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Endangered earthworms of Amazonia: an homage to Gilberto Righi

Patrick Lavelle* and Emmanuel Lapied

Laboratoire d'Ecologie des Sols Tropicaux, UMR137 IRD Universités de Paris 6, 7 et 12
32 rue Henri Varagnat, 93143 Bondy Cedex, France

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Summary

Gilberto Righi together with other taxonomists described the earthworm fauna of Amazonia in what is still a very limited number of sites. The Guayana Shield, North of the Amazon river and East of the Orinoco, comprises the largest extent of pristine forest on earth. One hundred and five species distributed among 36 genera have been recorded in this area. Eighty seven species were found in only one of the five large areas where some sampling had occurred which led us to estimate that the earthworm fauna of Amazonia probably comprises over 2000 species. Only 10 peregrine species, all exotic except for *Pontoscolex corethrurus*, were found in most regions where they colonise disturbed areas and tend to eliminate native species. Tentative estimates of the local-to-regional values of species richness for a few invertebrate groups show that earthworms have by far the lowest rates. It is, therefore, likely that deforestation of large areas results in the elimination of many species since the rate of endemism is extremely high in earthworms.

Key words: Earthworm fauna, Guayana Shield, local to regional diversity relationship

Introduction

Gilberto Righi made a great contribution to earthworm taxonomy in Amazonia in more than 30 published articles. He did some field sampling, especially in the areas of Roraima and Amapa although most of the descriptions were done on material provided by other collectors. Ecologists were a privileged source of material and many of us have collaborated with him. He would always provide identifications and descriptions of new species in remarkably short periods of time and honour us in naming species after our names. This has been the case for Andrea Nemeth at San Carlos de Rio Negro in Venezuela (Righi & Nemeth 1983), Jörg Römbke in Bolivia (Righi & Römbke 1987), Beto Pashanasi and Patrick Lavelle at Yurimaguas (Peru) (Righi 1992) and ecologists from the research stations of the Instituto Nacional de Pesquisas da Amazônia (INPA) at Manaus (Amazonas state) and Maraca in the Roraima state (Righi et al. 1978).

With these fast identifications and always cheerful comments G. Righi has supported efficiently the ecological studies of Amazonian earthworms and the emergence of young scientists in South America. He has also provided baseline data on biogeography and structure of earthworm communities.

*E-mail corresponding author: Patrick.Lavelle@bondy.ird.fr

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This paper synthesises information on earthworm taxonomy in the Northern part of Amazonia known as the Guayana Shield area where a large proportion of the taxonomic and geographic data was collected and/or organised by G. Righi. We first present all the information available and then discuss the general pattern of species distribution derived by comparing communities across the area. Secondly, comparison with similar datasets collected for other groups of invertebrates allows us to discuss the status of earthworm conservation in this area.

Results

The Guayana Shield is a very old granitic formation that attains 2772 m elevation at the highest point (Mount Roraima, the highest mountain in Brazil). It is mainly covered by tropical rainforest, with a large savanna area in Roraima and Bolivar states, and a large number of inselbergs and "tepuis" that may reach rather high elevations, and a few mountain ranges including Mount Roraima. The Guayana Shield area is a unique ecoregion that stretches over ca. $2.5 \cdot 10^6$ km^2 from the State of Amapa in Brazil, through French Guiana, Suriname, Guyana, the Venezuelan States of Bolivar and Amazonas, large parts of the Colombian Amazon, as well as the ecologically associated areas in the Brazilian States of Para, Roraima and Amazonas. The region is covered by 80 % almost untouched forest, and contains the largest complex of uninterrupted and intact primary tropical forest on earth.

Collection effort

Earthworms have been collected in 20 different places that can be divided into 5 main areas of unequal sizes: 1) the surroundings of San Carlos de Rio Negro in Venezuela; 2) the area of the Brazilian state of Roraima and adjacent state of Bolivar in Venezuela; 3) "Guayanas", a group of sites distributed in Guyana, Suriname and French Guiana; 4) Amapa state in Brazil; and, 5) the region of Manaus in the Amazonas state of Brazil (Fig. 1).

One hundred and five species from 36 different genera have been recorded so far (Table 1); 95 are only found in this region, and 10 are peregrine species with a wide distribution: *Amynthas rodericensis*, *Pheretima houlletti*, *Dichogaster bolaui*, *D. gracilis*, *D. modigliani*, *D. saliens*, *Eudrilus eugeniae*, *Pontoscolex corethrurus*, *Polypheretima elongata*, *Ocnerodrilus occidentalis*. Five Lumbricidae species of European origin have been found occasionally in French Guiana (Lapied unp. data). It does not seem, however, that their establishment is sustainable in these environments and they have not been included in Table 1.

San Carlos de Rio Negro is a unique location in Venezuela that comprises different plots of pristine rainforest close to the Rio Negro River. Soils are a mixture of tropical podzols and oxisols. Seven species have been described by Righi & Nemeth (1983); all of them were new. No exotic species was found in this sampling.

Thirty nine species, of which 6 are exotic, have been described from the INPA collections. They were collected in the immediate surroundings of Manaus (North of the Amazon), research sites 100 km north of this city, and a few other sites in the same area.

The Roraima and Bolivar region is a vast area that comprises mainly savannas in the middle of the Amazon forest. Twenty two species have been recorded of which 4 are exotic.

The Guayana region comprises the part of the Guayana Shield that faces the Atlantic Ocean, extending from Guyana to Suriname and the French Guiana. This area has been subjected to greater investigations than the others and many new species have been collected but not yet described (Lapied unp. data). Published records comprise 26 native species and 7 tropical exotics.

Finally, the Amapa region on the eastern edge of the area has 30 recorded species of which 4 are exotic; most of the investigation was done around the city of Serra do Navio.

Comparison of faunas from the five investigated areas

Of the 36 genera recorded, the exotic Dichogaster and Polypheretima were found in almost all areas. Another invasive species, *Pontoscolex corethrurus*, was found almost everywhere in disturbed sites. It is a worldwide distributed tropical peregrine species that is considered to originate from the Guayana Shield area (Righi 1984b). The native genera *Glossodrilus* (4 regions), *Onychochaeta* (3), *Pontoscolex* (*Pontoscolex*) (4), *Rhinodrilus* (4), *Andiorrhinus* (*Amazonidrilus*) (3), *Diachaeta* (*Amazo*) (2), *Diachaeta* (*Diachaeta*) (2), *Eukerria* (2), *Holoscolex* (2), *Martiodrilus* (2), *Pontoscolex* (*Meroscolex*) (2), *Righiodrilus* (2), *Thamnodrilus* (2) and *Wegeneriona* (2) have been found in several regions; the other 16 native genera were only found in one region.

Of the 105 species recorded, 86 were found in only one zone, 14 in two zones, 3 in 3 and 2 in 4. Of the 97 native species, one, *P. corethrurus* has been found everywhere and only 13 occured in 2 or 3 regions: *Andiorrhinus* (*Amazonidrilus*) *amazonius* (San Carlos de Rio Negro and Manaus); *Glossodrilus oliveirae* (Boli-

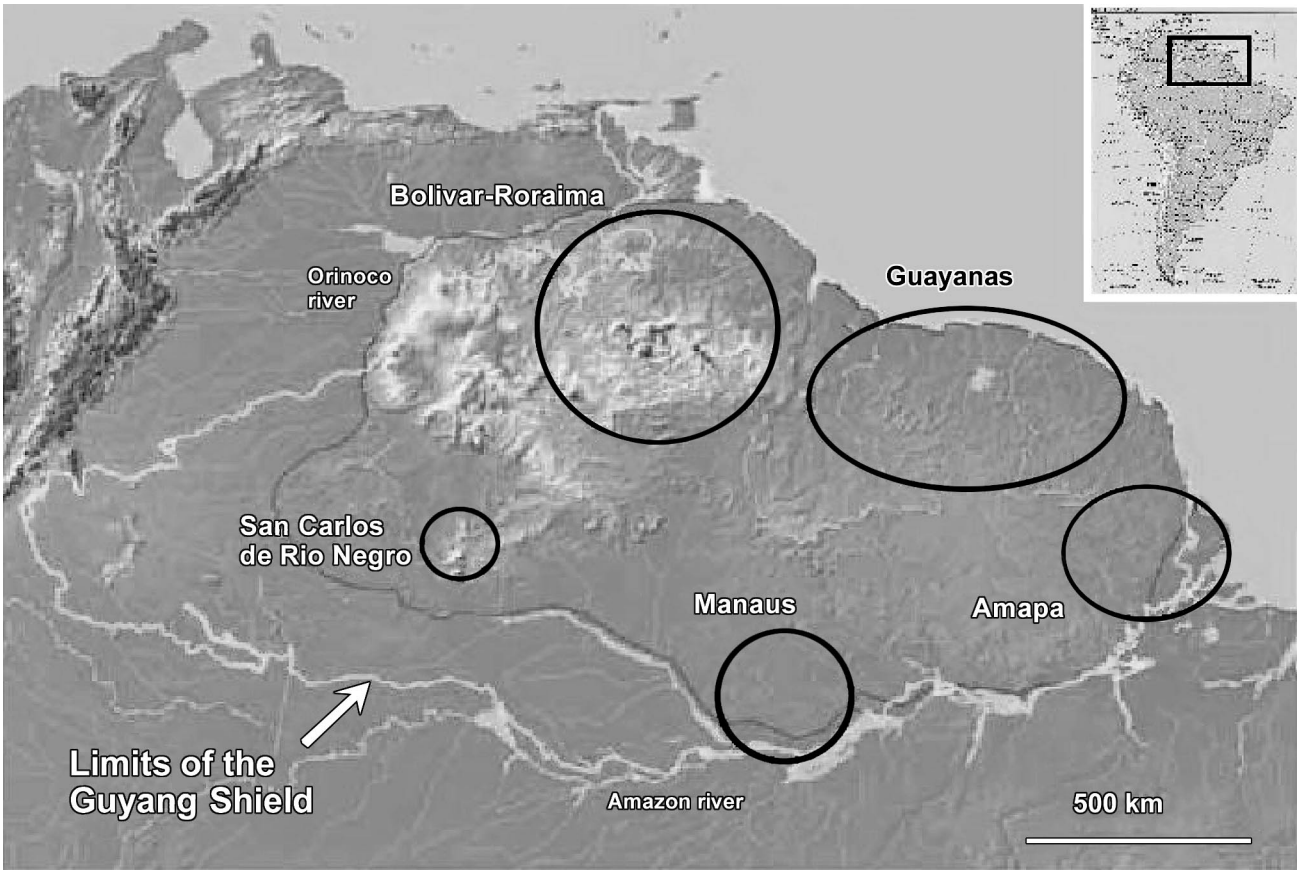

Fig. 1. Distribution of earthworm collection sites in the Guayana Shield region

var/Roraima, Guayanas and Amapa); *Glossodrilus schubarti* (Bolivar/Roraima and Manaus); *Glossodrilus sucunduris* (Manaus and Amapa); *Glossodrilus uete dithecae* (Manaus and Amapa); *Holoscolex caramuru* (Manaus and Amapa); *Martiodrilus duodenarius* (Guayanas and Amapa); *Onychochaeta windlei*, a widespred species of Carribean islands (Bolivar/Roraima, Guayanas and Amapa); *Pontoscolex* (*Pontoscolex*) *cuasi* (Bolivar/Roraima and Amapa); *Pontoscolex* (*Pontoscolex*) *vandersleni* (Manaus and Guayanas); *Righiodrilus tico* (Bolivar/Roraima and Guayanas); *Rhinodrilus lakei* (Bolivar/Roraima and Manaus) and *Rhinodrilus longus* (Guayanas and Amapa)

Exotic species are much more widely dispersed. Disturbed areas tend to be colonised by the same combination of species: the native peregrine glossoscolecid *Pontoscolex corethrurus*, a very aggressive endogeic coloniser of disturbed areas that tends to displace all other native endogeics when introduced; the endogeic megascolecid *Polypheretima elongata* that seems to preferentiably colonise areas with long dry seasons and clayey soils; the small endogeic polyhumic *Ocnerodrilus occidentalis*; and the epigeics *Dichogaster bolaui*, *D. saliens* and *D. modiglinai*. Other species can occasionally appear such as Lumbricidae observed once in a rainforest of French Guiana. They seem to have been accidentally introduced in nursery pots of tree seedlings brought from southern France (Lapied unp. data).

These results are obviously preliminary since the collection effort has been very limited and native species, unlike exotics, often have low densities and are difficult to find. However, it is unlikely that further collections will significantly invalidate the trends observed in this data set.

Rate of endemism in different invertebrate groups

Most invertebrate taxa have been poorly studied in the Guayana Shield region. The available data permit preliminary estimates of the relationship between local and regional species richness (Fig. 2). "Local" here is defined as the number of species likely to be found at a site among all the ecosystem types (i.e., the β diversity); "regional" is the total number of species already collected, or expected to be found, at the scale of the whole Guayana Shield region.

Table 1. List of species and genera collected in the five different areas of the Guayana Shield

	BOLIVAR (Venez.) RORAIMA (Braz.)	San Carlos de Rio Negro (Braz.)	Manaus (Braz.)	GUYANAS	AMAPA (Braz.)	References
EUDRILIDAE						
Eudrilus				*eugeniae*		Cernosvitov 1935
GLOSSOSCOLECIDAE						
Andiodrilus					*icomi*	Righi 1971
Andiorrhinus						
(***Amazonidrilus***)					*amaparis*	Righi 1971
		amazonius	*amazonius*			Righi et al. 1978; Righi Nemeth 1983; Zicsi et al. 2001
			brasiliensis buritis			Righi et al. 1978
			caudatus			Righi et al. 1978
			curiosus			Righi et al. 1978
		mandauaka				Righi Nemeth 1983
			venezuelanus tarumanis			Righi et al. 1978
Andiorrhinus (***Turedrilus***)		*baniwa*				Righi Nemeth 1983
		bare				Righi Nemeth 1983
Andioscolex					*antunesi*	Righi 1971
					freitasi	Righi 1971
					geayi	Righi 1971
					tinga	Righi 1971
Atatina			*gatesi*			Righi et al. 1978
Cirodrilus			*righii*			Zicsi et al. 2001
Diachaeta (***Amazo***)			*atroaris*			Righi et al. 1978
		mingua				Righi Nemeth 1983
Diachaeta (***Diachaeta***)					*carsevenica*	Righi 1971
		uaimiri				Righi Nemeth, 1983
			juli			Righi et al. 1978
Diaguita			*vivianae*			Righi 1990b
Enantiodrilus				*cognetii*		Michaelsen 1933; Righi 1971
Glossodrilus	*arapaco*					Righi 1982
	baiuca					Hamoui Donatelli 1983; Righi 1990a
					cigges	Righi 1971
	mairaro					Righi 1982
	motu					Righi 1990a
	oliveirae			*oliveirae*	*oliveirae*	Righi 1982, 1990a
	schubarti		*schubarti*			Righi 1982
			sucunduris		*sucunduris*	Righi et al. 1976
			uete dithecae		*uete dithecae*	Righi 1988
Holoscolex			*caramuru*		*caramuru*	Righi 1990b
			nemorosus tacoa			Righi 1990b

	BOLIVAR (Venez.) RORAIMA (Braz.)	San Carlos de Rio Negro (Braz.)	Manaus (Braz.)	GUYANAS	AMAPA (Braz.)	References
Martiodrilus				*duodenarius*	*duodenarius*	Cernosvitov 1934; Righi 1971
				geayi		Cernosvitov 1934
				gonggrijpi		Michaelsen 1933; Righi 1971
				helleri		Righi 1971
					matapi	Righi 1971
				potarensis		Righi 1971
				tenkatei		Cernosvitov 1934
				sp. nov. 1		Lapied, unp. data
				sp. nov. 2		Lapied, unp. data
				sp. nov. 3		Lapied, unp. data
				sp. nov. 4		Lapied, unp. data
Onychochaeta	*windlei*			*windlei*	*windlei*	Righi 1972
Perolofius		*ljungstromi*				Righi Nemeth, 1983
Pontoscolex (***Meroscolex***)				*guianicus*		Cernosvitov 1934
				hoogmoedi		Righi 1969, 1984b
				longissimus		Cernosvitov 1934
	roraimensis					Righi 1990a
Pontoscolex (***Pontoscolex***)	*corethrurus*		*corethrurus*	*corethrurus*	*corethrurus*	Michaelsen 1933; Cernosvitov 1934; Righi 1984b, 1990a; Righi Guerra 1985
	cuasi				*cuasi*	Righi 1984b, 1990a
			eudoxiae			Righi 1984b
				hingstoni		Righi 1971, 1984b
	maracaensis					Righi 1984b
	marcusi					Righi 1984b
	nogueirai					Righi 1984b, 1990a
	uairimensis					Righi 1985a
			vandersleni	*vandersleni*		Michaelsen 1933; Righi 1971; Zicsi et al. 2001
				sp. nov. 1		Lapied, unp. data
Righiodrilus	*tico*			*tico*		Righi 1982
				sp. nov. 1		Lapied, unp. data
				sp. nov. 2		Lapied, unp. data
Rhinodrilus					*annulatus*	Righi 1971
					bursiferus	Righi 1971
			contortus			Zicsi et al. 2001
	lakei		*lakei*			Righi 1971, 1985b longus longus Cernosvitov 1934; Righi 1971
			priollii			Righi 1985b; Zicsi et al. 2001
				sp. nov. 1		Lapied, unp. data
Thamnodrilus				*gulielmi*		Righi 1971
	salathei					Righi 1971
Tuiba			*dianae*			Righi et al. 1976; Zicsi et al. 2001

	BOLIVAR (Venez.) RORAIMA (Braz.)	San Carlos de Rio Negro (Braz.)	Manaus (Braz.)	GUYANAS	AMAPA (Braz.)	References
Urobenus			*brasiliensis*			Righi 1990b; Zicsi et al. 2001
			buritis			Righi et al. 1976
MEGASCOLECIDAE						
Amynthas				*rodericensis*		Cernosvitov, 1934
Pheretima				*houlletti*		Cernosvitov, 1934
Polypheretima	*elongata*			*elongata*		Cernosvitov, 1934; Righi 1971
OCNERODRILIDAE						
Eukerria	*eiseniana*					Righi Guerra 1985
			guamais			Righi 1990b
	urna					Righi Guerra, 1985
Exisdrilus			*rarus*			Righi et al. 1978
Haplodrilus			*tagua*			Righi et al. 1978
Ocnerodrilus			*occidentalis*		*occidentalis*	Righi 1990b
Pygmaeodrilus					*amapaensis*	Righi 1988
OCTOCHAETIDAE						
Dariodrilus			*ferrarius*			Righi et al. 1978
Dichogaster			*affinis*			Righi 1990b
	bolaui		*bolaui*	*bolaui*	*bolaui*	Cernosvitov 1934; Righi 1990a; Righi Guerra 1985
			gracilis			Righi 1990b
			ibaia			Righi et al. 1978
	modigliani		*modigliani*	*modigliani*		Cernosvitov 1934; Righi Guerra 1985
			saliens		*saliens*	Righi 1990b
			xecatu			Righi et al. 1978
Neogaster					*aidae*	Righi 1975
					americana	Cernosvitov 1934
					angeloi	Righi 1988
					gavrilovi	Righi Caballero, 1970
***Pickfordia* (*Omodeoscolex*)**			*tocaya*			Righi et al. 1978
Wegeneriella			*divergens itapecu*			Righi et al. 1978
Wegeneriona				*beauforti*		Michaelsen 1933
			belenensis			Righi 1988
					cernosvitovi	Righi Caballero, 1970
					michaelseni	Cernosvitov 1934
TOTAL	**22**	**7**	**39**	**33**	**30**	

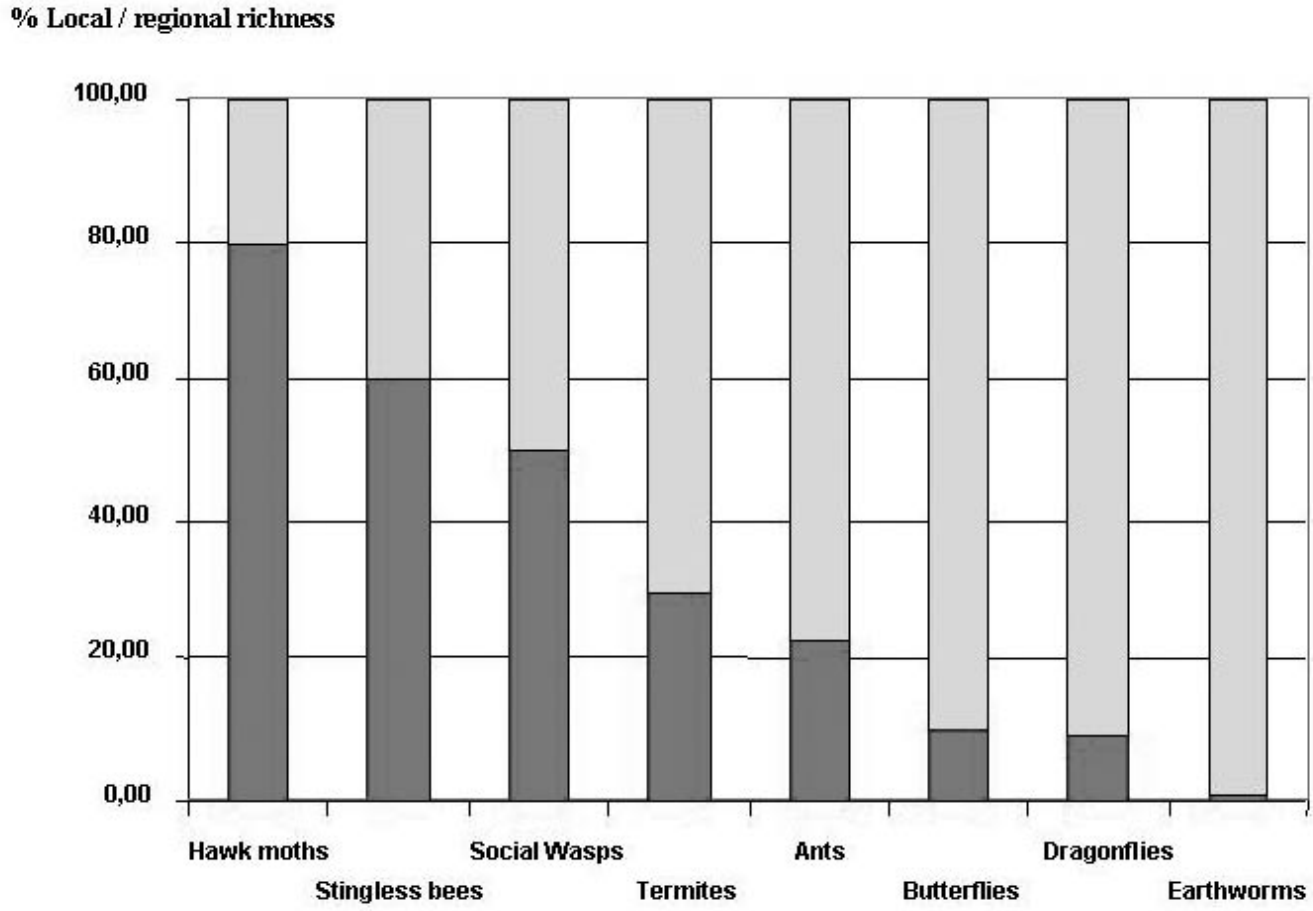

Fig. 2. Estimated ratios of local to regional diversity in different groups of invertebrates in the Guayana Shield region (P. Lavelle, P. Eggleton, J. Delabie, G. Andrade, J. Clavijo, F. Yepez, O. Silveira, B. de Dijn unpl. data)

Moths of the Sphingidae family are the group with the lowest rate of endemism. The total number of species recorded is 95, and only 16 are considered to be endemic. Stingless bees and wasps also have low rates of endemism, with estimated local to regional richness ratios greater than 50 %. Termites and ants have ratios close to 30 %, mainly due to their high dependence on specific types of habitats and landscape. Butterflies and dragonflies have ratios close to 10 % indicative of a rather large rate of endemism.

Earthworms are the group that exhibits by far the highest rate of endemism. Previous research conducted in the humid tropics indicated that a maximum number of ca. 20 species may be found at a given locality (Lavelle 1983; Fragoso & Lavelle 1987). A minimum estimate of the ratio of local to regional richness is therefore 20 : 106 if we only take into account the existing number of species already identified. However, given the small distribution area of species in the area demonstrated by the comparison, between communities in the 5 areas investigated, regional richness is probably greater than 2000 species and the ratio of local to regional richness would therefore not exceed a few percent. This estimate has been used in figure 1.

Discussion

Earthworm communities of the Guayana Shield region comprise a very large number of species with very limited distribution areas. The restricted ability of native earthworms to move and their sensitivity to disturbances explains this phenomenon. As a result species richness is very high. This situation had already been mentioned by Fragoso (2001) in Mexico, and this author estimated species richness at 20 species for each 100.000 km^2 area. Similar patterns have been indicated by Bouché (1972) in the South of France where speciation may occur whenever small geographical barriers impede earthworm movements.

These data contrast with data published by Wolters et al. (2000) who estimated the ratio of local to re-

gional richness to be 30 % for earthworms in Central Europe. This result however was obtained in an area that was recently covered by glaciers and was subsequently recolonised by a small number of Lumbricidae species. The same Lumbricidae are the ones that have shown great ability to colonise temperate areas of the world and they are to be considered as peregrine species.

This result shows that many earthworm species are in danger of extinction, or have already disappeared in many tropical areas of the world that are now colonised by exotic species. It also indicates that the estimated number of earthworm species worldwide (ca. 7000) is probably a gross underestimate.

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