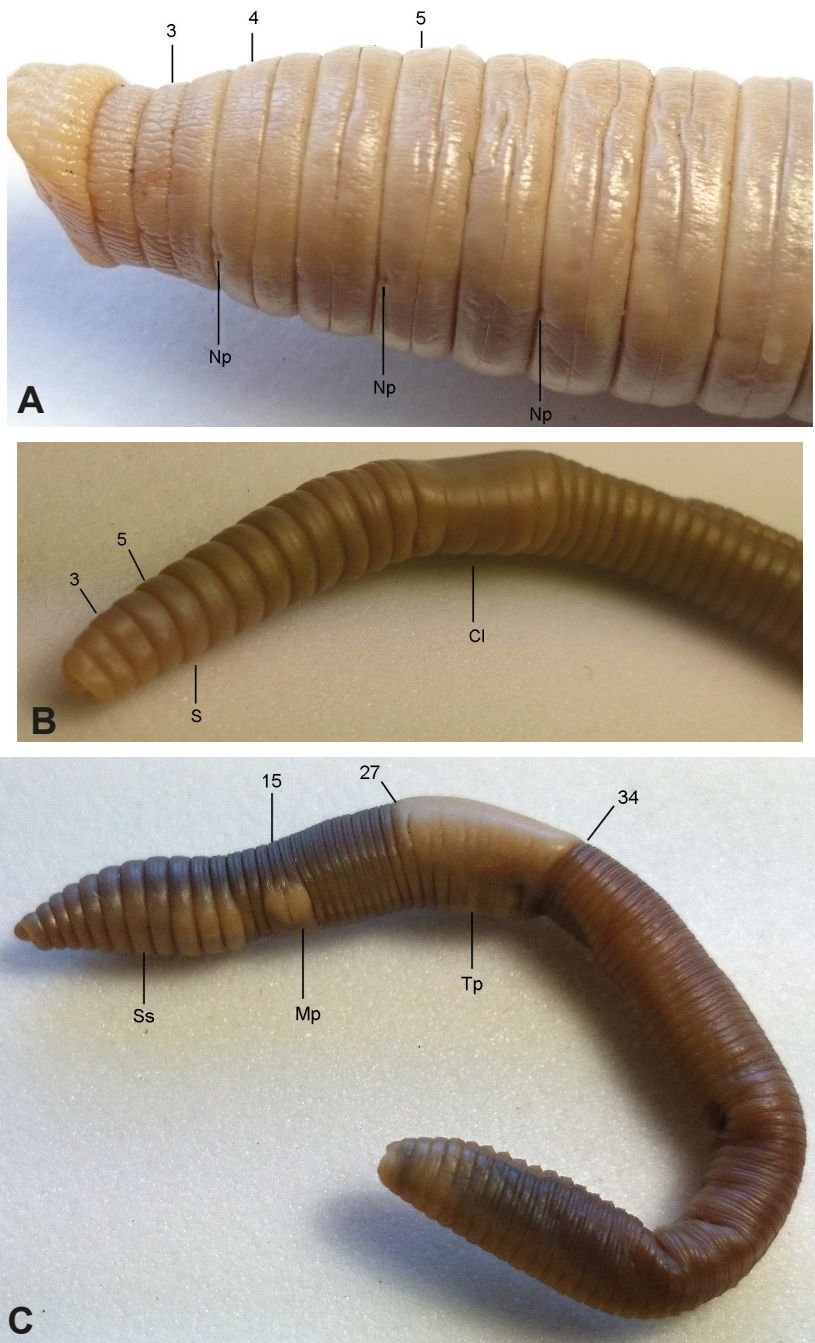


Fig. 8. Segmentation: (A) Secondary annulation: an anterior part of *Microchaetus papillatus* (Microchaetidae) showing intersegmental furrows separating segments, marked by nephridial pores of holoic nephridia; (B–C) simple: (B) *Eudrilus eugeniae* (Eudrilidae); (C) *Aporrectodea trapezoides* (Lumbricidae) showing tubercula pubertatis and male pore with tumescens.



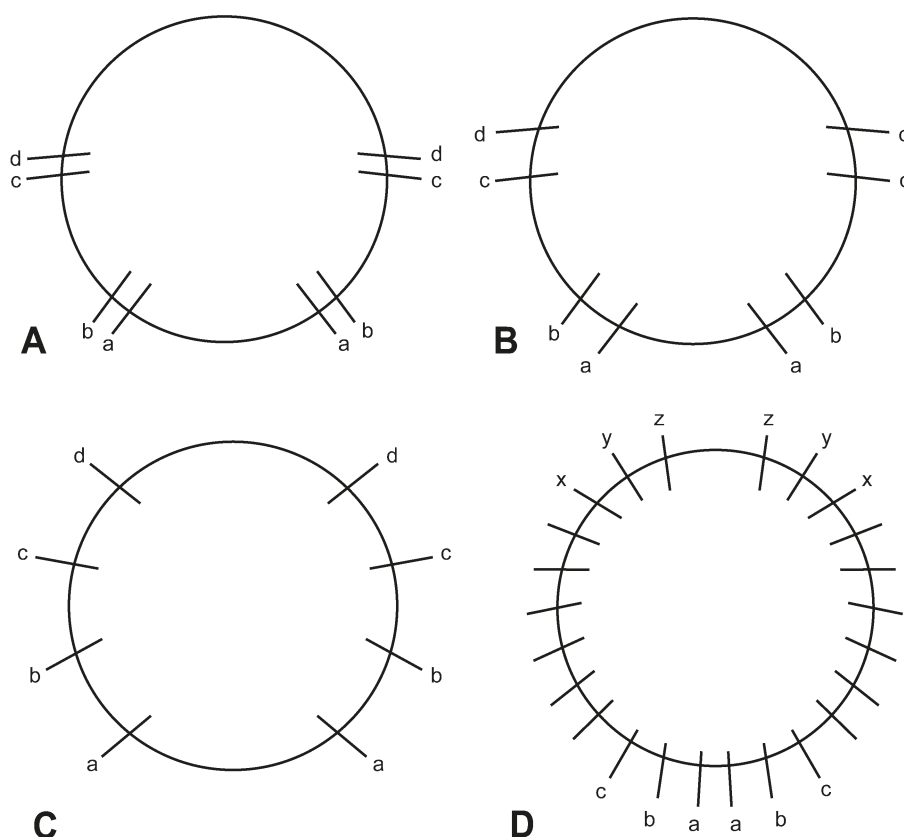


Fig. 9. Setal arrangements: (A –C) lumbricine arrangement: (A) closely paired; (B) widely paired; (C) separated in eight rows; (D) perichaetine arrangement.

Usually setae are arranged in regular lines. Exceptions are some species from the family Glossoscolecidae, where at the caudal part of the body the setae are in a peculiar set-up, e.g. quincunx (Fig 9E).

2. More than eight setae on each segment is termed a 'perichaetine arrangement' or 'setae perichaetine' (Fig 9D) as it occurs in Megascolecidae.

**setal formula:** a measurement of the distance between the setae allocated on segments. If they are only eight setae, they may be paired in four rows: closely paired, or widely paired, or separated in eight rows. They are marked by the letters: *a b c d*, at the right and left side of the body, starting from the ventral part of the body with '*a*', then '*b*', then '*c*' and dorsal is '*d*'. If they are in pairs, it is expressed as '*ab*' and '*cd*'. The distance between the setae is usually measured between *aa*, *ab*, *bc*, *cd*, *dd*; and is expressed as a ratio, e.g. *aa:ab:bc:cd:dd*: 7:3:5:2:18. Exceptions are some species from the family Glossoscolecidae, where at the caudal part of the body the setae are in a peculiar set-up, e.g. quincunx. If there are more than eight setae on each segment, it is important to count the number of setae, and note the distance between them. To identify a species to species-group it is necessary to know the number of setae located on the segments.

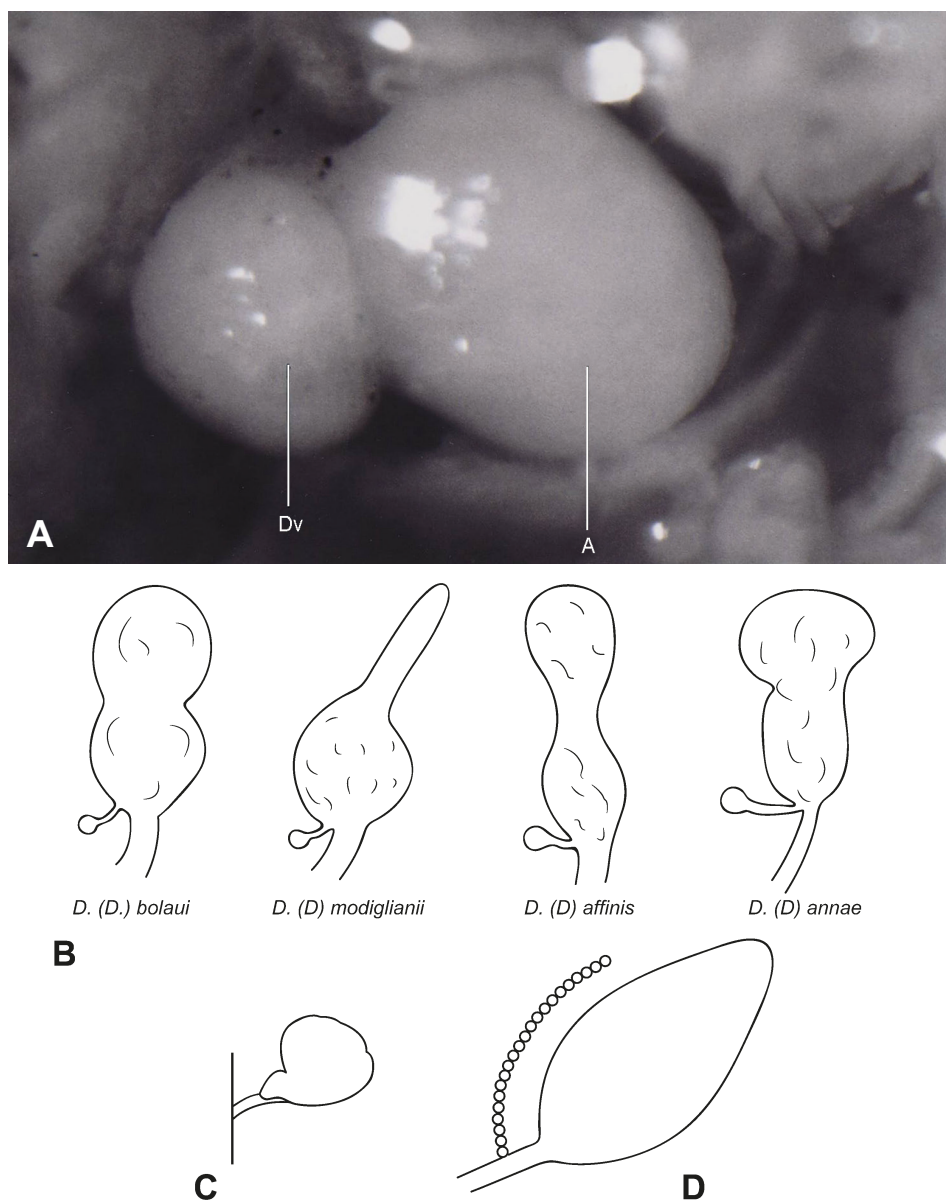


Fig. 10. Spermathecae: (A) Acanthodrilidae: *Udeina adriani*; (B) Benhamiinae: *Dichogaster* (*Diplothe-codrilus*) *bolaii*, *D. (D.) modiglianii*, *D. (D.) affinis* and *D. (D.) annae*; (C) Microchaetidae: *Proandicus pajori*; (D) Megascolecidae: *Amyntas aeruginosus*.

**sperm:** a male cell fertilising eggs during reproduction.

**spermatheca** (Figs 10A–10D) (pl. spermathecae): a male genital organ into which sperm from the partner is deposited during copulation, and stored until release for reproduction, when laying the cocoon. Shape, size and location are important for species recognition. They may be simple (in Lumbricidae, Microchaetidae and Tritogeniidae)

or with diverticulae (in Acanthodrilidae and Megascolecidae). In Eudrilidae they are combined with an ovarian duct, forming a specific organ.

**tanylobous**: a shape of prostomium when a tongue completely divides peristomium (see also other shapes of prostomium: epilobous, prolobous, zygolobous).

**testis** (pl. testes): male organ for sperm production. May occur only in one segment: 10 (proandric condition) or 11 (metandric); or in two segments, 10 and 11 (holandric).

**testis sac**: sac containing one testis or a pair of testes.

**Tritogeniidae**: a family name.

**tubercula pubertatis** (sing. tuberculum): the paired glandular swellings located near the ventro-lateral margins of the saddle-shaped clitellum. They are of various sizes and shapes; on immature species they may not be completely developed, or may be absent.

**typhlosole**: a longitudinal fold in the gut projecting into its lumen; shape and commencement are species features.

**vas deference** (pl. vasa deferentia): the ducts from the male funnels to the exterior of the male pores.

**vascular system**: the arterial and venous vessels forming a network for the transport of blood.

**zygolobous**: a shape of prostomium where the lobe is just like the extended little part of the peristomium. (cf. epilobous, prolobous, tanylobous).

#### TAXONOMY

The South African indigenous earthworm species of Acanthodrilinae, Microchaetidae and Tritogeniidae often occur together with the introduced taxa of Benhamiinae, Eudrilidae, Glossoscolecidae, Lumbricidae, Megascolecidae and Ocnerodrilidae, and may be externally distinguished by the presence or absence of prostatic pores (and internally by the presence or absence of prostates). When prostatic pores and prostates are present, the species may be distinguished according to the degree of the prostates' advancement and the arrangement of the male reproductive organs. The families' distinction and subsequent generic separation in the keys are based on the prostates' structure, which may be tubular or non-tubular (e.g. lobular, also termed 'racemose'). The Acanthodrilidae have their male reproductive organs assembled as an acanthodriline, microcoleline, or balantine arrangement, while the Megascolecidae have a megascoleline arrangement. A fusion of the male (spermathecae) and female (ovaries and oviducts) genitalia occurs in Eudrilidae. The introduced species of the Lumbricidae and Glossoscolecidae have no prostates and prostatic pores. The indigenous Microchaetidae and Tritogeniidae families also do not have prostates and prostatic pores. The taxonomic characters applied in part I of the key below, refer to features separating individuals at a family or subfamily level. The keys assembled under the chosen family should be used for identification of the genera and species. These may differ in distinct families due to different characters used in species description and identification and a number of the recorded species. It should be considered that some species (in various families) reproduce biparentally and parthenogenetically, creating morphs, in which the mature characters indicated in the key are not sufficient for these specimens' identification. In this case it is necessary to seek more completely developed representatives of the taxon.

## PART I

## Key to indigenous and introduced megadrile families and subfamilies occurring in South Africa

- 1 Prostatic pores and prostates absent (prostatic pores, if present, occur at the ventral part of the body in the area of segment 17–19 (Acanthodrilinae, Benhamiinae and Ocnerodrilidae) or are combined with male pores in intersegmental furrow 17/18 and covered by the ventral part of the clitellar tissues (Eudrilidae); they are ectal parts of prostatic ducts, opening near male pores or fused with them. Prostates are paired glands associated with the vasa deferentia extending to the exterior through the male pores). Setae lumbricine ..... 2
- Prostates and prostatic pores (Figs 1A–4B) present. Setae perichaetine (Fig. 9D) or lumbricine (Figs 9A–C) ..... 5
- 2 Segments simple on the whole body length (Figs 8B–8C) (sometimes marked transversely, frail, dorsally or ventrally) with no secondary annulation ..... 4
- Segment 3, 4–9, 10 with secondary annulation (annulated/ringleted) (Fig. 8A) ... 3

*Notes:* Female pores paired, in 14. Clitellum saddle-shaped. Tubercula pubertatis present. Spermathecal pores in some of the intersegmental furrows 9/10–16/17, paired or multiple.

- 3 One gizzard in segment 7. Excretory system holoic ..... **Microchaetidae** Michaelsen, 1900

Description: Body length from small to very long: 30 mm to 2 m 60 cm; elongated. Pigmented or unpigmented. Setae closely paired, sometimes somewhat irregularly distanced. Clitellum on some of the segments 10–32, 33. Tubercula pubertatis on some of the segments 13–23. Male pores in varying intersegmental furrows between 13/14–20/21, with tumescens or with no tumescens. Calciferous glands oesophageal, stalked or not stalked. Dorsal blood vessel simple through the body length or double in some preclitellar segments, simple when passing septa. Holandric, proandric or metandric. Spermathecae in varying segments, some of the segments 9–16, 17, paired or multiple. Seminal vesicles confined to one segment or extended backwards to two or more segments. Genital papillae and glands often present.

*Notes:* Four genera: *Microchaetus* Rapp, 1849; *Geogenia* Kinberg, 1867; *Proandricus* Plisko, 1992; *Kazimierzus* Plisko, 2006. All genera and species indigenous; occur in the whole of South Africa and are known from Lesotho and Swaziland. Autotomy observed in some species (*M. microchaetus*, *stuckenbergi*, *vernoni*). Indigenous.

- One gizzard in segment 6–7, or two gizzards: one in 6–7 and the second in 9. Excretory system meroic ..... **Tritogeniidae** Plisko, 2013

Description: Body length small to medium, not exceeding 145 mm, compact. Setae minute, often not noticeable on pre-clitellar segments. Clitellum saddle-shaped, on some of the segments 13–28, often less developed at ventral part of the body. Tubercula pubertatis present, variably shaped on some of the segments 18–22. Male pores in area of tubercula pubertatis. Calciferous glands oesophageal, stalked. Dorsal blood vessel double in some preclitellar segments and when passing septa; single after 10, 11 or 12. Holandric. Seminal vesicle confined to one, two or slightly extended to segment 13.

*Notes:* Two genera: *Tritogenia* Kinberg, 1867; *Michalakus* Plisko, 1996. Both indigenous to southern Africa. Known from the northeastern areas of South Africa, and a few localities in Botswana and Mozambique. Occurrence possibly extended to Zimbabwe. Indigenous.

- 4 Setae (lumbricine), placed the same at each segment on the whole body length (may be closely paired, widely paired or placed in eight rows). Clitellum saddle-shaped on some of the segments 22–36 (initiating on some of 22–33; terminating on some of 31–36). Tubercula pubertatis on some of clitellar segments 28–35. Male pores paired, on segment 15 (except on 13 in *Eiseniella tetraedra*), with clear swollen tumescens around pores (exception *Lumbricus rubellus* and *Lumbricus castaneus* having clear pores, but no swollen glands around). Calciferous glands present, oesophageal ..... **Lumbricidae** Rafinesque-Schmaltz, 1815

Description: Body length minute, small to medium. Pigmented or unpigmented. Prostomium epilobous or tanylobous. Female pores paired, in segment 14. Holandric. Excretory system holoic. Spermathecal pores in two intersegmental furrows 8/9 or 9/10 or absent.

Notes: Seven genera: *Allolobophoridiella* Mršćić, 1990; *Aporrectodea* Örley, 1885; *Dendrobaena* Eisen, 1873; *Dendrodriulus* Omodeo, 1956; *Eisenia* Malm, 1877; *Eiseniella* (Michaelsen, 1900); *Lumbricus* Linnaeus, 1758; *Octolasion* Örley, 1885. (19 species). Introduced.

- Setae (lumbricine), anterior closely paired, gradually wider apart, posteriorly the quincunx arrangement attained (setal couples are alternately closely and widely paired on successive segments. Clitellum saddle-shaped, initiating on segments 15, terminating at 22, 23 ..... **Glossoscolecidae** Michaelsen, 1900

Description: Female pores paired on segment 14. Calciferous glands oesophageal, extramural, present. Holandric. Excretory system holoic.

Notes: In this family seven genera display an irregular arrangement in the setal rows (Moreno 2004); amongst them is the genus *Pontoscolex* Schmarda, 1861. In RSA only one species of this genus occurs and the comprehensive description is given in the section 'The key to genera and species of the Glossoscolecidae'. The only one species of this family was recorded in South Africa, namely *Pontoscolex corethrurus* Müller, 1857; this species is known to have been distributed worldwide by humans. Introduced.

- 5 Prostates racemose (a system of branching ductlets with no central lumen). Setae perichaetine. Female pore single, midventral in 14. Clitellum annular (encircling the body). Male genitalia megascolecine (a single pair of prostates racemose, opened to the exterior in 18 together with the sperm ducts) ..... **Megascolecidae** Rosa, 1891

Description: Body length from small to medium size. Male pores on 18 or missing in parthenogenetic specimens, postclitellar. Gizzard in 8–10. Intestinal caeca (a blind diverticulum or pouch from the alimentary canal) present. Holandric (testes restricted to 10 and 11). Excretory system meroic (minute, numerous nephridial tubules in each segment), or exceptionally holoic (a single pair of nephridia present in each segment of the body). Spermathecae present or absent, if present occur in pre-testicular segments; shape and location important taxonomic characters. Prostates and spermathecae may be degraded or aborted in some parthenogenetic morphs as it was observed in some individuals of *A. diffringens* reported from polluted environment, where the prostatic glands have been found partly reduced or absent.

Notes: In RSA are known three genera: *Amyntas* (Kinberg, 1867); *Metaphire* Sims & Easton, 1972; *Perionyx* Perrier, 1872; *Pontodrilus* Perrier, 1874 (with one known species in RSA, *Pontodrilus litoralis*, whose taxonomical position needs confirmation (Blakemore 2007), and it is placed in the Appendix). Terrestrial; occur in cultivated fields or natural environment. All recorded species were introduced to RSA at different times by humans. Plisko (2010) summarised their occurrence in this country. Ljungström (1972) hypothesised various ways of species introduction. Introduced.

- Prostates tubular with central lumen; prostatic pores open beside or within a segment or two of the male pores. Seminal grooves variably shaped. Setae lumbricine. Female pores paired, in 14 (with a few exceptions in Benhamiinae being single)..... 6
- 6 Male reproductive organs with acanthodriline arrangement (two pairs of prostatic pores in segments 17 and 19 respectively, and male pores present in segment 18. This condition is usually associated with two pairs of spermathecae and their pores occurring in intersegmental furrows 7/8 and 8/9 respectively); or microscolecine (prostatic pores in 17 and 19, or absent; male pores in 17 or 18 or absent; spermathecal pores in 7/8 and 8/9 or 7/8 or 8/9); or balantine (prostatic pores in 18 or 19; male pores in 17 or 18; spermathecal pores in 7/8). Clitellum ring-shaped (rarely noted as saddle-shaped, possibly during partial maturity the clitellar ring is not completed) ..... **Acanthodrilidae** Claus, 1880 emend. Csuzdi, 1996

Description: Body size variable 20–270 mm. Pigmentation present or absent, smoothly segmented. Setae lumbricine, paired closely or not quite, sometimes changing distance between pairs of setae. Gizzard present or absent. Excretory system holoic or meroic. Calciferous glands present or absent. Clitellum ring-shaped on 12, 13–16, 17. Tubercula pubertatis absent.

*Notes:* Recorded worldwide with indigenous taxa introduced to various zones (Brown & Frago 2007.) On the African continent occur in western, central and eastern regions. In RSA there are 107 known indigenous species and two widely introduced taxa. Two subfamilies are recorded from South Africa: Acanthodrilinae and Benhamiinae.

- 6A Excretory system holoic. Extramural stalked calciferous glands absent. Male reproductive organs acanthodrilinae, microsclecine or balantine .....  
..... **Acanthodrilinae** Claus, 1880 emend. Csuzdi, 1996

Description: Body size 10–102 mm. Pigmented or not. Spermathecal pores two pairs in 7/8 and 8/9 respectively, or one pair in 7/8 or in 8/9. Male pores one pair or two pairs accordingly. Prostomium epilobous. Clitellum on 13, 14–16, 17. Genital markings present, located variably. Prostates one or two pairs or absent.

*Notes:* Various indigenous taxa to various parts of South America (Brown & Frago 2007; Blakemore 2005) are known. Four indigenous genera known in RSA: *Chilota* Michaelsen, 1899 = 12 species; *Eodriloides* Zicsi, 1997 = 17 species; *Parachilota* Pickford, 1937 = 65 species; *Udeina* Michaelsen, 1910a = 11 species, accredited to indigenous taxa. Also known genus *Microsclecus* Rosa, 1887 with its one species indigenous to South Africa, and two others distributed worldwide. Introduced.

- 6B Excretory system meroic. Extramural stalked calciferous glands present; 2–5 pairs commencing in or near segment 14, behind reproductive organs .....  
..... **Benhamiinae** Michaelsen, 1897 emend. Csuzdi 1996

Description: Body length minute to small (1.5–60 mm). Setae lumbricinae. Prostomium epilobous. Male reproductive organs in acanthodrilinae, incomplete microsclecine/balantine or in microsclecine state. Multiple gizzards may occur. Spermathecal ampullae characteristically subdivided, with variable shaped diverticulae (Figs 10B).

*Notes:* One sub-genus with six introduced species noted in RSA.

- Without combination of above characters, pores not in an acanthodrilinae arrangement ..... 7

- 7 Prostates tubular, modified, with enlarged central chamber ‘acorn-shaped’ (Sims & Gerard 1985) (sometimes named ‘euprostate’). Male and prostatic pores paired, combined, with mutual pore in 17/18. Female and spermathecal pores paired, combined, in segment 14 ..... **Eudrilidae** Claus, 1880

Description: Medium to large; pigmented with violet iridescence. Red-brown dorsally, ventrally brighter, beige; iridescence may be initiated by cuticle diffraction. Clitellum brown on 13, 14–18. Male pores in 17/18 with slightly wrinkled slits. Female pores laterally in 14, combined with modified spermathecal pores, anterior to *c* setae. Holandric. Excretory organs holoic. Paired ovaries in segment 13 with ovisacs and ental end of oviducts united with spermathecae develop modified form of spermathecae.

*Notes:* Characters given for recognition of this genus are limited to the external characters observed on the species *Eudrilus eugeniae* (Kinberg, 1867) recorded in RSA. Vermicomposting species.

Nearly 45 genera are known from tropical Africa south of the Sahara, with one species, *Eudrilus eugeniae*, introduced to other tropical areas. This species in recent years started to be used in vermiculture production. Four other species (from two other genera), namely *Eudriloides durbanensis* Beddard, 1893, *Nemertodrilus kellneri* Michaelsen, 1912, *N. kruegeri* Zicsi & Reinecke, 1992 and *N. transvaalensis* Zicsi & Reinecke, 1992, are probably native to South African soils (Plisko 2010), and are not included in this paper.

- Prostatic pores paired, in 17 and 19 separated from the paired male pores located in 17 or 18 in seminal grooves ..... **Ocnodrilidae** Beddard, 1891

Description: Small worms, usually with body length less than 40 mm, associated with limnic or sufficiently moist biotopes (may be also accredited to aquatic microdrile), rarely terrestrial. Setae lumbricinae, paired. Unpigmented. Gizzard present or absent. Spermathecae present or absent; if present, paired, in front of testis segments. Intestinal origin in 12. Calciferous glands present. Seminal vesicles present. Last pair of hearts in 11. Holandric or proandric. Excretory system holoic, avascular. Intestinal caeca absent.



*Notes:* Twenty-one genera are known from Africa and American tropical and subtropical areas, and possibly also from adjacent regions (Christoffersen 2008; Brown & Fragoso 2007). Terrestrial, although prefer moist, limnic or even aquatic environments. A few species transported intentionally or accidentally by humans (Rota 2013). In RSA five known species of four genera: *Eukerria* Michaelsen, 1935; *Nematogenia* Eisen, 1900; *Ocnerodrilus* Eisen, 1878; and *Pygmaeodrilus* Michaelsen, 1890. From these only *Eukerria saltensis* (Beddard, 1895b) may be accepted as introduced taxa. The other species reported by Plisko (2010) need taxonomic revision to establish their original identity. Some of them may be of African origin, or possibly indigenous to South Africa. Their inclusion in the present key is purely to indicate the differences observed between macrodriles and microdriles.

## PART II

### Family Acanthodrilidae Claus, 1880 emend. Csuzdi, 2010

At present *ca.* 768 Acanthodrilidae taxa are described (Csuzdi 2012). Three subfamilies are distinguished: Acanthodrilinae Claus, 1880, Benhamiinae Michaelsen, 1897 emend. Csuzdi, 2010 and Octochaetinae Michaelsen, 1900; of which the first two are known to occur in South Africa. In both these subfamilies numerous taxa are indigenous for certain parts of the world. Some of them may occur broadly, or have been transported to other regions, and have adapted under new environmental conditions. The representatives of Acanthodrilinae consist of 107 species indigenous to RSA, accredited to five genera: *Chilota* Michaelsen, 1899 (12 species), *Eodriloides* Zicsi, 1998 (17), *Parachilota* Pickford, 1937 (65), *Udeina* Michaelsen, 1910 (11), *Microscolex* Rosa, 1887 with one indigenous species, and two introduced species. Only two introduced species of the genus *Microscolex* (namely *M. phosphoreus* (Dugès, 1837) and *M. dubius* (Fletcher, 1887)) are recorded from South African soil, and five species from the subfamily Benhamiinae (*Dichogaster* (*Diplotheodrilus*) Csuzdi, 1996: *D. (D.) affinis* Michaelsen, 1890; *D. (D.) annae* (Horst, 1893); *D. (D.) bolau* Michaelsen, 1891; *D. (D.) modigliani* (Rosa, 1896); and *D. (D.) saliens* (Beddard, 1893)) are inserted in the present key. These species are known from many parts of the world and their occurrence in RSA was summarised by Plisko (2010). The key presented in this paper is designated for the identification of the species introduced to RSA; therefore, no indigenous acanthodrilids are included. The generic and species characters applied in the key are based on data given by the authors. It should be admitted that some of the species descriptions have been limited, or the species erroneously identified were afterwards transferred to synonyms. Finally, the descriptions were enhanced with additional, presently observed taxonomic characters, making available identification. The improvement in descriptions for the *Microscolex* species was taken from Pickford (1937); enlarged descriptions for Benhamiinae species are based on Csuzdi (2010).

### Subfamily Acanthodrilinae Claus, 1880

Characterisation of Acanthodrilinae species (considering the indigenous and introduced ones in RSA; after Pickford (1937)): Prostates tubular, with a central duct (two pairs, or one pair, or absent). Calciferous glands absent (in all South African species). Male reproductive organs acanthodriline, microscolecine or balantine. Gizzard oesophageal, variably developed, present or absent. Excretory system holoic; nephridia vesiculate or avesiculate. Holandric or some proandric. Spermathecae present or absent; if present, two pairs or one pair; diverticulate. Male pores present or absent; if present, paired, in 17 or 18 or 19. Prostatic pores two pairs, each pair in 17 and 19, or 18 and 20, respectively; or one pair in segment 17, 18 or 19. Clitellum saddle-shaped or ring-

shaped. Setae lumbricine, paired variably: closely or not quite, sometimes changing the dividing distance on some segments. Body cylindrical, size variable; length 20–370 mm. Pigmentation present or lacking.

*Notes:* Representatives of the subfamily are predominantly from Central and South America and parts of the western and southern African continent. However, a number of the family species are recorded widely throughout the southern hemisphere (Blakemore 2010). On the African continent they occur in the western, central and eastern regions, and in RSA indigenous representatives of the five genera, *Chilota*, *Eodriloides*, *Parachilota*, *Udeina*, with one indigenous species, and two broadly distributed species of the genus *Microscolex* Rosa, 1887, are known.

Genus *Microscolex* Rosa, 1887 emend. Pickford, 1937  
(based on species occurring in RSA)

Description: Length 10–102 mm. Unpigmented, darkish dorsally, pale ventrally. Setae lumbricine. Prostomium epilobous. Female pores paired, in 14. Microscolecine. Male pores paired in 17. Prostatic pores paired in 17 or 17 and 19. Clitellum annular. Spermathecae present, or absent. Gizzard various sizes: reduced or rudimentary. Dorsal blood vessel single. Holandric. Excretory system holoic with various bladder shapes. Calciferous glands absent. Typhlosole absent.

*Notes:* Two introduced species of this genus are recorded from RSA.

Key to species of *Microscolex* introduced to South Africa.

1 Spermathecae absent ..... ***M. dubius*** (Fletcher, 1887)

Description: Body length *ca.* 30–102 mm. Nephridial pores at each segment in *c* setal line, laterally. Female pores anterior to setae *a*. Male pores in *ab*, with circular porophores. Clitellum on 13–17. No genital markings. Septa 6/7–13/14 thickened. Gizzard small in 5. Salivary glands extend backwards over gizzard to segment 5 or 6. Oesophagus extends to 13, intestine widens between 16 and 18. Excretory system holoic, with ‘ocarina’-shaped bladders. Seminal vesicles in 10, 11, 12. Prostates single pair in 17, small, bent into L-shape with short ducts. Typhlosole absent.

*Notes:* A synantropic species, distributed worldwide. Abundant in moist soils, noted in drains. In RSA recorded from various localities in EC and WC, summarised by Plisko (2010). Occasionally found together with the introduced lumbricid *Aporrectodea rosea* and the indigenous *Proandricus timmianus* (Michaelsen, 1933). Various authors expected common distribution of this species; however, no new material has been reported (Plisko 2010).

– Spermathecae present ..... ***M. phosphoreus*** (Dugès, 1837)

Description: Body length *ca.* 10–55 mm. Nephridial pores from 4/5 slightly median to *c* lines. Male pores on 17 in a small longitudinal furrow near setae *ab*. Spermathecal pores in 8/9 near *a* setae. Clitellum on 12, 13–14/17, 17 with clear setae and intersegmental furrows. Genital markings present, at central depression in 17/18 and posterior to 17. Septa 5/6–11/12 weak, 12/13–15/16 membranous. Gizzard rudimentary in 5. Salivary glands extend into 7/8. Intestine initiates in 16. Seminal vesicles two pairs, occurring from septa 10/11 and 11/12 and extend to 11 and 12 respectively. Prostates in one or two segments; prostatic gland thick, tubular, slightly curved. Penial setae present.

*Notes:* Synantropic. Cosmopolitan; broadly distributed by humans. Common in pastures, moist plots, gardens, drains, glasshouses, pot plants; found also in native bushes, in soil rich in humus. Noted in variable biotopes (Csuzdi 1986). In RSA recorded by a number of authors from LP, FS, KZN, EC, WC and NC provinces, with its occurrence indicated by Plisko (2010). Pickford (1937) found this species in native forest (Soutpansberg) and in a number of other sites in various provinces, and predicted its broad distribution, suggesting a common occurrence in South Africa. However, during the past decades only one specimen has been added to the NMSA collection (Plisko 2010). According to Gates (1972) the discharged luminescence observed in this species when an individual is disturbed is produced either by symbiotic bacteria or by luciferin-luciferase reactions. The opalescent glandular masses noted around pharynx or oesophagus in 4–6 may be acting in this phenomenon.

### Subfamily Benhamiinae Michaelsen, 1897 emend. Csuzdi, 1996

The Benhamiinae subfamily was established by Michaelsen (1897a) within the Megascolecidae family with no precise definition. Csuzdi (1996) revised and redefined the superfamily Megascolecoidae and defined Megascolecidae and Acanthodrilidae. Further, the Acanthodrilidae was separated into three subfamilies: Acanthodrilinae, Octochaetinae and Benhamiinae (Csuzdi 2010). Although the taxonomical position of the Benhamiinae is under discussion (Blakemore 2005, 2006, 2010; James & Davidson 2012), it is accepted for the present key confined to species introduced in the soils of RSA. The most distinctive characters of the Benhamiinae are: a presence of the tubular prostates with a central duct, excretory system meroic, and extramural, stalked calciferous glands (2–3 pairs, commencing in or near segment 14). Multiple gizzards may occur.

### Subgenus *Dichogaster* (*Diplothecodrilus*) Csuzdi, 1996

Description: Body length minute to small (1.5–60 mm). Setae lumbricinae. Prostomium epilobous. Female pores paired, in 14. Holandric. Excretory system meroic. First dorsal pore in intersegmental furrow 5/6. Spermathecal ampulla subdivided with diverticulum at lower part of ampullae. Male reproductive organs acanthodriline or in the incomplete microscolecine/balantine state.

### Key to *Dichogaster* (*Diplothecodrilus*) introduced to RSA

- 1 Male reproductive organs acanthodriline ..... 2
- Male reproductive organs in the incomplete microscolecine/balantine state ..... *D. (D.) saliens* (Beddard, 1893)

Description: Male pores paired, in 17; prostatic pores one pair in 17, both open very close to each other, encircled by small papillae. Spermathecal pores paired in intersegmental furrow 7/8 and 8/9 respectively. Body length 25–65 mm. Unpigmented, although alive may be slightly brown. Setae lumbricinae. Prostomium epilobous. Female pores paired, median to setae *a*, in 14. Male pores paired, in 17 within pairs of *aa* setae. Prostatic pore one pair in 17. Spermathecal pores paired in intersegmental furrow 7/8 and 8/9 respectively. Nephropores minute. Clitellum saddle-shaped on 13–19, 20. Genital markings present; a small mid-ventral circular disk in 15/16. Septa 11/12–13/14 somewhat thickened. Two gizzards, in 5 and 6 respectively, slightly externally separated. Typhlosole present, lamellar. Calciferous glands in 15–17 with the anterior pair smallest. Last pair of hearts in 12. Holandric. Excretory system meroic. Seminal vesicles small in 11 and 12; vesicle in 12 may be absent. Prostates single pair in 17 as a long tubular gland. Spermathecae paired, in 8 and 9 respectively, with a mushroom-shaped ampulla with a thin duct half as long as ampulla. Penial setae uniform, 0.7 mm in length.

Notes: Widely spread worldwide. Pastures, grasslands, near cow sheds, gardens; noted in natural habitats, protected areas where imported trees or plants were introduced. In RSA recorded from various biotopes in LP and KZN (Plisko 2010). Five unpublished records kept in the NMSA refer to Mkhatabi Forest (EC). This species has an incomplete microscolecine arrangement, with two pairs of spermathecae in segment 8 and 9 respectively and only one pair of prostate in segment 17.

- 2 Female pores paired ..... 3
- Female pore single, medially in 14 ..... *D. (D.) bolau* (Michaelsen, 1891)

Description: Body length 20–40 mm. Unpigmented, sometimes dorsally with brownish tint. Setae lumbricinae. Prostomium epilobous. Male pores paired, in 18. Prostatic pores paired, in 17 and 19, respectively. Spermathecal pores close to setal *a* lines in intersegmental furrows 7/8 and 8/9. Clitellum annular on 13, 14–18, 19, 20. Genital field oblong. Nephropores minute. Septa 7/8–9/10 slightly thickened. Gizzards

muscular in 5–6. Typhlosole small, lamellar. Calciferous glands in 15–17. Hearts in 10–12. Nephridia 3–5 rows in each side of the segment. Holandric. Excretory system merioic. Prostates paired, in 17 and 19 respectively. Spermathecae paired, in 8 and 9 respectively; ampulla subdivided in similar two parts, with small diverticulum (Fig. 10B). Penial setae dimorphic, ornamented.

*Notes:* Occurs in moist biotopes; pastures, leaf bases, rotten logs, often in glasshouses, in pot plants; found in septic tanks, and many polluted places. Tropical and subtropical zone; known from various parts of the world, distributed by humans. Noted from polluted areas and sewer systems (Rota & Schmidt 2006; Csuzdi *et al.* 2008). In RSA occurs in agricultural land, mainly in sugarcane plantations and citrus fields; also known from natural biotopes, forests and bushes. Common in grasslands, parks and gardens. Occurs abundantly. Detailed record of the localities given in Plisko (2010).

3 Spermathecae subdivided in two parts, similar in shape and size.....4

– Spermathecae subdivided in two differing parts...**D. (D.) modiglianii** (Rosa, 1896)

Description: Body length 15–60 mm. Unpigmented, with greenish tint when alive, pale when preserved. Female pores median to setae *a* on 14. Male pores paired, in 18. Prostatic pores paired, in 17 and 19 respectively. Spermathecal pores close to setal *a* lines in intersegmental furrow 7/8 and 8/9 respectively. Clitellum annular, often thinner between *aa* lines, on 13–20. Genital field rectangle-shaped. Septa very thin. Gizzards in 5–6. Typhlosole present. Last pair of hearts in 12. 3–4 small nephridium at each side of the segment. Seminal vesicles in 11 or only in 12, or absent. Prostates paired, in 17 and 19 respectively; ducts slenderer than the glands. Spermathecae paired, in 8 and 9 respectively; rounded ampullae with thinner, elongated distal part, and a short diverticulum bearing an oval bulb (Fig. 10B). Penial setae dimorphic.

*Notes:* In soil rich in humus, under rotten barks, fallen trees, drains and many various moist biotopes. Known from tropical and subtropical areas in South America, West Africa, India, Burma and some Indonesian islands. In RSA noted only in a few localities in KZN (Plisko 2010).

4 Spermathecae paired, in 8 and 9 respectively, small; both parts of subdivided ampulla similar in size and shape, with short diverticulum bearing one unilocular ball (Fig. 10B). .....**D. (D.) affinis** (Michaelsen, 1890)

Description: Body length 20–50 mm. Pigmented. Female pores paired, in 14. Male pores paired in 18. Prostatic pores paired, in 17 and 19 respectively. Spermathecal pores paired, in intersegmental furrow 7/8 and 8/9 respectively. Clitellum annular on 13–21, 22. Genital field rectangle-shaped. Septa all thin. Muscular gizzards in 5 and 6. Typhlosole minute. Calciferous glands oesophageal in 15–17. Hearts in 11–12. Nephridia in three or four rows at each side of segment. Seminal vesicles vestigial in 11 and 12. Prostates paired, in 17 and 19 respectively. Penial setae length *ca.* 0.3–0.45 mm

*Notes:* Cultivated soils, gardens, glasshouses; forests, in the litter and under trees. Widely spread worldwide. In RSA reported only a few times: by Horn *et al.* (2007) from a few sites in the Soutpansberg forests (LP) and by Zicsi (1998) from Durban, Stamford Hill and Pietermaritzburg (suburb Sunnyside, at side of Celtis Rd) (KZN), collected with *annae*.

– Spermathecae paired in 8 and 9 respectively; the distal part extended laterally, somewhat sheltering lower part (Fig. 10B); small diverticulum bears 1–4 sperm-balls ..... **D. (D.) annae** (Horst, 1893)

Description: Body length 20–75 mm. Alive may be slightly green or colourless. Female pores paired, between *aa* setae on 14. Male pores paired in 18. Prostatic pores paired in 17 and 19 respectively. Spermathecal pores paired in 7/8 and 8/9 respectively. Clitellum annular though often thinner ventrally, on 12, 13–20. Genital field rectangle-shaped. Septa all membraneous. Gizzards in 5–6. Typhlosole present, medium size. Calciferous glands in 15–17 each of equal size. Hearts in 10–12. Nephridia with four pairs per segment at each side. Prostates paired in 17 and 19 respectively. Seminal vesicles absent (may be vestigial in 11 or 12). Penial setae 0.65–0.8 mm

*Notes:* Variable biotopes; usually rich with decomposing plants. Also known from composting loads. Tropical and subtropical parts of South America and Africa. From RSA reported by Zicsi (1998) from one locality in Pietermaritzburg (suburb Sunnyside, at side of Celtis Rd) (KZN) collected together with *affinis*.

### Family Eudrilidae Claus, 1880

Eudrilids are tropical and subtropical African taxa. Currently *ca.* 350 species of 45 genera, mostly endemic or indigenous to African tropics and subtropics, are known. From

these only one species *Eudrilus eugeniae* (Kinberg, 1867) is known as anthropochorous and has become cultured in many parts of the world. At present it is one of the common earthworm species in West African soils and it is widely distributed in many parts of the world. Primarily imported to RSA for a specific experimental study (Reinecke & Viljoen 1988, Reinecke *et al.* 1992; Reinecke *et al.* 1992; Viljoen & Reinecke 1994), it is adapting to habitats in this country. Being a tropical species it has the ability to survive under customary South African environmental conditions. It is a composting species used in the commercial production of compost, at vermicomposting farms, and in worm production for various uses. Other eudrilids (*Eudriloides durbanensis* Beddard, 1893, *Nemertodrilus kellneri* Michaelsen, 1912, *N. kruegeri* Zicsi & Reinecke, 1992 and *N. transvaalensis* Zicsi & Reinecke, 1992) reported by Plisko (2010) for RSA as introduced species are probably native to South African soils and are not included in this paper.

*Eudrilus eugeniae* (Kinberg, 1867)

Description: Body length 110–157 mm (raised under special conditions by Viljoen & Reinecke (1994) they reached 250–400 mm). Dorsally violetish-brown, iridescent, ventrally light yellow. Setae lumbricine, closely paired (with exclusion of first and the last segment). Prostomium epilobous. Dorsal pores absent. Clitellum saddle-shaped (Fig. 5B) on 13, 14–18, less developed ventrally. Male pores and prostatic pores combined in intersegmental furrow 17/18 between setal lines *c*. Female pores combined with spermathecal pores, in 14, median to setal lines *cc*. Septa 4/5–8/9 and 14/15 thickened. Lateral hearts in 7–11. Gizzard variably muscular in 5. Calciferous glands paired, in 12. Holandric. Excretory system holoic; a pair of large nephridium in each segment, starting in 5. Seminal vesicles in 11 and 12. Prostates paired, large, with enlarged central duct (this structure sometimes is named ‘euprostate’). Ovaries, ovisac, and ental end of oviducts united with spermathecae forming united organ.

Notes: This species is biparental, characterised by internal fertilisation. Successful cocoon production by adult worms was reported by Reinecke and Viljoen (1988), who indicated a mean of 2.7 hatchlings per cocoon with an 84 % hatchling success rate.

Family Glossoscolecidae Michaelsen, 1900

Nearly 600 nominal taxa forming *ca.* 35 genera accounted to Glossoscolecidae are confined to the Neotropical Region. Characterised by: a lack of prostates; setae lumbricine variably placed at segments; clitellum saddle-shaped, tubercula pubertatis present; calciferous glands present. Holandric. Excretory system holoic. Typhlosole present.

Notes: In this family seven genera display an irregular arrangement in the setal rows (Moreno 2004); amongst them is the genus *Pontoscolex* Schmarda, 1861. In RSA only one species of this genus is found and the comprehensive description is given below.

*Pontoscolex corethrurus* Müller, 1857

Description: Unpigmented. Body length 40–120 mm. Setae alternate/irregular: anterior closely paired, gradually wider apart, hind body with the quincunx arrangement (e.g. setal couples are alternately closely and widely paired on successive segments). Prostomium and peristomium invaginated inside the cavity forming a ‘proboscis’. Preclitellar seg-



ments may be slightly marked transversely with thin grooves, not connected to the septa. Caudal zone present or absent. Clitellum saddle-shaped on segments 15–22, 23. Tubercula pubertatis as a band on 19, 20–21, 22. Five pairs of the lateral hearts in 7–11 respectively. Calciferous glands extramural in segments 7–9. Typhlosole present in segments 21–24, terminates in area of segment 100. Seminal vesicles present or absent. If present, one pair in 12, extending variably to segment 20 or 22. Spermathecae present, three pairs, each in 7–9 respectively, adiverticulate; ampulla slightly elongated with duct longer than ampulla.

*Notes:* The species extends over a large part of the tropical/subtropical zone, mainly due to anthropogenic dispersal. Its great adaptability to variable ecological conditions has allowed it to spread in the tropics, especially near the coastal zone. In RSA the species occurs in the subtropical northeastern areas, in the coastal zone and in the hinterland along the Indian Ocean, south of the tropic, extending to 31°S latitude (Plisko 2001). The majority of the samples (*ca.* 70%) came from agricultural environments, to which the species was directly or indirectly introduced. Passive transport of the species has been observed, and Van Bruggen (1964) has noted this kind of infestation in South African soils. This species is commonly used in agriculture practices for crop improvement in a number of countries (Avendaño-Yáñez *et al.* 2014), although this practice has not yet been introduced in this country.

#### Family Lumbricidae Rafinesque-Schmaltz, 1815

Sixty-three genera with approximately 163 valid species accredited to the family Lumbricidae (Csuzdi 2012) are recorded from various terrestrial or semi-terrestrial and limnic biotopes. Of these, 33 species are cosmopolitan (Blakemore 2010), of which nineteen (species with subspecies) were recorded in RSA. The characters presented in the key are based on those observed at their collection; however, they are enriched by some other features noted in species during advanced study by Blakemore (2004*b*, 2010), Csuzdi & Zicsi (2003), Jamieson (1967) and Plisko (1973), and observation based on the material gathered in the NMSAD. To better understand the terminologies in the species descriptions, it is advised to refer to the Glossary. The key presented below refers to species recorded from South Africa to date. Specimens' external characters may indicate assignment to a species; however, dissection and internal study are advised to confirm the identifications. For further diagnostic characters and data on some other species possibly found in RSA, see Blakemore (2010), Csuzdi and Zicsi (2003), Stephenson (1930) and Michaelsen (1900).

The main characters of species known from RSA attributed to the family Lumbricidae: Body cylindrical, elongated for the entire length of the body, with some variability occurring at its posterior part, which may be flattened (*Lumbricus*) or square-shaped (*Eiseniella*). Body length from 20–150 mm, diameter 1.5–7 mm. Segmentation simple along the whole body (Fig. 8C), sometimes dorsally slightly marked superficially, transversally. Setae lumbricine (Fig. 9A–C) (e.g. eight setae at each segment with the exception of the prostomium and anal segment; variably located at segments: setae may be closely, moderately or widely paired in four rows, or distantly separated in eight lines). Prostomium (Fig. 7C, 7D) epilobous or tanylobous. Dorsal pores present; location of first pore variable, distinct for species. Spermathecal pores present or



absent; if present, paired, in intersegmental furrows 9/10 and 10/11 or in 9/10, 10/11, 11/12. Female pores paired (frequently inconspicuous) in 14 above setae *b* (exception *Eiseniella* where they are ventrally to setae *a*). Male pores paired, in segment 15 or exceptionally in 13 (*Eiseniella tetraedra*), with variably swollen glands around pores (exception *Lumbricus rubellus* and *Lumbricus castaneus*, where these appear as clear pores, with no swollen glands around). Clitellum saddle-shaped (Fig. 5B), appearing on some of the segments 22–36; a number of segments covered by clitellar tissues and their position is the taxonomic species character. Tubercula pubertatis present, (Fig. 8C) variably shaped, from band-like, ridge-like, knob-shaped to sucker-like tubercles, with location on some of the segments 24–35; it is an important, exclusive species character. Holandric condition (two pairs of testes; each with male funnels in segment 10 and 11 respectively). Spermathecae present or absent; if present: adiverticulate, paired, in segment 9 and 10 respectively, or in 9, 10, 11. Seminal vesicles paired, in four segments 9–12, or in three 9, 11, 12, or in two 11, 12. Excretory system holoic. Crop intestinal in 15–16. Gizzards intestinal in 17 or 17–18. Calciferous glands oesophageal, present; with or without lateral pouches. Intestinal caeca absent. Prostates absent.

*Notes:* It should be noted that *Lumbricus terrestris* Linnaeus, 1758 does not occur in RSA as had been previously indicated (Ljungström 1972; Plisko 2010).

#### Key to genera of the family Lumbricidae Rafinesque-Schmaltz, 1815 (introduced to South Africa)

- 1 Setae lumbricine closely paired in four regular rows (Fig. 9A).....2
- Setae widely paired in four rows, or distantly placed in eight regular lines. Prostomium epilobous (Fig. 7C).....6
- 2 Male pores in segment 13 or 14 or 15. Gizzard small, in 17 .....  
.....*Eiseniella* Michaelsen, 1900

Description: Pre-clitellar body cylindrical, in post-clitellar region quadrangular, with four pairs of setae at each segment located post-clitellar at the four corners of the body. Prostomium epilobous. Male pores with variably sized glandular swellings, not extending on neighbouring segments. Spermathecal pores paired, in intersegmental furrows 9/10 and 10/11 respectively. Spermathecae paired, in 9 and 10 respectively. Seminal vesicles in four segments 9–12. Body length 15–65 mm.

*Notes:* Only one species known from RSA: *E. tetraedra* Savigny, 1826

- Male pores in segment 15. Gizzard in 17–18 .....3
- 3 Prostomium epilobous. Male pores ventro-laterally, with variably developed glandular tumescens around the openings extended or not on the neighbouring segments .....4
- Prostomium tanylobous. No glandular tumescens around male pores.....  
.....*Lumbricus* Linnaeus, 1758

Description: Pigmented. Dark violet dorsally, light ventrally. Male pores very small, difficult to trace. Body length 30–145 mm. Spermathecal pores in intersegmental furrows 9/10 and 10/11. Spermathecae in 9 and 10. Seminal vesicles in three segments 9, 11, 12 respectively. Calciferous glands in 10–12. Excretory system holoic, nephridial bladders J-shaped.

*Notes:* Two species known from RSA: *L. castaneus* (Savigny, 1826) and *L. rubellus* Hoffmeister, 1843

- 4 Pigmented.....5
- Unpigmented.....*Aporrectodea* (Örley, 1885)

Description: Red, grey or with a tint of black. Male pores with small glandular swellings slightly extending on neighbouring segments. Body length 30–150 mm. Clitellum located on some of the

segments 24–35. Tubercula pubertatis as continuous bands or simple tubers separated or not by transverse furrows. Spermathecae and spermathecal pores present. Two pairs of spermathecae in segment 9 and 10 respectively, and their pores in intersegmental furrows 9/10 and 10/11. Calciferous glands in 10–12 with lateral pouches in 10. Excretory system holoic, with nephridial bladders U- or J-shaped. Seminal vesicles variable in size and number in: 11 and 12, or 9, 11 and 12, or 9, 10, 11, 12.

*Notes:* Four species: *rosea*, *longa*, *caliginosa* and *trapezoides*; all described under numerous synonymic names. Occur in variable biotopes, with easy adaptation to wide-ranging environmental conditions.

- 5 Dorsally dark red to violet, ventrally yellowish grey with no coloured stripes. Male pores with small glandular swellings, not extending on neighbouring segments .....

..... *Allolobophoridella* Mršić, 1990

Description: Body length 30–65 mm. Prostomium epilobous (*parva*) or occasionally tanylobous (*eiseni*). Clitellum present or absent; if present, on 23, 24, 25–32. Spermathecae, spermathecal pores and tubercula pubertatis absent. Seminal vesicles in two segments 11 and 12. Calciferous glands in 10–12, with lateral pouches. Excretory system holoic, with nephridial bladders U-shaped.

*Notes:* Two species known in RSA: *Al. eiseni* (Levinsen, 1884) and *Al. parva* (Eisen, 1884).

- Red-brown, with less pigmented intersegmental stripes, or dorsally more uniformly purple, yellow ventrally. Glandular swellings of male pores may slightly extend onto neighbouring segments .....

..... *Eisenia* Malm, 1877

Description: Body length 30–120 mm. Clitellum on segments 25, 26–32, 33. Tubercula pubertatis as narrow bands along ventral borders of clitellum covering three segments of 28, 29–30, 31. Septa 6/7–8/9, slightly thickened. Spermathecae and spermathecal pores paired, present in intersegmental furrows 9/10 and 10/11. Four pairs of seminal vesicles in segments 9–12. Calciferous glands in 10–12 without distinct lateral pouches. Excretory system holoic, with nephridial bladders simple, sausage-shaped.

*Notes:* Two species, *E. fetida* and *E. andrei*, are anatomically alike but differ at a molecular level.

- 6 Setae paired, and widely spaced with variable distances between paired setae..... 7  
– Setae spaced widely in eight regular lines along the body length, or occasionally the distance between setae varies .....

..... *Dendrobaena* Eisen, 1873

Description: Violet to light red dorsally, light ventrally, sometimes iridescent. Dorsal pores present or absent. Spermathecal pores present or absent; if present, in intersegmental furrows 9/10 and 10/11, or in 9/10, 10/11, 11/12. Clitellum on some of the segments 27–33. Tubercula pubertatis present or absent. Spermathecae present or absent; if present, in two segments 11 and 12, or in three, 9, 10, 11. Calciferous glands in 11–13, with lateral pouches in 11, 12; or in 11, 12 with lateral pouches in both; or in 10, 11, 12 with no pouches. Excretory system holoic, with sausage-shaped nephridial bladders.

*Notes:* Four species: *D. cognettii* (Michaelsen, 1903), *D. hortensis* (Michaelsen, 1890), *D. octaedra* (Savigny, 1826), and *D. veneta veneta* (Rosa, 1886).

- 7 Pigmented. Dorsally dark red to violet, pale ventrally.....

..... *Dendrodrilus* Omodeo, 1956

Description: Setae paired widely (Fig. 9B), with constant ratio. Body length 26–65 mm. Prostomium epilobous. Clitellum covers five to six segments, on some of 25, 26, 27–31, 32, not extending on 33. Tubercula pubertatis present or absent; if present, on 28–30 or 29–30 as broad rectangular bands, or reduced to slender strips. Spermathecal pores in 9/10 and 10/11, or absent. Seminal vesicles in three segments (9, 11, 12) or in two (11 and 12). Calciferous glands in 10–12, with lateral pouches in 10. Excretory system holoic, with nephridial bladders U-shaped.

*Notes:* One species *Dn. rubidus* (Savigny, 1826) with two subspecies: *Dn. rubidus rubidus* (Savigny, 1826) and *Dn. rubidus subrubicundus* (Eisen, 1873).

- Unpigmented. Colour whitish grey, sometimes slightly dark .....

..... *Octolasion* Örley, 1885

Description: Setae on first few segments paired moderately, then widely along the whole body. Body length 30–145 mm. Prostomium epilobous. Male pores with prominent glandular tumescens, often extending on neighbouring segments. First dorsal pores around intersegmental furrow 10/11. Clitellum initiates at segment 29 or 30, terminating at 34 or 35. Tubercula pubertatis as thin bands on 30–34, 35. Spermathecal pores paired, in 9/10 and 10/11. Seminal vesicles paired, in 9–12. Calciferous glands in 10–11 with lateral pouches in 10. Excretory system holoic, with nephridial bladders ‘ocarina’ shaped.

*Notes:* Two species: *O. cyaneum* (Savigny, 1826) and *O. lacteum* (Örley, 1881), morphologically similar, although differing in the species' constant position of the clitellum and tubercula pubertatis.

### Keys to the introduced species of Lumbricidae genera

#### Genus *Eiseniella* Michaelsen, 1900

Only one species *E. tetraedra* Savigny, 1826 is known from RSA.

**Description:** Body length 25–75 mm. Colour yellowish brown. First dorsal pore in intersegmental furrow 4/5. Nephropores alternate, irregular between *b* and *d*. Male pores in 13 or 14 or 15 with large glandular tumescens. Clitellum on 22, 23–27, at ventral side less developed. Tubercula pubertatis on 24–25. Calciferous glands in 10, as lateral pouches. Excretory system holoic.

*Notes:* Palearctic origin, known from the whole of Europe and many parts of the world; transported by natural forces, coincidentally or intentionally by humans. Amphibiotic, limicolous. In RSA known from various provinces, mainly from limnic biotopes with high decomposing organic matter (Jamieson 1967; Plisko 2010). May be found in various moist to saturated soils in areas of natural inland watercourses, or artificial lakes, and other biotopes with decaying organic matter. Transported by natural courses (river flow) or by humans.

#### Genus *Lumbricus* Linnaeus, 1758

Two introduced species known from RSA.

#### 1 Clitellum on 28–33 ..... *L. castaneus* (Savigny, 1826)

**Description:** Body length 30–50 mm. Dorsally dark red-violet, ventrally whitish grey. Male pores on 15, small slits, with no tumescens. Tubercula pubertatis at a ventral edge of the clitellum in the form of bands, on 29–32. First dorsal pore in intersegmental furrow 5/6 or 6/7. Spermathecal pores in 9/10 and 10/11. Calciferous glands in 10–12 with lateral pouches larger in 10. Gizzard small in 17–18.

*Notes:* Palearctic, distributed worldwide by humans. Terrestrial with wide range of biotopes: natural moist soil with high organic content, forests, grasslands, pastures and cultivated land. RSA: This species was found only once, in a garden in KZN, together with other introduced lumbricids and indigenous *Tritogenia lunata* (Plisko 1996, 2010). Topsoil species, endogeic.

#### – Clitellum on 26, 27–32 ..... *L. rubellus* Hoffmeister, 1843

**Description:** Body length 30–140 mm; post-clitellarly slightly depressed, caudally flattened. Pigmented, dorsally slightly violet to purple, sometimes iridescent; ventrally pale. Male pores on 15, small slits, with no tumescens. Tubercula pubertatis as extending bands above ventral, clitellar lines, on 28–31. First dorsal pore in 5/6–7/8. Calciferous glands in 10–12, first pair extending to segment 11.

*Notes:* Palearctic, distributed worldwide by humans. RSA: Recorded from various localities in KZN, EC, WC. Found together with other introduced lumbricids (*L. castaneus*, *Dn. rubidus*, and *O. lacteum*), and also indigenous *Tritogenia lunata*, as noted by Plisko (2010). Terrestrial, epigeic; may be found in biotopes where the environmental conditions allow. Quite often found under decaying bark and logs. Live also in composting heaps. Reproduce sexually and may reproduce parthenogenetically. The majority of the collected individuals were much smaller (30–57 mm) than those that were reproduced sexually.

#### Genus *Aporrectodea* (Örley, 1885)

Four species: *rosea*, *longa*, *caliginosa* and *trapezoides*; all described under numerous synonymic names. Occur in variable biotopes, with easy adaptation to wide-ranging environmental conditions.

#### 1 First dorsal pore in intersegmental furrow 4/5, often expelling yellowish white coelomic fluid (not smelly). In life slightly red..... *A. rosea* Savigny, 1826

Description: Body length 25–120. The openings of male pores between setae *b* and *c* variably sized, with large semi-circular glandular tumescens, frequently extending to neighbouring segments. Spermathecal pores present or absent; if present, in 9/10 and 10/11 between lines *cd*. Clitellum on 24, 25–32, 33. Tubercula pubertatis as continuous bands on 29–31. Seminal vesicles in four segments 9–12 or in two segments 11 and 12. Excretory system holoic, with nephridial bladders U-shaped.

Notes: A synantropic species distributed worldwide. Subsoil, endogeic. Daily cast production of this species was estimated as 71, 85 mg dry mass per 1 g of living mass of the individual (Csuzdi & Zicsi 2003). Various experimental studies conducted in agricultural production confirmed the beneficial improvement in soil productivity in the presence of *A. rosea* (Stephens *et al.* 1994). In RSA recorded under various synonymic names from various provinces (Plisko 2010), and occurs abundantly in variable biotopes: pastures, grasslands, forests and agricultural fields. Common in gardens and in cultivated fields. Occurs with other introduced earthworm species of various families. Also found together with indigenous acanthodrilids and microchaetids. Under unfavourable conditions the species may be found in an aestivation state. Bisexual and parthenogenetic reproduction commonly observed.

- First dorsal pore in intersegmental furrow behind 4/5 .....2
- 2 First dorsal pore in intersegmental furrow 8/9 or 9/10.....3
- First dorsal pore in intersegmental furrow 12/13 .....4
- 3 Clitellum on 27, 28–34. Tubercula pubertatis on 31 and 33 as simple tubers separated by transverse furrows in 32.....*A. caliginosa* (Savigny, 1826)

Description: Body length 40–150. In life whitish grey, dorsally dark. Male pores with variably shaped tumescens (Fig. 8C). Seminal vesicles in four segments, 9–12. Excretory system holoic, with nephridial bladders S-shaped, twisted backwards.

Notes: Palearctic, synantropic, most widely distributed, described under a number of synonyms. Reproduces biparentally, and in parthenogenesis, with morphs common. Recorded broadly in RSA, although it is less common than the dominant *trapezoides*. Commonly occurs in various biotopes, but is found predominantly in agriculture fields and disturbed environments. Species has adapted widely to a variety of ecosystems. Subsoil.

- Clitellum on 27, 28–34. Tubercula pubertatis on 31–33, 34 as continuous band .....*A. trapezoides* (Dugès, 1828)

Description: Body length 50–150 mm. Excretory system holoic with S-shaped nephridial bladders.

Notes: Synantropic, described under numerous synonyms, often as a subspecies or a form of *caliginosus*, from which it differs in the shape of the tubercula pubertatis. Subsoil. In RSA it is the dominant lumbricid, and has been recorded over one hundred times from various biotopes.

- 4 First dorsal pore in intersegmental furrow 12/13. Clitellum on 28–34, 35. Tubercula pubertatis on 32–34 as continuous strips ..... *A. longa* (Ude, 1885)

Description: Body length 120–150 mm. In life dorsally dark. Male pores with prominent glands extending to neighboring segments. Septa 5/6–10/11 thickened. Seminal vesicles in four segments, 9–12. Excretory system holoic with nephridial bladders J-shaped.

Notes: Native to Palearctic, widely distributed worldwide. Synantropic, anecic. Occurs in pastures, gardens and forests. Found only twice in RSA, in garden soil in two distant localities of GP and WC (Plisko 2010).

### Genus *Allolobophoridella* Mršić, 1990

Only two species known from RSA: *Allolobophoridella eiseni* (Levinsen, 1884) and *A. parva* (Eisen, 1874), both morphologically similar, but differ in the histology of the muscles. No histological study has been done on the material collected in RSA. It is possible that after histological and molecular analysis the species may be classified with a more precise description, as pointed out by Plisko (2010). Possibly these species are parthenogenetic morphs of a species not yet identified. At present, if similar specimens are found, they should be identified using the following description of the genus.

**Description:** Body length 30–65 mm. Dorsally dark red to violet, ventrally yellowish grey. Setae closely paired. Prostomium epilobous (*parva*) or occasionally tanylobous (*eiseni*). Male pores with small glandular swellings, not extending to neighbouring segments. Clitellum present or absent; if present on 23, 24, 25–32. Spermathecae, spermathecal pores and tubercula pubertatis absent. Seminal vesicles in two segments, 11 and 12. Calciferous glands in 10–12, with lateral pouches. Excretory system holoic, with nephridial bladders U-shaped.

**Notes:** Both species are regarded as being of Atlantic origin, and have spread widely over many parts of the world. However, because of their frequent erroneous identification, their distribution has possibly been produced incorrectly. These forms are possibly parthenogenetic reproductions of the non-established original species. In RSA a collection record also can not be confirmed because both were recorded under various synonyms with a lack of complete descriptions. Both species may be found in patches of foreign plantations, under decaying bark and moist litter, in gardens, under pot plants in greenhouses, and in any other biotopes where human interaction is expected. However, it should be said that the taxonomical position of these species with their various generic accreditations, their numerous synonymic names, and the lack of a completed new study, suggest the need for a species revision on the accessible new material. Inclusion of histological and molecular studies should be considered and Genbank should be searched for molecular data.

#### Genus *Eisenia* Malm, 1877

Two species, *E. fetida* (Savigny, 1826) and *E. andrei* Bouché, 1972, are morphologically and anatomically alike but differ at a molecular level. Both species occur in RSA and may be identified using the following description of the genus.

**Description:** Body length 30–120 mm. Red-brown, with less pigmented intersegmental stripes, or dorsally more uniformly light purple, and yellow ventrally. Glandular swellings on the male pores may extend slightly onto neighbouring segments. Clitellum on segments 25, 26–32, 33. Tubercula pubertatis as narrow bands along ventral borders of clitellum covering three segments of 28, 29–30, 31. Septa 6/7–8/9 slightly thickened. Spermathecae and spermathecal pores paired, present in intersegmental furrows 9/10 and 10/11. Four pairs of seminal vesicles in segments 9–12. Calciferous glands in 10–12 without distinct lateral pouches. Holandric. Excretory system holoic, with nephridial bladders simple, sausage-shaped. Differ at a molecular level.

**Notes:** The original range of both species may be attributed to a forested-steppe area in the Caucasus, as suggested by Perel (1997). At present widely distributed; synantropic. Well known all worldwide as the manure earthworm. Common in composting heaps, decaying organic matter and damp rotting vegetation, and in nurseries and around barns. In recent decades has been widely distributed worldwide in the compost trade, and in vermicomposting farms for various uses. In RSA they are common in various biotopes and in vermicomposting. *E. andrei* has been used for various laboratory studies (Reinecke & Kriel 1981; Venter & Reinecke 1987; Reinecke & Vijoer 1991). The recognition of *E. andrei* is still under discussion (Blakemore 2010). Voua Otomo *et al.* (2013) checked selected vermicomposting farms in RSA using molecular tools and concluded that there was no evidence of the presence of *E. fetida* in all the locations studied. *E. fetida* material



at the NMSA was also investigated by Voua Otomo using molecular tools to check whether these belonged to *E. fetida* or *E. andrei*, but the investigation was inconclusive because of the material's previous exposure to formalin; therefore, the two species are kept as separate species, as indicated by Pérez-Losada *et al.* (2005). However, because their distinction may be apparent only at a molecular level, the species identification should be based on the external characters described at the generic level.

#### Genus *Dendrodrilus* Omodeo, 1956

One species, *Dendrodrilus rubidus* (Savigny, 1826), with subspecies *D. rubidus rubidus* (Savigny, 1826) and *D. rubidus subrubicundus* (Eisen, 1873).

*Notes:* The validity of the subspecies is in question (Csuzdi & Zicsi 2003). Both reproduce parthenogenetically in variable morphs and have been described under numerous synonyms. Palearctic origin, distributed occasionally or intentionally by humans. Frequently reported from numerous localities in RSA (Plisko 2010) under various synonyms. Epigeic, occur under bark of fallen trees, in the litter and between the roots of plants in grasslands and various plantations. Common in gardens and occur abundantly in natural and cultivated environments, from various altitudes. Present separation into two subspecies is based on documented data by Csuzdi and Zicsi (2003), and Blakemore (2010), and Genbank may be searched for molecular data.

- 1 Clitellum on some of the segments 25, 26–31, 32. Tubercula pubertatis elongated strips on 29–30.....***D. rubidus rubidus*** (Savigny, 1826)

Description: Body length 26–50 mm. Spermathecal pores in 9/10 and 10/11 or absent. Seminal vesicles in three segments 9, 11, 12, or in 11, 12; usually first pair located in 9 much smaller than the others.

*Notes:* In RSA is more frequent than *subrubicunda*. Occurs abundantly in natural and cultivated fields, at sea level and at high altitudes in the Drakensberg mountains. Recorded from KZN, FS, GP, EC, WC. Epigeic. Found together with various species of indigenous microchaetids, tritogeniids and acanthodrilids, and also with other introduced lumbricids and megascoleids (Plisko 2010). A great consumer of organic matter (Csuzdi & Zicsi 2003), it may compete for food with other invertebrates and possibly its distribution and developing populations within a country should be controlled, as indicated by Plisko (2010).

- Clitellum on some of the segments 26, 27–31, 32. Tubercula pubertatis present, on 28–30, as compact bands, or reduced to slender strips.....

.....***D. rubidus subrubicundus*** (Eisen, 1873)

Description: Body length 30–65. Spermathecal pores in 9/10 and 10/11. Seminal vesicles in three segments, 9, 11, 12.

*Notes:* In KZN less frequent than *rubidus rubidus* although the need for control of its growing populations is emphasised.

#### Genus *Dendrobaena* Eisen, 1873

Four species in RSA: *D. cognettii* (Michaelsen, 1903), *D. hortensis* (Michaelsen, 1890), *D. octaedra* (Savigny, 1826), and *D. veneta veneta* (Rosa, 1886).

- 1 Setae widely spaced in eight regular lines (Fig. 9C). Clitellum on 28, 29–33. Tubercula pubertatis on 31–33, as small bands .....***D. octaedra*** (Savigny, 1826)

Description: Body length 30–60 mm. Colour violet-reddish, often iridescent. First dorsal pore in 4/5. Spermathecal pores in three intersegmental furrows 9/10, 10/11, 11/12. Spermathecae in 9, 10, 11. Seminal vesicles in three segments, 9, 11, 12. Calciferous glands in 11–12 with well-developed lateral pouches in both segments. Holandric. Excretory system holoic, with nephridial bladders 'octaedra' shaped.



*Notes:* Palearctic species, broadly distributed worldwide. Reproduces biparentally and parthenogenetically, with high morphological variations, and variable morphs. Epigeic. In RSA occurs commonly in plantations and forests into which foreign plants or trees have been introduced. Nearly thirty records refer to protected areas (Plisko 2010). Known from high altitudes above 1700 m in the Drakensberg mountains. Noted together with other introduced lumbricids and megascoleids.

- Setae in four distant pairs. Clitellum on 26, 27–32, 33. Tubercula pubertatis on 30–31 ..... ***D. veneta veneta*** (Rosa, 1886)

Description: Body length 35–100 mm. First dorsal pore in 5/6. Male pore glands slightly protruding onto neighbouring segments. Spermathecal pores in 9/10 and 10/11. Septa 7/8–9/10 thickened. Spermathecae in 9 and 10. Seminal vesicles in 9, 10, 11, or 11 and 12. Calciferous glands in 10–12, with no lateral pouches. Excretory system holoic, with small nephridial bladders.

*Notes:* Origin in East Mediterranean area; spread to other European countries and also to other continents in tandem with the developing vermicomposting industry. Synantropic. In RSA it is recorded from garden soil and composting heaps (Plisko 2010). Common in vermicomposting. Muyima *et al.* (1994) studied the species' adaptability for vermicomposting production.

- 2 Clitellum on segments 33–36, 37. Tubercula pubertatis absent. Setae distantly located, in pairs ..... ***D. cognettii*** (Michaelson, 1903)

Description: Body length 35 mm. Violet to light red dorsally, light ventrally, sometimes iridescent. Setae widely spaced, in pairs. Dorsal pores absent. Spermathecae absent. Seminal vesicles in 11, 12. Calciferous glands in 11–13, with lateral pouches in 11, 12. Excretory system holoic; nephridial bladders in postclitellar segments bilobate.

*Notes:* Palearctic origin. Its distribution is not well known. The initial species Descriptions were possibly based on a parthenogenetic morph, and its small size has put the species' validity in question for nearly a century. The species' taxonomical position was discussed by Csuzdi and Zicsi (2003) and a species revision was suggested. Blakemore (2010) synonymised *D. cognettii* with a few other controversial species, which together probably form a highly polymorphic parthenogenic species-complex. In RSA the species was found only in the Cape Peninsula (WC) in the litter of a pine plantation that has been integrated into the indigenous Newlands Forest.

- Clitellum on 27–33. Tubercula pubertatis on 30–32, 33 ..... ***D. hortensis*** (Michaelson, 1890)

Description: Body length 70–125 mm. Setae in eight rows with distance between *ab* and *cd* shorter than *bc*. First dorsal pore in 5/6. Male pores with moderate glandular tumescens protruding onto neighbouring segments. Spermathecal pores present, in 9/10 and 10/11. Septa 7/8–9/10 thickened. Spermathecae in 9 and 10. Seminal vesicles in 9, 10, 11, or 11 and 12. Calciferous glands in 11–13, lateral pouches lacking. Holandric. Excretory system holoic, nephridial bladders sausage-shaped.

*Notes:* Known from Central and Western Europe, distributed over Europe and other continents mainly in connection with the vermicomposting industry. Synantropic, occurs in manure, composting heaps or any litter rich in decaying organic matter. In RSA it is recorded from garden soil and composting heaps (Plisko 2010).

### Genus *Octolasion* Örley, 1885

Two species: *O. cyaneum* (Savigny, 1826) and *O. lacteum* (Örley, 1881). Morphologically similar, although the constant position of the clitellum and tubercula pubertatis indicates difference.

- 1 Clitellum initiates at segment 29, terminates at 34. Tubercula pubertatis along the ventral borders of the clitellum, thin bands on 29–33 ..... ***O. cyaneum*** (Savigny, 1826)

Description: Body length 7–145 mm. Unpigmented, grey. Setae at anterior part closely paired, post clitellum distant. First dorsal pore in 11/12. Male pores with small tumescens not extending to neighbouring segments. Spermathecal pores in 9/10 and 10/11. Calciferous glands in 10–11. Holandric. Excretory system holoic, nephridial bladders ocarina-shaped.

*Notes:* Native to Palearctic, transported broadly to many parts of the world. Kuu and Ivask (2010) observed the species' quick adaptation to new environmental conditions. Endogeic. In RSA it has

been found only twice; once in a garden between the roots of imported plants in EC, and a recent new record in WC.

- Clitellum constantly on 30–35. Tubercula pubertatis on 30–35.....  
..... *O. lacteum* (Örley, 1881)

Description: Body length 30–145 mm. Unpigmented, grey. Setae at anterior part paired more closely than at posterior. Male pores with tumescens slightly extending to neighbouring segments. Spermathecal pores in 9/10 and 10/11. Calciferous glands in 10–11 with lateral diverticula in 10.

Notes: Palearctic origin, broadly distributed worldwide. Described under various synonyms. In RSA common in moist-to-wet biotopes, and in rich organic matter in forests, grasslands and gardens. Endogeic. Reproduces bisexually and parthenogenetically. The small, 30–45 mm morphs produced via parthenogenetic polyploid reproduction create abundant communities. Under the favourable climatic conditions found in RSA, the species occurs in large populations in wet biotopes, and has spread to cultivated and natural fields. Control of its growing population is advised.

### Family Megascolecidae Rosa, 1891

Megascolecidae is a second family belonging to the superfamily Megascolecoidae (compare notes for Acanthodrilidae), and is the largest group of megadrile, accounting for around 2000 taxa recorded into various ranks and various generic/family statuses (Csuzdi 2012; Sims & Easton 1972; Easton 1979, 1982; Blakemore 2002). From these, nearly 30 species are known to be distributed worldwide and to adapt easily under various conditions in new biotopes. These species have been described/re-described under numerous synonyms in various genera, creating a long list of names. Sims and Easton (1972), Easton (1982) and Blakemore (2004a, 2010) have eliminated a number of the synonyms and have grouped some of the accepted names into species-complexes. Species known from RSA have also been reported under various synonyms. Some of them have been positively accredited to valid species and their recorded presence in the country has been summarised by Plisko (2010). However, a large portion of the material collected in this country and accessioned in the NMSA has also been recorded under various synonyms, or simply marked as ‘*Pheretima*-group’, possibly referring to a presently unidentified species. This paper includes only those species which have been positively identified and assigned to a ‘species group’, as indicated by Sims and Easton (1972) or Blakemore (2004a), and have been found in RSA. In the case of specimens that differ from those placed in the key, it is necessary to consult other literature (Michaelsen 1900; Stephenson 1930; Gates 1972; Blakemore 2002, 2010) and newly described megascolecid species.

In RSA 12 species of three genera are known: *Amyntas* (Kinberg, 1867) – eight species; *Metaphire* Sims & Easton, 1972 – two species; *Perionyx* Perrier, 1872 – one species. *Pontodrilus litoralis* (Grube, 1855), assigned to Megascolecidae by Plisko (2010), is placed separately in the Appendix of this paper. The megascolecids recorded in this key were introduced to RSA at different times, either naturally, or intentionally or coincidentally by humans, by means of one of the various mechanisms of species introduction hypothesised by Ljungstöm (1972). Their appearance in RSA has been summarised by Plisko (2010).

The species are terrestrial, occurring in cultivated fields (mostly in sugar cane plantations); in parks and gardens; in natural biotopes to which they were transported along with introduced bushes and other plants; in experimental plots; on riverbanks; and in other moist areas. They are often found in polluted spots, and are common in composting heaps, vermiculture farms, nurseries and pot plants.

All the species reproduce bisexually, although parthenogenetic reproduction is frequently noted. In parthenogenetic morphs the prostates and spermathecae may be degraded or aborted, and the male pores malformed or absent. Ljungström (1972) found that in a majority of *A. diffringens* the prostates and spermathecae were degraded or aborted. In the material collected from a polluted field in the Pietermaritzburg area (KZN) it was also found that the prostates were greatly deformed, although the spermathecae were present and well developed (personal observation).

A practical/shortened characterisation of the megascolecids occurring in RSA soils may be given as follows: Body cylindrical, segments clear, not marked externally by furrows. Length 20–150 mm. May be pigmented or not. Setae perichaetine (numerous setae distributed around the body at each segment). Prostomium epilobous (Fig 7C). Dorsal pores present (there are external intersegmental openings to the coelomic cavity in some of the intersegmental furrows). Female pore single, in 14 (a single pore is characteristic for South African megascolecids). Male reproductive organs megascolecine (the term megascolecine indicates that the single pair of prostates open their pores in segment 18, together with the ectal part of the male ducts, in male pores). Male pores paired, in 18, postclitellar, (parthenogenetic morphs may lack male pores or these may be degenerated). Spermathecal pores paired, in some of the intersegmental furrows 4/5–8/9; the number of pores and their location are specific characters. Clitellum annular (Fig. 5A). Gizzard in 8–10. Intestinal caeca can be present. Ovaria paired in 13. Holandric (testes restricted to segment 10 and 11). Excretory system meroic (minute, numerous nephridial tubules in each segment) or holoic (a single pair of large nephridium in each segment). Prostate racemose (with no central canal) (Fig. 6A). Spermathecae paired, in pre-testicular segments. Copulatory pouches (invagination of the male pores) present or absent. Calciferous glands absent.

#### Key to introduced Megascolecidae genera in South Africa

- 1 Excretory system meroic ..... 2
- Excretory system holoic (one pair of nephridial tubules per segment) ..... *Perionyx* Perrier, 1872

Description: Unpigmented. Setae perichaetine. Female pore single, median on 14. Clitellum annular. Holandric. Male reproductive organs megascolecine. Male pores paired in 18. Prostate racemose, paired. Seminal vesicles present. Intestinal caeca absent. Calciferous glands absent, although some calciferous tissues may be present in part of the esophageous. Dorsal pores absent. No typhlosome.

- 2 Copulatory pouches absent ..... *Amyntas* Kinberg, 1867

Description: Body cylindrical. Length 20–150 mm. Pigmented or not. Setae perichaetine. Prostomium epilobous. First dorsal pore in one of the intersegmental furrows 11/12–13/14. Clitellum annular on 14–16, or slightly extended to neighbouring segments. Male genitalia megascolecine. Female pore single, in 14 midventral. Spermathecal pores paired, between intersegmental furrows 4/5–8/9; the number and location is a specific character. Male pores in 18, superficial. Genital markings present or absent. Gizzard in 8–10. Intestinal caeca present, paired, originating in segment 27 or in the area, extending forwards through a few segments. Excretory system meroic (nephridia minute, multiple in one segment, formed by fragmentation of the embryonic original single nephridial pair). Holandric. Prostates racemose. Calciferous glands absent. Spermathecae paired, with variable diverticulum; the shapes of ampulla and diverticulum are exclusive, taxonomic, features.

Notes: The species of this genus are broadly dispersed around the world and appear in variable biotopes. In RSA are common and were recorded from numerous localities, summarised by Plisko (2010). Ljungström (1972) provided extensive information on their possible introduction to this country. Athecate species present in this genus are listed under *minimus* group = *Amyntas illotus* species-group (Blakemore 2010).

- Copulatory pouches present ..... *Metaphire* Sims & Easton, 1972  
Description: Length 40–130 mm. Body cylindrical. Setae perichaetinae. Prostomium epilobous. Clitellum annular on 14–16. Male pores paired on 18. Female pore single, on 14. Excretory system meroic. Spermathecal pores paired, present. Dorsal pores present. Spermathecae present, paired. Typhlosole present. Caeca present. Genital markings absent. Holandric. Male genitalia megascolepine. Prostates racemose. Calciferous glands absent. Spermathecae paired, with variable diverticulum; the shapes of ampulla and diverticulum are exclusive, taxonomic, features.

### Key to introduced species of *Amyntas* Kinberg, 1867

- 1 Spermathecal pores paired, present in one intersegmental furrow (5/6), degraded or absent. .... *A. minimus* (Horst, 1893) species-group (Sims & Easton 1972: 213)

Description: Length 20–40 mm. Number of segments 70–80. First dorsal pore in 11/12. Clitellum on 14–16, sometimes degraded. Female pore minute on 14. Male pores paired on 18, variably raised on small porophores. Genital markings present or absent. Septa 5/6, 6/7 and 7/8 moderately thickened, 8/9 and 9/10 aborted. Gizzard in 8–9. Intestinal origin in 15. Caeca simple, originating in 27, extended forwards to 24. Spermathecae, degraded or absent; if present in 6. Seminal vesicles present, degraded or absent. Prostates present in 17–19, or degraded. Copulatory pouches lacking

Notes: Described under numerous synonyms (Blakemore 2010) and is known worldwide. Thecate and athecate populations are also known from many parts of the world (Blakemore 2010) and from RSA (Plisko 2010; NMSAD). The large population of athecate, degraded specimens collected in QEP (Nxele 2012) indicates parthenogenetic reproduction. Ljungström (1972) likewise collected parthenogenetic morphs with spermathecae and seminal vesicles developed, degraded or absent. Abnormality in the development of the clitellum was also observed. The species is known from grasslands and meadows, and forested, natural and cultivated land (Zicsi 1998; Plisko 2010). Thecate degeneration is attributed to the parthenogenetic reproduction, and has been widely discussed (Gates 1932, 1972; Tsai *et al.* 2002; Blakemore 2003, 2010) with the species' systematic position being considered (Gates 1972; Sims & Easton 1972; Blakemore 2003). Indicated as a '*minimus* species-group' by Sims and Easton (1972: 213), following Gates's (1932) '*illotus*-group'.

- Spermathecal pores in more than one intersegmental furrow ..... 2
- 2 Spermathecal pores in two intersegmental furrows ..... 3
- Spermathecal pores in three or four intersegmental furrows ..... 4

- 3 Spermathecal pores in intersegmental furrows 5/6, 6/7. ....  
..... *A. morrissi* (Beddard, 1892) species-group (Sims & Easton 1972: 236).

Description: Length 63–107 mm. Segments 73–97. Setae numerous, *ca.* 40–50 per segment. First dorsal pore in 10/11. Spermathecal pores minute, superficial. Male pores minute on small disc-shaped porophores. Clitellum annular on 1/n14, 14–1/n16. Genital markings present, variable; paired, disc-shaped on 6–7, two or three on each porophore forming a triangle; one to six pre-setal markings on 17 or 18 or 19 or 20. Septa 4/5–7/8 thickened, 8/9, 9/10 absent. Gizzard in 7/8–9/10. Intestine originates in 15. Caeca simple, originates at 27 and extends forwards to 24. Spermathecae paired, in 6 and 7 respectively; spherical ampulla with long slender duct with a single diverticulum. Seminal vesicles in 11–12. Prostatic glands, multi-branched in 17/18–19/20, ducts muscular with single loops.

Notes: Species known under numerous synonyms (revised by Blakemore 2010). Distributed worldwide in tropical and temperate regions. In RSA collected from a riverbank in Potchefstroom (NW), and from the Sabie area (MP). Recorded in the NMSAD from Pretoria city parks (GP) (Plisko 2010). May be found in pastures, grasslands, in riverbanks in the gravel of the waterline, and in the moist, rich organic matter found in the top layer of the soil. Indicated as a '*morrissi* species-group' by Sims and Easton (1972: 236).

- Spermathecal pores in intersegmental furrows 7/8 and 8/9 .....  
..... *A. aeruginosus* Kinberg, 1867 species group (Sims & Easton 1972: 234).

Description: Length 50–115 mm. Segments 80–110. Pigmented, with brown-violet tint. Prostomium epilobous. First dorsal pore in 11/12. Female pore single, mid-ventral in 14, inconspicuous. Male pores paired in 18, on small porophores (copulatory pouches absent). Genital papillae and markings present, variable. Intestinal caeca paired, simple; initiate in 27 and extend forwards to 19, 18. Last pair of hearts in 13. Testis enclosed. Seminal vesicles paired, in 11 and 12, respectively. Ovaries paired in 13. Prostatic glands in 18; large, extending forwards to 17, 16, and backwards to 19, 20. Prostatic ducts

short, muscular with slender ental region. Spermathecae in 8 and 9; ampulla and duct similar length; diverticulum slender with convoluted end.

*Notes:* Known from Pacific Islands (see Blakemore 2010: 305). Recorded in RSA from agricultural fields in the KZN area (Dlamini 2002), and from parks and in various locations (Plisko 2010). May occur also in various locations that are rich in organic matter. It is a variable species that has been recorded under a number of synonyms, and revised and re-described by Sims and Easton (1972) and Blakemore (2010). Sims and Easton (1972: 234) assigned it to the '*aeruginosus* species-group'.

- 4 Spermathecal pores in three intersegmental furrows (5/6, 6/7 and 7/8) ..... 5
- Spermathecal pores in four intersegmental furrows (5/6, 6/7, 7/8 and 8/9) ..... 6

- 5 Spermathecal pores in 5/6, 6/7 and 7/8. Spermathecae with long diverticulum; ampulla almost round, diverticulum moniliform .....  
..... *A. hawayanus* (Rosa, 1891) species group

*Description:* Length 100–130 mm. Segments 96–98. First dorsal pore in 10/11. Clitellum annular on 1/n14–1/n16. Genital markings present, variable; three or four pairs on 18 forming a semicircle between the male porophores. Septa 6/7, 7/8 and 10/11, 11/12 thickened; 8/9, 9/10 absent. Intestinal origin in 15. Caeca originating in 27, extends forward to 24. Seminal vesicles in 11, 12. Prostatic glands large, in 16–23, 24. Three pairs of coelomic genital markings in 18.

*Notes:* Described under various synonyms, accredited to *A. gracilis*. Species denoted as '*hawayanus* species-group' by Sims and Easton (1972: 213).

- Spermathecal pores in 5/6, 6/7 and 7/8. Spermathecae large, round; diverticulum elongate ..... *A. gracilis* (Kinberg, 1867) accredited to *hawayanus* species-group (Sims & Easton 1972: 215).

*Description:* Length 100–130 mm. Segments 85–95. Prostomium epilobous. First dorsal pore in 10/11. Clitellum annular on 14–16. Female pore single on 14, minute. Male pores paired on 18. Genital markings present, three pairs near the male pores on 18, forming the shape of a semicircle. Septa 6/7 and 7/8 slightly thickened, 8/9 and 9/10 aborted. Gizzard in 8. Intestinal origin in 15. Caeca simple, originating in 27, extending forward to 24. Seminal vesicles in 11–12. Prostatic glands large, in 17–21, 22.

*Notes:* Tropical and subtropical on most continents, distributed by humans. Occurs in greenhouses in warm temperate zones. Occurs in grasslands, pastures, riverbanks, farms and gardens. May be found in vermicomposting heaps. In RSA recorded from natural and agricultural habitats in MP and WC (Plisko 2010). Reproduction presumably biparental and parthenogenetic. Described under various synonyms (Blakemore 2010).

- 6 Spermathecal pores in four intersegmental furrows. Spermathecal pores dorsally in 5/6, 6/7, 7/8 and 8/9. Spermathecae large, slightly rounded, with long diverticulum, rosary-shaped ..... *A. rodericensis* (Grube, 1879) species-group

*Description:* Spermathecae large, slightly rounded, with long, rosary-shaped diverticulum. Length 70–110 mm. Segments 80–100. Setae absent on clitellar segments. First dorsal pore on 9/10. Clitellum annular on 14–16. Female pore single, minute on 14. Male pores paired on 18, on swollen porophores. Genital markings present; on 17–18, as paired discs. Septa thin, 8/9 and 9/10 aborted. Gizzard in 8–10. Intestinal origin in 15. Caeca simple, originate in 27, extending forward to 24. Seminal vesicles in 11–12; various sizes. Prostatic glands in 17–21, 22.

*Notes:* Assigned by Sims and Easton (1972: 235) to '*diffringens* species-group'. Described under numerous synonyms (listed and revised by Blakemore 2010), and distributed worldwide, in various habitats. In RSA the most common species are known from LP, KZN, EC and MP (Plisko 2010). It is common in natural and agricultural fields (Ljungström 1972; Zicsi & Reinecke 1992; Horn *et al.* 2007; Plisko 2010).

- Not so ..... 7

- 7 Spermathecae large and in 6–9; ampulla conical with narrow duct, nearly as long as the ampulla; diverticulum slender, stalk and small simple seminal chamber. Spermathecal pores in 5/6–8/9.....  
..... *A. corticis* (Kinberg, 1867) accredited to *corticis* species-complex

*Description:* Length 60–150 mm. Segments 80–118. Dark brown dorsally, paler ventrally. Setae numerous, *ca.* 40–60 per segment. First dorsal pore in 11/12. Clitellum annular on 14–16. Male pores



on low porophores in 18. Genital markings present, variable. Septa 4/5–5/6 thin, 8/9 and 9/10 aborted; 10/11–12/13 slightly thickened. Last pair of hearts in 13. Gizzard between septa 7/8 and 9/10. Intestinal caeca paired, in 27–19, 18. Seminal vesicles in 11 and 12. Coelomic pouches paired on septa 12/13 and 13/14. Prostatic glands extending from 16, 17–19, 20; prostatic ducts short and muscular; sometimes degraded.

*Notes:* It is a variable species described under a number of synonyms. It is very widely distributed, and has been recorded from temperate and tropical regions throughout the world. In RSA it occurs mostly in sugar cane plantations, and in cultivated lands with various plantations; it has been recorded at experimental plots at Cedara Agriculture College (KZN). Found also in natural biotopes, in parks and gardens in conjunction with introduced bushes and plants. Parthenogenetic morphs may be observed. A comprehensive taxonomic review is given by Sims and Easton (1972) and Blakemore (2010: 329). Sims and Easton (1972: 234) accredited this species to the '*diffringens* species-group', while Blakemore (2010) placed it in the *Amyntas corticis* species-complex *sensu* Blakemore 2003: 14.

- Spermathecae with diverticulum slightly longer than duct; duct rather thick and shorter than the ampulla; ampulla triangular with a broad ental portion, becoming increasingly bigger and more compressed backwards. Spermathecal pores paired, in 5/6–8/9, superficial, minute ..... ***A. diffringens*** (Baird, 1869) species-group

Description: Length 49–95 mm. Segments 80–115. Prostomium epilobous. Setae absent on clitellum, but present ventrally on acitellate specimens. First dorsal pore 10/11. Clitellum on 14–16. Female pore single, minute on 14. Male pores on big conical porophores on 18. Genital markings present; small disc-shaped, usually paired, ventral on 7–9. Septa 8/9, 9/10 absent or vestigial. Gizzard in 8. Intestinal origin in 15. Intestinal caeca simple, originating in 26, extending forward, reaching 24. Typhlosole single, straight, thickened at intersegments, ending in 65–105. Last pair of hearts in 13. Testis sacs unpaired. Seminal vesicles various sizes, in 11, 12. Prostatic glands present, or absent or degenerated. If present, in 18 extending into two segments. Often vestigial or absent on both sides, or only missing parts at one side.

*Notes:* Parthenogenetic reproduction appears in many populations, especially in those from chemically polluted fields. Various degrees of prostatic gland degeneration are observed in various sized morphs. This is a topsoil species, and is always found in the upper layer of the soil. It is most abundant in sugar cane fields, in naturally decomposed leaf litter, and in composting heaps. Used in composting and vermiculture production. Indicated as a '*diffringens*' species-group (Sims & Easton 1972: 235).

### Key to introduced species of *Metaphire* Sims & Easton, 1972

- 1 Spermathecae oval-shaped with spermathecal diverticula a zigzag shape ..... ***M. californica*** (Kinberg, 1867) species-group

Description: Length 50–132 mm, width 3–5 mm. Segments 80–112. Spermathecal pores minute, superficial in 7/8–8/9. Male pores in 18. Copulatory pouches present. Female pore single, median on 14. Clitellum annular on 13, 14–16. First dorsal pore in 11/12. Prostomium epilobous. Genital markings absent. Septa 8/9–9/10 aborted, 5/6 or 6/7–7/8 and 10/1–13/14 muscular. Intestinal origin in 15 or 16. Caeca simple at 27–22. Typhlosole lamelliform, irregular, translucent posteriorly, ending in region of 64–74 segments. Last heart in 13.

- Spermathecae paired, in 8 and 9 respectively; small duct shorter than ampulla; diverticulum slender, longer than ampulla, coiled ..... ***M. quadragenaria*** (Perrier, 1872)

Description: Length 50–130 mm, width: 3–5 mm. Segments 80–110. Prostomium epilobous. First dorsal pore in 6/7–12/13, 13/14. Setae perichaetinae *ca.* 45–50 per segment setae sometimes missing on clitellum. Clitellum annular on 14–16. Male pores *ca.* 0.2 circumference apart in copulatory pouches on 18 (Michaelsen 1900; Sims & Easton 1972: 215 – although they do not state how deep these are). Female pores single on 14. Spermathecal pores two pairs *ca.* 0.3 circumference apart in 7/8/9 (Sims & Easton 1972: 215). Genital markings absent. Septa 4/5–7/8 thickened; 8/9–9/10 absent; 10/11 thickened. Gizzard between 7/8 and 9/10. Calciferous glands and oesophageal pouches absent. Excretory system meroic. Caeca simple, paired, at 27–23, 24. Last heart in 13. Holandric. Seminal vesicles paired, in 11 and 12 respectively. Coelomic pouches paired on septa 12/13 and ?13/14. Prostates racemose, large 16–22; ducts S- or U-shaped pass into copulatory pouches that each contain a small penis-like papilla.



Genus *Perionyx*, 1872*Perionyx excavatus* Perrier, 1872

Description: Length 20–120 mm. Unpigmented or slightly red dorsally, slightly yellow at ventral side. Prostomium epilobous. First dorsal pore in some of the intersegmental furrows 2/3–5/6. Nephropores conspicuous, in irregular lines. Spermathecal pores paired, in intersegmental furrows 7/8–8/9 respectively. Female pore single, mediventral. Male pores paired, in 18. Clitellum on 13–17. Gizzard present or absent. Intestinal origin in 15–16. Small parts of calciferous tissues may occur in segment 13, 14 or 15. Last lateral heart in 12. Excretory system holoic, avesiculate. Seminal vesicles in 11 and 12, last pair often extended through septa 12/13–14/15. Prostates in 18, ducts short, straight. Spermathecae paired, large with short ducts. Penial setae present.

Notes: Distributed widely worldwide. May be found under the bark of rotten, fallen logs; under moss and debris; on riverbanks; in soil rich in organic matter; in manure heaps and composting areas; and in any considerably moist biotope. Recently used in vermicomposting farms. In RSA breeding is possible under favourable climatic conditions. This species was used in various experiments by Reinecke *et al.* (1992), and Reinecke and Pieters (1997, 1998), and may be found near previous experimental fields.

## Appendix to Megascolecidae

Genus *Pontodrilus* Perrier 1874

Genus *Pontodrilus* is characterised by tubular prostates connected with male pores on segment 18. Excretory system holoic (although nephridia may be absent from a few anterior segments) and setae lumbricine. After a few attempts at generic and species revision (Easton 1983; Blakemore 2000, 2002, 2006, 2008a, 2010), the taxonomic status of the genus is still under discussion. Plisko (2010) recorded it under megascolecids, although here the genus and its species *Pontodrilus litoralis* (Grube, 1855) are provisionally placed in the appendix to megascolecids.

*Pontodrilus litoralis* (Grube, 1855)

Description: Length 40–75 mm. Segments *ca.* 100. Prostomium epilobous. Setae lumbricine, widely paired. Nephropores small near setae *a* lines, as from intersegmental furrow 12/13. Clitellum saddle-shaped on 12, 1–17. Male pores paired in 18 near *b* lines, in small depression, on porophores. Female pores paired, near *aa* lines, in 14. Spermathecal pores paired in two intersegmental furrows 7/8 and 8/9. Genital markings present, midventrally in intersegmental furrow 12/13, and in 19/20. Septa 5/6 attached to gizzard, 6/7–12/13 thickened. Gizzard vestigial in 5. Nephridia paired, in *b* lines, absent in 1–12 and 14b. Lateral hearts in 10–13. Holandric. Seminal vesicles in 11 and 12. Ovaries in 13, with no ovisacs. Prostates paired, in 18; tubular glands with thick, curving duct. Spermathecae paired in 8 and 9 respectively; each with slightly bulbous duct; ampulla with a long diverticulum. Penial setae absent. Dorsal pores absent. Calciferous glands absent. Typhlosole absent.

Notes: In RSA recorded by Michaelsen (1913) from the coastal area in KZN under the synonym *bermudensis* f. *typicus*, which Blakemore (2008a) accredits to *litoralis*. More information on the species' synonyms and its occurrence may be found in Michaelsen (1910b) and Blakemore (2008a).

### Ocnerodrilidae Beddard, 1891

Currently *ca.* 181 species are described and located in 21 genera (Blakemore 2010; Csuzdi 2012). Ocnerodrilinae occur mainly in tropical/subtropical South America and Africa, with some species extending into the temperate zone of Central and North America, and the European northern hemisphere, while Malabarinae are restricted to India and the Seychelles Islands. Christoffersen (2008) recorded 70 Ocnerodrilidae (with no family subdivision) species in South America, with South American endemics accounting for 86 % of the taxa. A small ratio of them was assigned to a group distributed accidentally or intentionally by human actions. However, only two of these, *Eukerria saltensis* (Beddard, 1895) and *Ocnerodrilus occidentalis* Eisen, 1878, are pantropical, extending also to the temperate zone of the northern hemisphere (Rota 2013).

*Important characters:* Prostates tubular, variable, could be paired or 3 pairs with pores between 16–21. Male pores paired in 17 or 18, associated with openings of prostates, at ventral part of clitellum. Setae lumbricine, paired. Clitellum annular but does not cover the body completely on the ventral side, separated by seminal grooves (clitellum may be seen as saddle-shaped). Tubercula pubertatis absent. Gizzard present or absent. Spermathecae present or absent; if present, paired, in front of testis segments. Intestinal origin in 12. Calciferous glands oesophageal or absent. Seminal vesicles present. Last pair of hearts in 11. Holandric or proandric. Excretory system holoic, avesculate. Intestinal caeca absent. Unpigmented.

*Notes:* Twenty-one genera are known from African and American tropical and subtropical areas and possibly also from adjacent regions (Christoffersen 2008; Fragoso & Rojas 2009). Individuals are small, usually shorter than 130 mm, living in moist to semi-aquatic biotopes; they may be terrestrial, although they prefer moist, limnic or even aquatic environments. A few species have been transported intentionally or accidentally by humans (Rota 2013). In RSA four species of four genera are known: *Eukerria* Michaelsen, 1935; *Nematogenia* Eisen, 1900; *Ocnerodrilus* Eisen, 1878; and *Pygmaedrilus* Michaelsen, 1890. From these only *Eukerria saltensis* (Beddard, 1895) may be accepted as an introduced taxa. The other species reported by Plisko (2010) need taxonomic revision to establish their original identity although they are included in the present paper. Some of them may be of African origin, or possibly indigenous to South Africa. The recent opinion of a few researchers (Christoffersen 2008; Rota 2013) is that the Ocnerodrilidae form a homogeneous taxon and according to the classical phylogeny compose the most recent off-shoot from the ancestral root-genus of all megascolecoïd forms.

#### Genus *Eukerria* Michaelsen, 1935

Only *Eukerria saltensis* is known to occur in RSA.

#### *Eukerria saltensis* (Beddard, 1895)

Description: Length 35–63 mm. Colour variable: grey, sometimes with greenish tint. Setae lumbricine, paired. Prostomium epilobous. Spermathecal pores with tumescence at intersegmental furrows 7/8 and 8/9, median to line of *c* seta. Clitellum saddle-shaped, nearly annular on 13, 14–19, 20, separated ventrally by two longitudinal seminal grooves connecting the prostate pores of 17 and 19, and male pores in 18. Gizzard in 7.

Calciferous glands, one pair in 9. Proandric. Nephridia aversiculate (in some segments absent or rudimentary). Spermathecae paired in 8 and 9. Tubular prostates thin, may extend into 3–7 segments.

*Notes:* The species may be aquatic or littoral, although it has also been noted in terrestrial biotopes. The number of new occurrences noted recently worldwide may be connected with increased exotic gardening, freshwater angling, intense port activities, and probably also with climate change, which is affecting aquatic systems by raising water temperatures, and increasing environmental changes (Rota 2013). In RSA the species has been recorded in a number of littoral biotopes by Jamieson (1967), Ljungström (1972), and Viser and Reinecke (1977). In NMSAD more than twenty records are noted (Plisko 2010).

It should be noted that the clitellum is nearly ‘annular’ although it does not cover the ventral part of the body and it is separated by longitudinal seminal grooves, as noted by Rota (2013). In this paper it is described as ‘saddle-shaped’, following the descriptions of the clitellum included in the Glossary.

#### Genus *Nematogenia* Eisen, 1900

##### *Nematogenia lacuum* (Beddard, 1893)

Description: Length 25 mm. Grey to slightly brown. Nephropores inconspicuous. Clitellum saddle-shaped on  $\frac{1}{2}13$ – $\frac{1}{2}26$ . Septa 5/6–9/10 thickened. Gizzards in segments 6 and 7. Paired calciferous glands in 9. Nephridia aversiculate, first pair in 6. Proandric. Seminal vesicles paired in 12. Spermathecae paired, in 9; duct longer than ampulla. Prostates long.

*Notes:* Noted only twice in RSA, on both occasions in garden soil (Zicsi 1998).

#### Genus *Ocnerodrilus* Eisen, 1878

##### *Ocnerodrilus occidentalis* Eisen, 1878

Description: Length 30–40 mm. Prostomium epilobous. Male pores in 17, with male porophores extending to the ventral part of the clitellum, connected by seminal grooves with prostatic pores. Clitellum saddle-shaped on 13–19, 20, marked ventrally by prominent, paired male porophores on 17, connected by a ventral transverse groove between prostatic pores in 17 and 19. Nephropores near *b* setae. Prostates one pair, much elongated, can reach segment 24. Septa 5/6–11/12 thickened somewhat thickened. Gizzard absent. Holandric. Calciferous glands paired, large, in segment 9. Spermathecae absent.

*Notes:* Widely distributed in tropical and temperate areas, as noted by Righi (1984) and Zicsi (1996, 1997). In RSA reported by Černosvitov (1940), Ljungström (1972), and Zicsi (1998). A thecate form of this species, *Ocnerodrilus africanus* Beddard, 1878, assigned by Michaelsen (1913) and Zicsi (1998) to the genus *Ilyogenia*, may not occur in this country, as discussed by Plisko (2010), and is not included in this paper.

#### Genus *Pygmaeodrilus* Michaelsen, 1890

##### *Pygmaeodrilus arasionensis* Michaelsen, 1910

Description: Length 25–45 mm. Unpigmented, slightly white. Setae lumbricine, closely paired. Epilobous or zygalobous. Female pores at 14 in *ab* line. Male pores in

17 with small glands near setae *ab*. Clitellum saddle-shaped on  $\frac{1}{2}$  of 12,  $12-\frac{1}{2}$  of 19. Septa 5/6–10/11 thickened. Crop in 4–7. Gizzard absent. Calciferous glands in 9. Holandric. Excretory system holoic. Seminal vesicles initiated at 11/12 extending to 12. Spermathecae paired, ampullae in 9 with similar size of diverticulae in 9. No penial setae.

*Notes:* Described from Bothaville in Orange Free State [Free State]; recorded from a few sites in RSA and Namibia (Jamieson 1967). Possibly indigenous to southwestern Africa and transported to RSA by rivers.

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#### REFERENCES

- AVENDAÑO-YÁÑEZ, M.L., ORTIZ-CEBALLOS, Á.I., SÁNCHEZ-VELÁSQUEZ, L.R., M.R. PINEDA-LÓPEZ, M.R. 2014. Synergic effect of *Mucuna pruriens* var. *Utilis* (Fabaceae) and *Pontoscolex corethrurus* (Oligochaeta, Glossoscolecidae) on the growth of *Quercus insignis* (Fagaceae) seedlings, a native species of the Mexican Cloud Forest. *Open Journal of Forestry* **4** (1): 1–7. DOI: 10.4236/ojfor.2014.41001
- BAIRD, W. 1869. Description of a new species of earthworm (*Megascolex diffirgens*) found in north Wales. *Proceedings of the Zoological Society of London* **1869**: 40–43.
- BEDDARD, F.E. 1891. New genera of aquatic Oligochaeta. *Transactions of the Royal Society of Edinburgh* **36**: 273–305.
- 1892. On some species of the genus *Perichaeta* (sensu stricto). *Proceedings of the Zoological Society of London* **1892**: 153–172.
- 1893. Two new genera and some new species of earthworms. *Quarterly Journal of Microscopical Science* **34**: 243–278.
- 1895a. *A monograph of the order of Oligochaeta*. Oxford: Clarendon Press.
- 1895b. Preliminary account on new species of earthworms belonging to the Hamburg Museum. *Proceedings of the Zoological Society of London* **1895**: 210–238.
- BHADOURIA, T. & SAXENA, K.G. 2010. Role of earthworms in soil fertility maintenance through the production of biogenic structures. *Applied and Environmental Soil Science*. Article ID **816073**: 1–7. DOI: 10.1155/2010/816073
- BLAKEMORE, R.J. 2000. *Tasmanian Earthworms*. CD-ROM Monograph with Review of World Families. 'VermEcology', PO BOX 414 Kippax 2615. Canberra, December, 2000. 800 pp.
- 2002. *Cosmopolitan earthworms – an eco-taxonomic guide to the peregrine species of world families*. Monograph. CD ROM.
- 2003. Japanese earthworms (Annelida: Oligochaeta): a review and checklist of species. *Organisms, Diversity & Evolution* **3** (3): 241–244.
- 2004a. Checklist of Pheretimid earthworms after Sims & Easton (1972). In: Moreno, A.G. & Borges, S., eds, *Advances in earthworm taxonomy (Annelida: Oligochaeta)*. Madrid: Editorial Complutense, Universidad Complutense, pp. 127–162.
- 2004b. A provisional list of valid names of Lumbricoidea (Oligochaeta) after Easton, 1983. In: Moreno, A.G. & Borges, S., eds, *Advances in earthworm taxonomy (Annelida: Oligochaeta)*. Madrid: Editorial Complutense, Universidad Complutense, pp. 75–120.
- 2005. Introductory key to the revised families of earthworms of the world (modified after Blakemore 2000, 2002 and Csuzdi 1996, 2000). In: Ito, M.T. & Kaneko, N., eds, *Series of Searchable Texts on Earthworm Biodiversity, Ecology and Systematics from Various Regions of the World*. CD edition. Yokohama: Soil Ecology Research Group, Graduate School of Environment & Information Sciences, Yokohama National University.
- 2006. Whither Octochaetidae? Its family status reviewed. (Annelida: Oligochaeta). In: Pop, V.V. & Pop, A.A., eds, *Advances in Earthworm Taxonomy II (Annelida: Oligochaeta)*. Proceedings IOTM2. Romania: Cluj University Press, pp. 63–84.

- 2007. Origin and means of dispersal of cosmopolitan *Pontodrilus litoralis* (Oligochaeta: Megascolecidae). *European Journal of Soil Biology* **43** (Suppl. 1): S3–S8.
- 2008a. Phylogeny of Megascolecoida revisited with recourse to non-molecular means. In: Pavliček, T. & Cardet, P., eds, *Advances in earthworm taxonomy III (Annelida: Oligochaeta)*. Nicosia: Imprinta LTD, pp. 11–21.
- 2008b. Review of Oriental pheretimoids (*Pheretima* auct. Megascolecidae) with description of a new genus. In: Pavliček, T. & Cardet, P., eds, *Advances in earthworm taxonomy III (Annelida: Oligochaeta)*. Nicosia: Imprinta LTD, pp. 23–36.
- 2008c. Review of Southern Ocean, South Atlantic and Subantarctic Island earthworms updated from Lee (1994). In: Kaneko, N. & Ito, M.T., eds, *A Series of Searchable Texts on Earthworm Biodiversity, Ecology and Systematics from Various Regions of the World*. 3<sup>rd</sup> Ed. CD edition. Yokohama: Soil Ecology Research Group, Graduate School of Environment & Information Sciences, Yokohama National University.
- 2010. Cosmopolitan Earthworms: an Eco-Taxonomic Guide to the Peregrine Species of the World. 4th Ed. VermEcology. Yokohama, Japan.
- BOUCHÉ, M.B. 1972. *Lombriciens de France. Écologie et systématique*. Paris: Institut National de la recherche agronomique.
- BRINKHURST, R.O. & JAMIESON, B.G.M. 1971. *Aquatic Oligochaeta of the world*. Edinburgh: Oliver & Boyd.
- BROWN, G.G. & FRAGOSO, C. (Eds). 2007. *Minhocas na América Latina: biodiversidade e Ecologia*. Londrina: Embrapa Soja.
- BURTELOW, A.E., BOHLEN, P.J. & GROFFMAN, P.M. 1998. Influence of exotic earthworm invasion on soil organic matter, microbial biomass and denitrification potential in forest soils of the northeastern United States. *Applied Soil Ecology* **9**: 197–202.
- ČERNOSVITOV, L. 1940. On some Oligochaeta from Palestine. *Annals and Magazine of Natural History* (11) **6**: 438–447.
- CHRISTOFFERSEN, M.L. 2008. A catalogue of the Ocnerodrilidae (Annelida, Oligochaeta) from South America. *Italian Journal of Zoology* **75** (1): 97–107. DOI: 10.1080/11250000701695250
- CLAUS, C. 1880. *Grundzüge der Zoologie. Vierte durchaus umgearbeitete und verbesserte Auflage*. Marburg: N.G. Elwert'sche Verlagsbuchhandlung.
- CORTET, J., GOMOT-DE VAUFLERY, A., POINSOT-BALAGUER, N., GOMOT, L., TEXIER, C. & CLUZEAU, D. 1999. The use of invertebrate soil fauna in monitoring pollutant effects. *European Journal of Soil Biology* **35** (3): 115–134.
- CSUZDI, Cs. 1886. Über ein Vorkommen von *Microscolex phosphoreus* Dugès, 1837 Oligochaeta: Acanthodrilidae in Ungarn. *Opuscula Zoologica Budapest* **22**: 63–66.
- 1996. Revision der Unterfamilie Benhamiinae Michaelsen, 1897 (Oligochaeta: Acanthodrilidae). *Mitteilungen aus dem Museum für Naturkunde in Berlin* **72** (2): 347–367.
- 2010. *A monograph of the Paleotropical Benhamiinae earthworms*. (Annelida: Oligochaeta, Acanthodrilidae). Budapest: Hungarian Natural History Museum.
- 2012. Earthworm species, a searchable database. *Opuscula Zoologica, Budapest* **43** (1): 97–99.
- CSUZDI, C., PAVLIČEK, T. & NEVO, E. 2008. Is *Dichogaster bolau* (Michaelsen, 1891) the first domicole earthworm species? *European Journal of Soil Biology* **44** (2): 198–201.
- CSUZDI, C. & ZICSI, A. 2003. *Earthworms of Hungary (Annelida: Oligochaeta, Lumbricidae)*. Budapest: Hungarian Natural History Museum.
- DLAMINI, T.C. 2002. *Influence of land use on soil organic matter status, microbial biomass C and size and composition of earthworm communities in northern KwaZulu-Natal*. MSc (Agric) dissertation. Pietermaritzburg: University of Natal.
- DLAMINI, T.C., HAYNES, R.J. & VAN ANTWERPEN, R. 2001. Exotic earthworm species dominante in soils on sugarcane estates in the Eshowe area of the North Coast of KwaZulu-Natal. *Proceedings of the South African Technologists Association* **75**: 217–225.
- D'UDEKEM, J. 1855. Nouvelle classification des Anélides sétigères abranches. *Bulletins de l'Académie Royale des Sciences, de Letters et des Beaux-Arts de Belgique* **22** (2): 533–555.
- DUGÈS, A. 1828. Recherches sur la circulation, la respiration et la reproduction des Annelides abranches. *Annales des Sciences Naturelles* **15**: 284–337.
- 1837. Nouvelles observations sur la zoologie et l'anatomie des Annelides abranches sétigères. *Annales des Sciences Naturelles, Sér. 2* **8**: 15–35.
- EASTON, E.G. 1979. A revision of the “acaecate” earthworms of the Pheretima group (Megascolecidae: Oligochaeta): Archipheretima, Metapheretima, Planapheretima, Pleionogaster, and Polypheretima. *Bulletin of the British Museum (Natural History) Zoology* **35**: 1–126.
- 1982. Australian pheretmoid earthworms (Megascolecida: Oligochaeta): a synopsis with the description of a new genus and five new species. *Australian Journal of Zoology* **30**: 711–735.
- 1983. A guide to the valid names of Lumbricidae (Oligochaeta). In: Satchell, J.E., ed., *Earthworm ecology – from Darwin to Vermiculture*. London: Chapman & Hall, pp. 475–487.



- EISEN, G. 1873. Om Skandinavien Lumbicider. *Öfversigt af Kongliga Vetenskaps-akademiens Förhandlingar* **30** (8): 43–56.
- 1878. On the anatomy of *Ocnerodrilus*. *Nova Acta Regiae Societatis Scientiarum Upsaliensis, Series 3* **10**: 1–12.
- 1884. New Englands och Canadas Lumbicider. *Öfversigt af Kongliga Vetenskaps-akademiens Förhandlingar* **31** (2): 46.
- 1900. Researches in American Oligochaeta with especial reference to those of the Pacific Coast and adjacent islands. *Proceedings of the Californian Academy of Sciences* **2**: 87–256.
- FLETCHER, J.J. 1887. Notes on Australian earthworms. Part II. *Proceedings of the Linnean Society of New South Wales* **2** (2): 375–402.
- FRAGOSO, C., KANYONYO, J., MORENO, A., SENEPATI, B.K., BLANCHART, E. & RODRIGUEZ, C. 1999. A survey of tropical earthworms: taxonomy, biogeography and environmental plasticity. In: Lavelle, P., Brussaard, L. & Hendrix, P., eds, *Earthworm management in tropical ecosystems*. Wallingford: CABI, pp. 1–26.
- FRAGOSO, C. & ROJAS, P. 2009. A new *Ocnerodrilid* earthworm genus from southeastern Mexico (Annelida: Oligochaeta), with a key for the genera of *Ocnerodrilidae*. *Megadrilogica* **13** (9): 141–152.
- GATES, G.E. 1932. The Earthworms of Burma. III, The Megascolecinae. *Records of the Indian Museum* **34**: 357–549.
- 1972. Burmese earthworms, an introduction to the systematics and biology of megadrile oligochaetes with special references to southeast Asia. *Transactions of the American Philosophical Society* **62** (7): 1–362.
- GRUBE, E. 1855. Beschreibungen neuer oder wenig bekannter Anneliden. *Archiv für Naturgeschichte* **21**: 81–136.
- 1879. Annelida. *Philosophical Transactions of the Royal Society of London* **168**: 554–556.
- HALLATT, L., REINECKE, A.J. & VILJOEN, S.A. 1990. Life cycle of the oriental compost worm *Perionyx excavatus* (Oligochaeta). *South African Journal of Zoology* **25** (1): 41–45.
- HALLATT, L., VILJOEN, S.A. & REINECKE, A.J. 1992. The moisture requirement and life-cycle of *Perionyx excavatus* (Oligochaeta). *Soil Biology and Biochemistry* **24** (12): 29–34.
- HENDRIX, P.F., CALLAHAM, M.A., DRAKE, J.M., HUANG, C., JAMES, S.W., SNYDER, B.A. & ZHANG, W. 2008. Pandora's Box contained bait: The global problem of introduced earthworms. *The Annual Review of Ecology, Evolution and Systematics* **39**: 593–613.
- HOFFMEISTER, W. 1843. Beitrag zur Kenntnis deutscher Landanneliden. *Archiv für Naturgeschichte* **91**: 183–98.
- HORN, J.L., PLISKO, J.D. & HAMER, M.L. 2007. The leaf-litter earthworm fauna (Annelida: Oligochaeta) of forests in Limpopo Province, South Africa: diversity, communities and conservation. *African Zoology* **42** (2): 172–179.
- HORST, R. 1883. New species of the genus *Megascolex* Templeton (*Perichaeta* Schmarida) in the collection of the collection of the Leyden Museum. *Notes from the Leyden Museum* **5**: 182–196.
- 1893. Earthworms from the Malay Archipelago. In: Weber, M., ed., *Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien*. Vol. 3. Leiden: E.J. Brill, pp. 28–77.
- JAMES, S.W. & DAVIDSON, S.K. 2012. Molecular phylogeny of earthworms (Annelida: Crassicitellata) based on 28S, 18S and 16S gene sequences. *Invertebrate Systematics* **26**: 213–229.
- JAMIESON, B.G.M. 1967. New records of *Ocnerodrilidae* and *Lumbricidae* (Oligochaeta) from South African Rivers. *Zoologica Africana* **3** (1): 59–86.
- KINBERG, J.G.H. 1867. Annulata nova. *Öfversigt af Kongliga Vetenskaps-akademiens Förhandlingar* **23**: 97–100.
- KUU, A. & IVASK, M. 2010. Distribution of *Octolasion cyaneum* (Savigny, 1826) in Estonia 1993–2008. *Zoology in the Middle East Suppl.* **2**: 75–81.
- LAVELLE, P., BRUSSAARD, L. & HENDRIX, P. 1999. Earthworm management in tropical agroecosystems. Wallingford: CABI.
- LAVELLE, P., DECAËNS, T., AUBERT, M., BAROT, S., BLOUIN, M., BUREAU, F., MARGERIE, P., MORA, P. & ROSSI, J.P. 2006. Soil invertebrates and ecosystem services. *European Journal of Soil Biology* **42**: S3–S15.
- LEVINSEN, G.M.R. 1884 [1883]. Systematisk-geografisk oversigt over de nordiske Annulata, Gypherea, Chaetognathi og Balanoglossi. *Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjöbenhavn* **43**: 92–350.
- LINNAEUS, C. 1758. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. 10th Ed. Holmiae [= Stockholm]: Salvius.
- LJUNGSTRÖM, P.O. 1972. Introduced earthworms of South Africa. On their taxonomy, distribution, history of introduction and on the extermination of endemic earthworms. *Zoologische Jahrbücher. Abteilung für Systematik* **99**: 1–81.
- MALERI, R.A., REINECKE, S.A., MESJASZ-PRZYBYLOWICZ, J. & REINECKE, A.J. 2007. Growth and reproduction of earthworms in ultramafic soils. *Archives of Environmental Contamination and Toxicology* **52**: 363–370.



- MALERI, R.A., REINECKE, S.A. & REINECKE, A.J. 2008. Metal uptake of two ecophysiologically different earthworms (*Eisenia fetida* and *Aporrectodea caliginosa*) exposed to ultramafic soils. *Applied Soil Ecology* **38**: 42–50.
- MALLETT, J.B., LANG, P.M. & ARATHON, A.J. 1987. Changes in a Doveton clay loam after 12 years of directdrill maize production. *South African Journal of Plant and Soil* **4** (4): 188–192.
- MALM, A.W. 1877. *Göteborgs och Bohusläns fauna, Rygggradsdjuren*. Göteborg. Göteborgs Bohusläns Fauna: 1–674.
- MICHAELSEN, W. 1890a. Die Lumbriciden Norddeutschlands. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten* **7**: 3–19.
- 1890b. Beschreibung der von Herrn Dr. Franz Stuhlmann im Mündungsgebiet des Sambesi gesammelten Terricolen. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten* **7**: 21–50.
- 1891. Oligochaeten des Naturhistorischen Museums in Hamburg. IV. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten* **8**: 301–340.
- 1897. Neue und wenig bekannte africanische Terricolen. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **14** (2): 3–71.
- 1899. Oligochaeten von den Inseln des Pacific, nebst Erörterungen zur Systematik der Megascoleciden. Terricolen (Nachtrag). In: *Ergebnisse einer Reise nach dem Pacific. Zoologische Jahrbücher, Abteilung für Systematik* **12**: 211–247.
- 1900. *Oligochaeta*. In: *Das Tierreich*. Lief. 10. Berlin: R. Friedländer & Sohn, pp. 1–575.
- 1903. *Die geographische Verbreitung der Oligochaeten*. Berlin: R. Friedländer & Sohn.
- 1910a. Oligochaeten von verschiedenen Gebieten. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **27** (2): 47–169.
- 1910b. Die Oligochaeten fauna vorderindisch-Ceylonischen Region. *Abhandlungen aus dem Gebiete der Naturwissenschaften herausgegeben von dem Naturwissenschaftlichen Verein in Hamburg* **19** (5): 1–108.
- 1912. Die terrestrischen Oligochaeten des tropischen Afrikas und ihre geographischen Beziehungen. Bd 3. Zoologie 1. In: *Wissenschaftliche Ergebnisse der Deutschen Zentral-Afrika Expedition 1907–1908*. Leipzig: Klinkhardt & Biermann, pp. 1–90.
- 1913. The Oligochaeta of Natal and Zululand. *Annals of the Natal Museum* **2** (4): 397–457.
- 1933. Opisthophore Oligochaeten aus dem mittleren und dem südlichen Africa hauptsächlich gesammelt von Dr F. Haas während der Schomburgh-Expedition 1931–1932. *Abhandlungen Senckenbergischen Naturforschenden Gesellschaft* **40** (4): 409–433.
- 1935. Oligochaeta from Christmas Island, south of Java. *Annals and Magazine of Natural History* **15** (10): 100–108.
- MORENO, A.G. 2004. Who is *Pontoscolex* (*Pontoscolex*) *corethrurus* (Müller, 1857) (Annelida, Glossoscolecidae)? In: Moreno, A.G. & Borges, S., eds, *Advances in earthworm taxonomy (Annelida: Oligochaeta)*. Madrid: Editorial Complutense, S.A., pp. 63–73.
- MRŠIĆ, N. 1990. Description of a new subgenus, three new species and taxonomic problems of the genus *Allolophora* sensu Mršić and Šapkarev 1988 (Lumbricidae, Oligochaeta). *Biološki vestnik* **38** (1): 49–68.
- MÜLLER, F. 1857. *Lumbricus corethrurus*, Bürstenschwanz. *Archiv für Naturgeschichte* **23**: 113–116.
- MUYIMA, N.Y.O., REINECKE, A.J. & VILJOEN, S.A. 1994. Moisture requirements of *Dendrobaena veneta* (Oligochaeta), a candidate for vermicomposting. *Soil Biology and Biochemistry* **26** (8): 973–976.
- NXELE, T.C. 2012. The megadriale fauna of Queen Elizabeth Park, South Africa: species composition and distribution within different vegetation types (Annelida: Oligochaeta). *African Invertebrates* **53** (2): 543–558.
- OMODEO, P. 1956. Contributo alla revisione dei Lumbricidae. *Archivio Zoologico Italiano* **41**: 129–212.
- ÖRLEY, L. 1881. A magyarországi Oligochaeták faunája. I. Terricolae. *Mathematikai és természettudományi Közlemények* **16**: 562–611.
- 1885. A palaearktikus övben élő Terrikoláknak revíziója és elterjedése. *Értekezések a Természettudományok Köréből* **15**: 1–31.
- PEREL, T.S. 1997. *The earthworms of the fauna of Russia, cadaster and key*. Moscow: Nauka.
- PÉREZ-LOSADA, M., EIROA, J., MATO, S. & DOMÍNGUEZ, J. 2005. Phylogenetic species delimitation of the earthworm *Eisenia fetida* (Savigny, 1826) and *Eisenia andrei* (Bouché, 1972) (Oligochaeta, Lumbricidae) based on mitochondrial and nuclear DNA genes. *Pedobiologia* **49**: 317–324.
- PERRIER, E. 1872. Recherches pour servir à l'histoire des lombriciens terrestres. *Nouvelles Archives du Museum d'Histoire Naturelle, Paris* **8**: 5–198.
- 1874. Sur un nouveau genre indigène des Lombriciens terrestres (*Pontodrilus marionis* E.P.). *Compte rendu hebdomadaire des seances de l'Academie des Sciences Paris* **78**: 1582–1586.
- PICKFORD, G.E. 1937. *A monograph of the Acanthodriline earthworms of South Africa*. Cambridge: W. Heffer & Sons Ltd.

- PLISKO, J.D. 1973. *Lumbricidae, dżdżownice (Annelida: Oligochaeta). Fauna Poloniae. No. 1.* Warszawa: Państwowe Wydawnictwo Naukowe.
- 1996. Six new earthworm species of the southern African genus *Proandricus* Plisko, 1992 (Oligochaeta: Microchaetidae). *Annals of the Natal Museum* **37**: 295–307.
- 2001. Notes on the occurrence of the introduced *Pontoscolex corethrurus* (Müller, 1857) in South Africa (Oligochaeta: Glossoscolecidae). *African Invertebrates* **42**: 323–334.
- 2004. Review of the balantine genus *Udeina* Michaelsen, 1910 with descriptions of six new species in South Africa (Oligochaeta: Acanthodrilidae, Acanthodrilinae). *African Invertebrates* **45**: 287–313.
- 2010. Megadrile earthworm taxa introduced to South African soils (Oligochaeta: Acanthodrilidae, Eudrilidae, Glossoscolecidae, Lumbricidae, Megascolecidae, Ocnerodrilidae). *African Invertebrates* **51** (2): 289–312.
- 2013. A new family Tritogeniidae for the genera *Tritogenia* and *Michalakus*, earlier accredited to the composite Microchaetidae (Annelida: Oligochaeta). *African Invertebrates* **54** (1): 69–92.
- RAFINESQUE-SCHMALTZ, C.S. 1815. *Analyse de la nature, on tableau de l'univers et des corps organisés.* Palermo: Jean Barravecchia.
- REINECKE, A.J. & ALBERTS, J.N. 1994. Earthworm research in southern Africa since W. Michaelsen, with emphasis on the utilization of the earthworm (*Eisenia fetida*) as a protein source. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **89** (2): 23–36.
- REINECKE, A.J. & KRIEL, J.R. 1981. Influence of temperature on the reproduction of the earthworm *Eisenia foetida* (Oligochaeta). *South African Journal of Zoology* **16** (2): 96–100.
- REINECKE, A.J. & LJUNGSTRÖM, P.O. 1969. An ecological study of the earthworms from the banks of the Mooi river in Potchefstroom, South Africa. *Pedobiologia* **9**: 106–111.
- REINECKE, A.J., VENTER, J.M. & VILJOEN, S.A. 1990. The influence of feeding patterns on growth and reproduction of the vermicomposting earthworm *Eisenia fetida* (Oligochaeta). *Biology and Fertility of Soil* **10**: 184–187.
- REINECKE, A.J. & VILJOEN, S.A. 1988. Reproduction of the African earthworm *Eudrilus eugeniae* (Oligochaeta) cocoons. *Biology and Fertility of Soil* **7**: 23–27.
- 1991. A comparison of the biologies of *Eisenia fetida* and *Eisenia andrei* (Oligochaeta). *Biology and Fertility of Soil* **11**: 295–300.
- REINECKE, A.J., VILJOEN, S.A. & SAAYMEN, R.J. 1992. The suitability of *Eudrilus eugeniae*, *Perionyx excavatus* and *Eisenia fetida* (Oligochaeta) for vermicomposting in southern Africa in terms of their temperature requirements. *Soil Biology and Biochemistry* **24** (12): 1295–1307.
- REINECKE, S.A. & PIETERS, R. 1997. The morphology of male reproductive structures of *Perionyx excavatus* (Oligochaeta). *South African Journal of Zoology* **32** (3): 64–71.
- 1998. The morphology of female reproductive structures of *Perionyx excavatus* (Oligochaeta). *South African Journal of Zoology* **33**: 166–171.
- REYNOLDS, J.W. 1977. *The earthworms (Lumbricidae and Sparganophilidae) of Ontario.* Life Science Miscellaneous Publications. Royal Ontario Museum. Toronto: Hunter Rose Company.
- RIGHI, G. 1984. On a collection on neotropical megadrile Oligochaeta I. Ocnerodrilidae, Acanthodrilidae, Octochaetidae, Megascolecidae. *Studies on Neotropical Fauna and Environment* **19** (1): 9–31.
- ROSA, D. 1886. Note sui lombrici del Veneto. *Atti del Reale Istituto Veneto di Scienze* **4**: 673–687.
- 1887. *Microscolex modestus* n. gen., n. sp. *Bollettino dei Musei di Zoologia ed Anatomia Comparata della Reale Università di Torino* **2** (19): 1–2.
- 1891. Die exotische Terricolen des k.k. Naturhistorischen Hofmuseums. *Annalen des K. K. Naturhistorischen Hofmuseums Wien* **6**: 381–406.
- 1896. I lombrici raccolti a Sumatra dal Dott. Elio Modigliani. *Annali del Museo di Storia Naturale di Genova, Ser. 2* **16**: 502–532.
- ROTA, E. 2013. From Corsica to Britain: new outdoor records of *Ocnerodrilidae* (Annelida: Clitellata) in western Europe. *Biodiversity Data Journal* **1**: e985. DOI: 10.3897/BDJ.1.e985
- ROTA, E. & SCHMIDT, O. 2006. *Dichogaster bolau* (Oligochaeta: Octochaetidae), an unusual invader in a swimming pool in Ireland. *Journal of Natural History* **40** (3–4): 161–167.
- SAVIGNY, J.C. 1826. [La multiplicité des espèces de ver de tere]. In: Cuvier, G. *Analyse des Travaux del'Academie royale des Sciences, pendant l'année 1821, partie physique. Mémoires de l'Académie des Sciences de l'Institut de France (Physique), Paris* **5**: 176–184.
- SCHMARDA, L.K. 1861. Neue wirbellose Thiere, beobachtet und gesammelt auf einer Reise um die Erde 1853–1857. *Neue Turbellarien, Rotatorien und Anneliden, Vol. I, Pt. II.* Leipzig: Wilhelm Engelmann.
- SIMS, R.W. 1987. Review of the central African earthworm family Eudrilidae (Oligochaeta). In: Bonvicini, A.M. & Omodeo, P., eds, *On Earthworm Selected Symposia and Monographs U. Z. I., 2.* Modena: Mucchi, pp. 359–388.

- SIMS, R.W. & EASTON, E.G. 1972. A numerical revision of the earthworm genus *Pheretima* auct. (Megascolecidae: Oligochaeta) with the recognition of new genera and an appendix on the earthworms collected by the Royal Society North Borneo Expedition. *Biological Journal of the Linnean Society* **4** (3): 169–268.
- SIMS, R.W. & GERARD, B.M. 1985. *Earthworms. Keys and notes to the identification and study of the species. Synopsis of the British Fauna (New series) No. 31*. Leiden: E.J. Brill, pp. 171.
- STEPHENS, P.M., DAVOREN, C.W., DOUBE, B.M. & RYDER, M.H. 1994. Ability of the earthworm *Aporrectodea rosea* and *Aporrectodea trapezoids* to increase plant growth and the foliar concentration of elements in wheat (*Triticum aestivum* cv. Spear) in a sandy loam soil. *Biology and Fertility of Soils* **18**: 150–154.
- STEPHENSON, J. 1930. *The Oligochaeta*. Oxford: Clarendon Press.
- TSAI, C., SHEN, H. & TSAI, S. 2002. A new athecate earthworm of the genus *Amyntas* Kinberg (Megascolecidae: Oligochaeta) from Taiwan with discussion on phylogeny and biogeography of the *A. Illotus* species group. *Journal of Natural History* **36**: 757–765.
- UDE, H. 1885. Über die Rückenporen der terricolen Oligochaeten, nebst Beiträgen zur Histologie des Leibschlauches und zur Systematik der Lumbriciden. *Zeitschrift für wissenschaftliche Zoologie* **43**: 87–143.
- VAN BRUGGEN, A.C. 1964. The distribution of introduced mollusc species in Southern Africa. *Beaufortia, Series of Miscellaneous Publications, Zoological Museum* **11** (144): 161–169.
- 1978. Megadrilacea (Oligochaeta). In: Werger, M.J.A., ed., *Biogeography and ecology of Southern Africa*. The Hague: W. Junk, pp. 663–676.
- VENTER, J.M. & REINECKE, A.J. 1987. Can the commercial earthworm *Eisenia fetida* (Oligochaeta) reproduce parthenogenetically or by self-fertilization? *Revue d'Ecologie et de Biologie du Sol* **24** (2): 157–470.
- VILJOEN, S.A. & REINECKE, A.J. 1994. The life cycle and reproduction of *Eudrilus eugeniae* under controlled environmental conditions. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **89** (2): 149–157.
- VILJOEN, S.A., REINECKE, A.J. & HARTMAN, L.E. 1991. Life-cycle of the European compost worm, *Dendrobaena veneta* (Oligochaeta). *South African Journal of Zoology* **26** (1): 43–48.
- VOUA OTOMO, L., VOUA OTOMO, P., BEZUIDENHOUT, C. & MABOETA, M.S. 2013. Molecular assessment of commercial and laboratory stocks of *Eisenia* spp. (Oligochaeta: Lumbricidae) from South Africa. *African Invertebrates* **54** (2): 499–511.
- ZICSI, A. 1996. Neue und bekannte Regenwürmer (Oligochaeta) aus Ost-Afrika. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **93**: 17–37.
- 1997. Revision der Gattung *Eudriloides* Michaelsen, 1890 (Oligochaeta: Eudrilidae). *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **94**: 49–71.
- 1998. Neue und seltene terrestrische Oligochaeten aus Südafrika. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **95**: 59–77.
- ZICSI, A. & REINECKE, A.J. 1992. Regenwürmer aus dem Krüger National Park in Süd Afrika (Oligochaeta: Eudrilidae). *Acta Zoologica Academiae Scientiarum Hungaricae* **38** (1–2): 149–158.