Diversity of exotic earthworms in Australia - a status report.

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Abstract

Surveys, on the ground and of the literature, have found 66 exotic earthworm species belonging to eight families. A checklist is provided with 18 species new to Australia from the author's studies, including the first record of *Lumbricus terrestris* Linnaeus. State totals are increased, eg. Queensland's exotics are doubled to 36 species, Tasmania's total is raised from seven to 26. The various modes of introduction and dispersal are briefly discussed. As much of the continent has yet to be systematically surveyed, it is anticipated that the tally of exotics will continue to grow, allowing this resource, valuable for sustainable primary production and waste management, to be further investigated for its potential to assist the Australian environment.

[Keywords: Exotic earthworms biodiversity, introduced species, quarantine, vermiculture.]

Introduction

Earthworms, or the often larger 'megadrile' annelids of the class Oligochaeta, are ubiquitous and among the most ancient of terrestrial animal groups. They play a vital role in the formation and maintenance of fertile soils and are thus paramount for primary production. Charles Darwin (1837; 1881) was one of the first scientists to give credence to the conventional wisdom from earlier civilizations about the importance of earthworms to soil fertility, and thus human survival. Recently there has been a resurgence in interest in earthworms, driven by environmental and economic concerns, particularly the need to understand and utilize their function in sustainable agriculture, and to exploit their potential for recycling of organic 'wastes' (Lee 1985; Sims and Gerard 1985). One of the first steps to this understanding is to reliably identify which species are involved and to determine their distributions.

Apart from Blakemore (1994), no comprehensive guide or checklist for the megadrile oligochaetes of Australia as a whole exists (*cf*. Pinder and Brinkhurst 1994 for aquatic microdriles). Intermittent papers that have been mainly concerned with the taxonomy or regional zoogeography of parts of the Australian native fauna are summarized in Abbott (1994), while considerations of exotic species are more rare, eg. Easton (1982). Approximately 350 native species in about 30 genera are currently described for Australia, but an estimate of total number is about three times as large (Blakemore 1997a). For fieldworkers, the difficulties of identifying specimens, due to lack of adequate identification tools, are compounded by the problems of differentiating native from exotic species and of knowing the full extent of those exotic species that are present. Summaries of exotic earthworms in Australia have been compiled by Blakemore (1994) and Mele *et al*. (1996), both documenting 34 species, and by Blakemore (1997a) listing 43 species. A recent "National Survey of the Earthworm Fauna of Urban and Agricultural Soils in Australia" by Baker *et al*. (1997) lists only 27 exotic species but, since "No dissections were attempted", some of these records must be treated with caution. The current paper provides a status report on our knowledge of the diversity and distribution of exotic species. Their probable modes of initial introduction and subsequent dispersal are briefly discussed.

Methods and Results

An updated checklist with distributions of 66 exotic species has been compiled from various sources (Table 1), those records marked with an asterisk are the results of the author's collection and incidental specimen identification requests. There are several conflicting family level classifications in current use, the one adopted here is based on that of Sims (1982), as presented in Sims and Gerard (1985), overlain by the prevailing nomenclature of species. Although several 'neglected' texts have been resourced, vague references to species occurring in "Australia" are not included, nor are some earlier reports that were unsupported by species descriptions or deposition of voucher specimens. Materials identified by the author are housed in these institutions: SA specimens in CSIRO Division of Soils, Adelaide; Tasmanian specimens in Queen Victoria Museum, Launceston; all other mainland Australia samples are lodged at CSIRO Division of Entomology, Canberra (Blakemore 1995). Full taxonomic descriptions and precise distributional details will be presented elsewhere.

Table 1 represents the most current tally of exotic species from Australia, based on available information, and reveals a previously unrecognized level of biodiversity. For *Begemius*, only the most widespread of the known species, *B. queenslandicus*, which was fully redescribed and figured in Blakemore (1994: 335-339), is included. Easton (1982) referred eight species to this genus which he believed to be indigenous to both New Guinea and northern Queensland, although its affinities are clearly closer to the oriental pheretimoids than to truly native Australian genera. The report of *Dendrobaena attemsi* in Australia must be questioned as superficially it resembles several other lumbricid species and is stated to be "rare" by Sims and Gerard (1985:68) - known only from a single record in Britain. Conversely, Sims and Gerard (1985:60) believe that *Aporrectodea limicola* may be more common than the few records would suggest, due possibly to confusion with *A. caliginosa*. Unconfirmed reports of some other species, especially in the families Acanthodrilidae and Megascolecidae, must be treated with caution as these may easily be confused with native species. Similarly, *Amynthas* species can be mistaken one with another, unless dissections are attempted. A few species in the table remain unnamed as searches of the literature have yet to yield corresponding descriptions.

Discussion

Of a worldwide total of almost 4,000 described megadrile species, detailed ecological studies have been made on fewer than 20 of these (Reynolds 1998:28), despite the vital role earthworms have for maintaining fertile soils, for recycling organic 'wastes', for environmental monitoring, and as links in the food chains of many organisms. Compared to some other regions, Australia with ca. 350 described natives and at least 66 exotic species, has a relatively rich earthworm fauna (*cf*. New Zealand's total of 192 earthworm species, about 20 of these introduced, according to Lee 1959: 14-16). Australian earthworm communities are comprised of four component: native species that are often highly endemic; introduced exotics that tend to be more widespread; translocated natives; and "neo-endemic" species. High earthworm diversity has been recorded from some sites, for example: 23 species were identified from a farm at Samford in south-east Queensland (Blakemore 1994; 1997a); twelve species were found one weekend on a 45 ha property in the Southern Highlands of NSW (Blakemore, unpublished); while the average Australian garden can support a varied community of both known and new species (eg. Blakemore 1997b). This diversity is due to persistence of natives, combined with contributions from the pool of exotics originating from various temperate and tropical regions of the world. Of the 66 exotic species now known from Australia, about half correspond with those, mainly lumbricids, recorded from the British Isles by Sims and Gerard (1985) - their total of ca. 44 species includes an Australian native that was introduced into Scotland in an attempt to reduce peat turf mats. Although Blakemore (1994, 1997a) conducted laboratory, glasshouse and field experiments using cultures of 27 species, both natives and exotics, these represent just part of the megadriles available for study and an even smaller fraction of the total Australian fauna, much of which awaits discovery and description.

Geographical origin, directly or indirectly, of the earthworms introduced to Australia include: eastern Asia and the Indo-Australasian archipelago (Moniligastridae, Octochaetidae, and pheretimoid Megascolecidae); Central/South America (Glossoscolecidae, Ocnerodrilidae and Acanthodrilidae); Europe/North America (Lumbricidae); and Africa (Eudrilidae, Ocnerodrilidae and Octochaetidae). Some genera are believed to be indigenous to particular regions: the Indo-Pacific region (eg. *Drawida*, some *Dichogaster* spp., *Octochaetona*, *Ramiella*, *Perionyx*, *Lampito*, *Polypheretima*); southern South America (*Microscolex*, *Eukerria*); eastern North America (*Bimastos*); Africa (*Gordiodrilus*, *Dichogaster* spp.); and New Zealand (*Rhododrilus*). However several of the most common cosmopolitan, or peregrine, species are so widely distributed around the world that their exact origins are

indeterminable. Other 'exotics', such as *Pontodrilus*, may yet prove to be indigenous to Australia (Gates 1972).

Initial introduction of most of these earthworms was incidental to human commerce, such as accidental transportation in soil in plant pots or ships' ballast. Gates (1976) reported that the US Bureau of Quarantine, over a period of 25 years, intercepted 50 earthworm species (24 lumbricids of European origin, and 26 belonging to other families, mainly oriental pheretimoids), most found in soil from potted plants. The large number of exotic species with type locality at Kew Gardens, London (Stephenson 1930:664; Sims and Gerard 1985) also attests to this mode of introduction. As many of the peregrine species are parthenogenetic (i.e., capable of self reproduction), theoretically only a single specimen is required for populations to become established (Gates 1972; Sims and Gerard 1985; Lee 1987).

Some species are known to be euryhaline (salt tolerant) and are therefore presumed to be dispersed by oceanic drifting on debris, or carriage on the feet of seabirds (Stephenson 1930; Sims 1980). Examples are found in the genera *Rhododrilus*, *Microscolex* and *Pontodrilus*; another species, *Pontoscolex corethrurus* that originated in northeastern South America, because of its prevalence in earlier reports from coastal locations in the tropics and subtropics around the world, is possibly subject to a similar means of dispersal, perhaps in resistant cocoons (Sims 1980: 117; Blakemore, 1994: 249). A few species, sometimes referred to as "neo-endemics" (eg. Dyne and Wallace 1994: 62), have sojourned long enough in new environments to have undergone speciation; likely examples being found in *Rhododrilus*, *Microscolex* and *Begemius*.

Once introduced, exotic (and native) earthworms spread by both active and passive means of dispersal. The common sight of their stranding on impenetrable surfaces following rain (eg. Darwin, 1881) is indicative of their migrations (the author has observed various exotic species wandering on an asphalt carpark after overnight rain, at least 20 m from their nearest possible source). Mechanisms of passive dispersal of earthworms, or their cocoons, are by unintentional or deliberate transportation by humans; by movement of machinery, stock or other animals; and by fluvial transport (Lee 1985; Schwert 1980). In Australia, just 100 years after European settlement, Fletcher (1887, 1890) recounted how lumbricid "interlopers" had colonised "almost every locality" in NSW from which he obtained earthworms, as well as to Victoria and Adelaide - a rate of spread (discounting the trans-oceanic component) equivalent to >10 km yr^{-1}.

However, dispersal of some exotics may predate the arrival of European settlers, reflecting earlier, undocumented commerce with south-east Asia and Indo-Pacific islands. Pheretimoids such as *Begemius*, and *Polypheretima*, which are indigenous to New Guinea, and eastern Indonesia, respectively (Easton 1976, 1982), may provide evidence of such human movements. Europeans have been responsible for the global transportation of earthworms only in the last 500 years; prior to this there have been Indonesian, Indian, Arabian and Chinese traders; Polynesian and Melanesian peoples, for at least the last 3,000 years, have migrated in the southwest Pacific (carrying with them food plants). What contact and trade occurred in ancient times is not well known, certainly there has been a long period of human settlement in Australia, possibly extending back 100,000 years.

More recently, anglers and growers who cultivate earthworms (vermiculture) for fishing, gardening, and waste management, are responsible for unmonitored dispersal of species. One worm grower in Queensland informed me that he imported his initial stock of *Eudrilus eugeniae* (known as the 'African Nightcrawler') as cocoons from Canada. This and other species, including the commonly cultivated but frequently mis-identified *Eisenia fetida* ('Tiger Worm') and its variant *E. andrei* ('Red Tiger Worm'), and *Perionyx excavatus* ('Indian Blue'), are routinely traded around the country. Claims by worm growers of commercial cultivation of *Lumbricus rubellus* ('Red Worm'), however, are unsubstantiated (J. Buckerfield pers. comm.; Edwards 1998: 337; and pers. obs.). Certain native species are similarly distributed and therefore translocated from their natural range. For example, native "Scrub Worms" from Tasmania are sold as fishing bait around Australia (eg. in Canberra, pers. obs. 1999), those sold in the central montane Great Lakes region of Tasmania come from St. Helens in the coastal north-east. Farmers and gardeners also distribute earthworms informally, but particular species will fail to establish under soil conditions to which they are not adapted.

CONCLUSION

The variety of species of both native and exotic earthworms available for ecological or agronomic investigation in Australia is considerable but, as yet, only a proportion of this valuable resource has been identified, let alone studied. There is an urgent need to produce a reliable and comprehensive guide to the earthworms of Australia that is accessible to the non-specialist and which can be regularly updated. Incomplete identifiers to the 'common' species serve to reinforce the notion held by the novice that there are only a few common worms in Australia. Concurrent strategic surveys are also

required, particularly in the tropical zones, where a rich fauna can be anticipated (as is found on Christmas Island in the Indian Ocean), and of botanic gardens, as it is only through knowledge of the range of species potentially and actually present in a region that meaningful guides to the fauna can be compiled. In the meantime, the importance of lodgment of voucher specimens of study material is emphasized so that identifications can be verified by specialist taxonomists. Stricter quarantine control in recent times has presumably reduced the incidence of accidental importations, but the full extent of the species previously admitted is not yet realized (evinced by the doubling of the list of known exotics over the last couple of years by way of relatively modest surveys and searches of the literature). A matter of concern is the level of unmonitored transportation of earthworms (and their attendant parasites and pathogens) around the country. Few other major faunal groups would have less regulation and greater neglect, albeit earthworms are generally considered to be beneficial or, at least, benign.

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Table 1. Current records of non-endemic earthworms from Australian States and Territories (given their usual abbreviations).

	Families and Species	NSW	ACT	Vict.	Qld.	SA	WA	Tas.	NT
1	**Moniligastridae**								
1	*Drawida barwelli* (Beddard, 1886)				*				
2	**Glossoscolecidae**								
2	*Pontoscolex corethrurus* (Müller, 1856)	*D			*KD		K(CI)		D
3	**Lumbricidae**								
3	*Allolobophora chlorotica* (Savigny, 1826)			QU		Y		*M	
4	*Aporrectodea caliginosa* (Savigny, 1826)	*FGKRaD	*	*QUD	D	*CE?D	AORbD	*MD	
5	*Aporrectodea limicola* (Michaelsen, 1890)					Y			
6	*Aporrectodea longa* (Ude, 1885)	GV		GU	S	Y	O	*MD	
7	*Aporrectodea trapezoides* (Dugès, 1828)	*IJKTD	*	QD	*TD	*CEKD	ABOD	*KMD	
8	*Aporrectodea tuberculata* (Eisen, 1874)	K		Q		Y			
9	*Bimastos constrictus* (Rosa, 1884)	Ra				Y	L		
10	*Bimastos parvus* (Eisen, 1874)	*			*		Rb		
11	*Dendrodrilus rubidus rubidus* (Savigny, 1826)	*?K			KT	*Y	K	*	
12	*D. rubidus subrubicundus* (Eisen, 1874)	*Ra				*			
13	*D. rubidus tenuis* (Eisen, 1874)		N(HI)			*?		*?N(MI)	
14	*Eisenia andrei* Bouché, 1972			Y				*?	
15	*Eisenia fetida* (Savigny, 1826)	*IJK	*	*JK	*	*J	AKLRb	*	*
16	*Eisenia hortensis* (Michaelsen, 1890)					Y		*	
17	*Eisenia* (=*Aporrectodea*) *rosea* (Savigny, 1826)	*FKVD	*	QD	*D	*CEKD	AOD	*MD	

18	*Eisenia* (=*Dendrobaena*) *veneta* (Rosa, 1886)					Y			
19	*Eiseniella tetraedra* (Savigny, 1826)	FKRa		*Q		*Y	KL	*K	
20	*Lumbricus castaneus* (Savigny, 1826)	*				Y		*	
21	*Lumbricus eiseni* Levinsen, 1884							*	
22	*Lumbricus rubellus* Hoffmeister, 1843	*VD	*	*QUD		YD	D?	*MD	
23	*Lumbricus terrestris* Linnaeus, 1758							*	
24	*Octolasion cyaneum* (Savigny, 1826)	KraTV	*K	QU	*	CKY	A	*M	
25	*Octolasion tyrtaeum lacteum* (Örley, 1881)	*J?							
26	*O. tyrtaeum tyrtaeum* (Savigny, 1826)	K							
4	**Ocnerodrilidae**								
27	*Gordiodrilus elegans* Beddard, 1892				*				
28	*Ocnerodrilus occidentalis* Eisen, 1878	*		*	*			*	
29	*Eukerria kukenthali* (Michaelsen, 1908)						K$^{(CI)}$		
30	*Eukerria saltensis* (Beddard, 1895)	*GKRa		G?	*		KL	*	
5	**Acanthodrilidae**								
31	*Microscolex dubius* (Fletcher, 1887)	*FJ	*K?	Q	*J?T	*CE?J	ABLRb	*	
32	*Microscolex kerguelarum* (Grube, 1877)		N$^{(HI).}$						
33	*Microscolex macquariensis* (Beddard, 1896)							* N$^{(MI)}$	
34	*Microscolex phosphoreus* (Dugès, 1837)	*	*	Q	*	Y	L	*	
35	*Rhododrilus kermadecensis* Benham, 1905					Y?		*	
6	**Octochaetidae**								
36	*Dichogaster affinis* (Michaelsen, 1890)	*?			*				
37	*Dichogaster bolaui* (Michaelsen, 1891)	*			*KT		K$^{(CI)}$		
38	*Dichogaster curgensis* Michaelsen, 1921	*							
39	*Dichogaster saliens* (Beddard, 1893)				*		K$^{(CI)}$		*
40	*Dichogaster* sp. nov?								*
41	*Octochaetona beatrix* (Beddard, 1902)				*				
42	*Ramiella bishambari* (Stephenson, 1914)						K$^{(CI)}$		

7	**Megascolecidae**								
43	*Pontodrilus litoralis* (Grube, 1855)	*W			W	Y	KLRbW		
44	*Pontodrilus* sp. nov?							*	
45	*Perionyx excavatus* Perrier, 1872	*	*	*	*	Y		*	
46	*Amynthas corticis* (Kinberg, 1867)	*HJ		Q	*H	*Y	HLRb	*	
47	*Amynthas gracilis* (Kinberg, 1867)	*			*H				H
48	*Amynthas minimus* (Horst, 1893)				*KH				
49	*Amynthas morrisi* (Beddard, 1892)				H				
50	*Am. morrisi* group *s.* Sims & Easton, 1972				*				
51	*Amynthas rodericensis* (Grube, 1879)	*D?	D?	D?	*HKD?		$K^{(CI)}D?$		D?
52	*Begemius queenslandicus* (Fletcher, 1886)				*HJ				
53	*Lampito mauritii* Kinberg, 1866						$K^{(CI)}$		
54	*Metaphire bahli* (Gates, 1945)								*H
55	*Metaphire californica* (Kinberg, 1867)				*HT				
56	*Metaphire houlleti* (Perrier, 1872)				H		P		*H
57	*Metaphire posthuma* (Vaillant, 1868)						$K^{(CI)}$		
58	*Pheretima darnleiensis* (Fletcher, 1887)				HJ				
59	*Pithemera bicincta* (Perrier, 1875)				H		$K^{(CI)}$		
60	*Polypheretima brevis* (Rosa, 1898)						$W^{(CI)}$		
61	*Polypheretima elongata* (Perrier, 1872)				*HK				
62	*Polypheretima taprobanae* (Beddard, 1892)				*H				
8	**Eudrilidae**								
63	*Eudrilus eugeniae* (Kinberg, 1867)	*			*	Y			
	Unconfirmed species								
64	*Dendrobaena attemsi* (Michaelsen, 1902)	X?		X?		X?		X?	
65	*Argilophilus marmoratus* Eisen, 1893	Z?							
66	*Metaphire javanica* (Kinberg, 1867)				Z?				

	TOTAL recorded spp	**32**	**12**	**19**	**36**	**26**	**27**	**26**	**8**
	in State or Territory	NSW	ACT	Vict	Qld	SA	WA	Tas	NT

(CI) from Christmas Island (HI) from Heard Island (MI) from Macquarie Island

? - indicates some ambiguity of taxonomic description, specimen condition, or veracity of report.

Source Codes:

***** - Current studies (R.J. Blakemore); A - Abbott 1981, 1985; B - Abbott and Parker 1980; C - Baker *et al.* 1992; D - Baker, *et al*. 1997; E - Barley 1959; F - Barley and Kleinig 1964; G - Blackwell and Blackwell 1989; H - Easton 1982; I - Fletcher 1886a,b; J - Fletcher 1887; K - Gates 1972; L - Jackson 1931; M - Kingston and Temple-Smith 1989; N - Lee 1968; O - McCredie and Parker 1988; P - McKenzie and Dyne 1991; Q - Mele *et al*. 1996; Ra - Michaelsen 1907a; Rb - Michaelsen 1907b; S - Robertson 1989; T - Stephenson 1933; U - Tisdall 1985; V - Wood 1974; W - Easton 1984; X - G. Baker (pers. comm.); Y - J.C. Buckerfield (pers. comm.); Z - Jamieson 1977.