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MORE ON EARTHWORM DISTRIBUTION IN NORTH AMERICA

By G. E. Gates[1]
Tall Timbers Research Station
Tallahassee, Florida 32303

The earthworm fauna of the United States has been much misunderstood both at home and abroad. Consideration of certain beliefs, rather commonly held in the United States, at least in the past, is the main purpose of the present contribution. Primarily involved is the Quaternary climate and the fact (Gates, 1970:9, No. 1) that all earthworms must have been exterminated, at the very least throughout the areas then covered with ice thousands of feet thick.

Subsequently, in America as also in Europe, the native earthworms actively followed the retreating glacial ice northward (Smith, 1912, who merely stated a rather generally accepted belief). Involved in any such northward migration theoretically there could have been included six genera in five families, three of which are solely American. Much more recently, European lumbricids supposedly replaced (in active competition?) native earthworms "as was described by Smith whose observations were supported by Goff, and has been commonly accepted" (Stebbings, 1962: 905). Of the six genera that could have been involved, Stebbings seems to have been concerned only with one, the acanthodrilid *Diplocardia.*

Past misunderstandings, as well as present misconceptions, require emphasis on the following: Native earthworms of any part of the world were unknown until well after European travels and settlements therein. Almost everywhere Europeans went, except in tropical lowlands and in arctic permafrost, earthworms from Europe eventually were recognized.

[1] Mailing address, 251 Silver Road, Bangor, Maine 04401

For example, consider Smith's portion of central Illinois. Even as the first native American earthworm, *Diplocardia communis*, was being described, at least four European species, *Aporrectodea rosea* and *A. trapezoides* (if not also *A. turgida* and *A. tuberculata*), *Eisenia foetida* and *Octolasion tyrtaeum*, already had become so well domiciled as to be characterized as "frequent" to "abundant", though Garman (1888) only mentioned three of them. Also, the only agent known to be engaged in transporting earthworms on a large and continuous scale (for centuries if not millenia) is man.

Data for the report (Smith, 1928) that provided the basis for "the commonly accepted" belief mentioned by Stebbings were secured from study of a small area of glaciated Illinois centering around Champaign-Urbana. The worms were considered in three undefined classes:

1) "Woodland species", better characterized as litter feeders. They move about on the surface of the soil while searching for those concentrations of organic matter in which they usually abound. No change in woodland populations during the period involved, 1892–1927, was recognized. Only three species were mentioned (Idem, p. 349) as belonging to the group and two of them obviously are native; *Bimastos gieseleri* and *B. hempeli*. The third, now known as *Dendrodrilus rubidus*, has been found around the world in appropriate climates such as are furnished by South Africa, Australia, New Zealand, southern South America and various oceanic islands.

2) "Stream-bank species". Of those so regarded by Smith, two are better characterized as limiphagous or limicolous. One, the European *Eiseniella tetraedra* only very rarely, and the other, the American *Sparganophilus eiseni*, never is naturally found away from saturated mud. Other worms listed as stream bank forms really are geophagous or litter feeders. Some of the former have shown a tendency to aggregate at or near mildly contaminated sites such as soil near or under cow-manure pats. Some of the litter feeders do adapt to polluted habitats like those along the banks of the sewage-contaminated stream that was studied. Along that stream bank was made the only continuously recorded survey for any part of the Champaign-Urbana area. During 1922–1923, a graduate student dug from 11 sites along the bank 5,134 worms. Number of collections at a site varied from one to 12 but usually was more than three. Information was not provided as to how close to the polluted water the worms were dug nor as to the liability to flooding at each site during any part of the year. Few native forms were obtained, and these at only two of the sites, neither of which had previously been searched! The species were *D. communis* (2 specimens) and *D. singularis* (94 specimens). The latter native was not again mentioned although earlier it had been said to be "common" in upland regions of central Illinois (Smith, 1915: 556). Are we supposed to assume without supporting evidence that those natives formerly had been present at each of the other nine sites? The largest number of specimens to be listed (Smith,

1928: 332, Table 1) was of a geophagous form called *Helodrilus caliginosus trapezoides* (now known as *Aporrectodea trapezoides*) but which could have comprised at least two other species. Each one of the three is geophagous, as common if not more so away from stream banks, and better characterized by its feeding.

3) "Upland-soil species", better characterized also as geophagous because of their diet. Most of these do not ordinarily crawl about on the surface unless forced there during rains. *Lumbricus terrestris* may also sometimes be forced to the surface during rain but it alone feeds and copulates on the surface during the night when conditions are favorable to such activities. Although a number of species (including seven of those found at the stream bank sites) could have been considered here, the discussion was restricted to but two and then only with reference to individuals seen above ground during and after rain. Referring to one of the pair, the American *Diplocardia communis* Garman (1888), its author was quoted as follows: "Hundreds were seen in this locality, migrating during showers of rain." Migrating seems a poor word for worms that probably were forced out of their abode, many perhaps to die the next day, as often happens. The other species, the European *Lumbricus terrestris*, was first seen in the same area (but only after rain and when it already may have become fairly well established) "probably about 1896". Subsequently, the night crawler was thought to have become abundantly stocked (judged by observations after rainfall). Meanwhile, the native species decreased until on the last night of recording in March, 1927, only 19 specimens were seen in the streets bordering 24 city blocks. Nevertheless, Smith did state that the American worm still was abundant in 1927 in areas further to the east where the night crawler was rarely seen (after rain).

Geophagous earthworms do surface after the soil has been poisoned by dilute solutions of various chemicals, as is well known to those who must collect them without digging. Observations for more than 20 years at a single site in Bangor, Maine, indicate that any particular rain rarely, if ever, brings up each and every species known to be present. On the contrary, different rains produce different species on different occasions and in different percentages. So it can be suggested that the night crawler may have replaced the native *D. communis* in the lawns of the two Illinois cities for two reasons: First, because the soil-infiltrating, industrial poisons in the rain were more deleterious to the native than to the exotic form. Second, because the grass lawns of the cities may be more like the normal habitat for *L. terrestris* than for *D. communis* (*cf.* Harman, 1960: 66).

All species of the genus *Bimastos* are native to the southern states of this country. One, *B. longicinctus*, was common in soils and parkings of Urbana when first described in 1915 (Smith, 1915: 537). Another, *B. zeteki*, was said at the same time to be common in central Illinois. All species of that genus as well as most of two other American genera

were ignored by Smith in his discussion of the subject under consideration. Even in 1928, "replacement" of the native species in central Illinois was far from complete. How partial replacement may have been now seems to be indeterminable, in absence of information as to when natives of the three genera did reach central Illinois and how extensive their distribution was before man started bringing exotic species from all around the world to America after 1500 A.D. Certainly, Smith provided little basis for the "commonly accepted" replacements which Stebbings himself hesitated to accept. However, Stebbings' doubts seem to have been mostly about conditions west of the Mississippi River, a region with which this contribution is not concerned.

Smith did say (1928: 347), "The tendency is toward an increasing domination of European species, and a corresponding decrease in abundance of some indigenous forms." However, it probably would have been more accurate to end that sentence in some such way as ". . . in city lawns and along banks of a sewage polluted stream." Certainly, Smith did no more than suggest that a similar change might be under way in other parts of the state. Accordingly, parts of Stebbings' discussion are irrelevant, as they seem to be based on an unwarranted (even if widely held?) assumption that the replacements supposedly found by Smith involved much, if not most, of all states in a central part of the country. Furthermore, Smith did not take into consideration the role of man in modification of the environment and its influence on earthworm faunas. Some such factors may be more important than competition between endemics (possibly hemerophobic) and exotics that are strongly hemerophilic (favored by human culture).

But what evidence is there for a post-Quaternary northward earthworm migration? And from where? The answer now suggested: None worthy of much serious consideration. Obviously, migrating natives never reached Canada which lacks a single endemic species and even several American litter-feeders now domiciled elsewhere in the world—or New England, with Massachusetts and Connecticut each having but one record of a native species and each at a site to which the species obviously was introduced—or New York, with one to several isolated records of three litter-feeding natives but no records of any geophagous natives. Murchie (1954) found the sole geophagous native, *D. singularis*, only at four closely spaced localities of three contiguous Michigan counties. Of the American litter feeders, one was obtained from a single locality in each of five widely separated counties. Another was found at two localities of two widely separated counties. Another, *B. longicinctus*, was found at a single site of one county, just as in one county each of Illinois (Harman, 1960) and Ohio (Olson, 1928). In contrast, at least half a dozen European exotics are widely distributed throughout Michigan. A similar situation is shown by Olson's (1928) maps for Ohio. Of his three geophagous natives, two were recorded in Ohio only from a small central area. A third did have a greater north-south distribution

but the area involved was much smaller than that occupied by each of a half dozen European exotics. Four litter feeders were shown as from one of three localities each, but two others were indicated only from 12–13 counties, mostly in the central part of the state. Data for American species from Michigan and Ohio, like that for Massachusetts and Connecticut, suggest more recent and fewer introductions than of the exotic Europeans. In Indiana, four geophagous natives probably were present (Joyner, 1960) in 1960. Subsequently two more were added.

Fortunately, more recent results of three years' collecting in 46 central Illinois counties are available. Included of course was the Champaign-Urbana area of Smith's observations. One outstanding demonstration of the effects of man was provided by Harman's (1960) finding that all but one of Smith's stream bank species had disappeared since 1927 as a result of increased pollution. The sole survivor was the European manure worm, *Eisenia foetida*. Harman did think that *D. communis* (Idem: 66), though ranked sixth in number of times collected, "probably" was becoming less abundant but because of "present restriction to flood plains, occasional uncultivated areas and along roadside". Even so, the species was obtained in 20 collections from 16 counties (including Champaign) as against 21 collections from 15 counties for the supposedly replacing night crawler. Another geophagous native, *D. singularis*, mostly ignored in Smith's discussion, was even thought by Harman (1960: 69) "to be increasing its distribution" in central Illinois where it was secured in 18 collections from 11 counties. Not mentioned by Smith in 1928 was another geophagous native, *D. verrucosa*, he earlier characterized (Smith, 1915: 536) as "abundant" and which was obtained by Harman (1960) in 16 collections from 15 counties.

Even more interesting are the results of a Tennessee study (Reynolds *et al.*, 1974). Their figures show that 15 species of European worms are present in every one of the 95 counties of that state. None of the American species, whether litter feeders or geophagous, are as widely distributed as two or three of the European. As European earthworms were introduced directly or indirectly by man into every one of the 95 Tennessee counties, it is now possible to suggest that each of the native species, whether geophagous or litter feeders also could similarly have been brought into the state, and perhaps, less frequently and more recently. For more than a century, greenhouses, conservatories, etc., may have been importing and distributing exotic earthworms in the soil around the roots of live plants. ("During 1825–1860, wealthy estates in Tennessee and Kentucky had greenhouses. The Belmont mansion, near Nashville, had three buildings each 300 feet long." Gates, 1966: 251.)

Of the 23 European earthworm species now domiciled in North America, 18 of the most widely distributed frequently were intercepted (Gates, in MMS) at American ports of entry during the last 26 years. Each of the others is known only from one, two or several widely separated American sites. Accordingly, and regardless of how Julin's (1949)

habitat and life classifications are interpreted, each one of those colonizing European species seemingly can be regarded as hemerophilic as they owe so much of their distribution to man.

Detailed information that has been desired as to immediately post-Quaternary conditions in relation to earthworm life was not found in the literature. Answers were sought in vain to the following questions: Did not arctic gales, blowing for millenia across thousands of miles of thousand-foot thick ice, exterminate earthworms below the southernmost limit of glacial advance? If so, how far from the glacial boundary? Was there permafrost in the soil south of the glacial boundary? If so, at what depths and when did it finally disappear? How soon after disappearance of the ice would the deposited rock flour, sand, gravel and boulders have acquired enough organic matter to support geophagous earthworm populations? Did the Appalachian mountain tops, even shortly, have local glaciers? If so, how many centuries were required for geophagous earthworms to eat their way up to and then down the northern slopes of those mountains in order to digest their way through Tennessee and Kentucky into central Illinois? Originally, this author merely said (Gates, 1967: 174) "for as yet unknown distances below the southern ice face, the climate was too frigid for earthworms to survive." Later on, it was suggested (Gates, 1970: 9, No. 2) that the area of supposed extermination may have included all of the area north of the Appalachians (unfortunately, again without attracting interest, discussion or repercussions). Extermination is now suggested to have extended at least to the tops of the Appalachians if not also somewhat down on the southern side into what now appears to have been one of two earthworm refugia in North America.

The other refugium comprises a narrow strip along the Pacific coast about from San Francisco to the Canadian border. Between that strip and the 100th meridian of longitude, or thereabouts, endemic earthworms are lacking. An American species accidentally introduced from elsewhere may occasionally be found. Yet, wherever there is water, European and Asiatic worms flourish in a vast area that includes the region once marked on maps as "The Great American Desert". Efforts to obtain a geological explanation for the absence of native earthworms in such a large area have all been fruitless.

The "rival hypotheses" of Omodeo and Gates discussed by Ball (1976), again involved the amphi-atlantic distribution of the Lumbricidae. Two of its genera are endemic in a southern part of the United States. All other lumbricid genera (to as many as 14 according to which classification is followed) are endemic in Eurasia, for the family reaches into Korea and Japan. The origin and evolution of the Lumbricidae has had less consideration than that of some other megadrile families. An eastern origin of the family, because of the greater number of genera there, may have been assumed. However, possibility of an American origin but with greater Quaternary exterminations than in Eurasia, perhaps should be

considered. When a North Atlantic bridge for the lumbricids was first suggested cannot now be stated. Undoubtedly, it was assumed by that master architect of bridge builders, Wilhelm Michaelsen. Such a bridge was acceptable to Stephenson who argued effectively against Michaelsen's other bridges. "A bridge betweeen Europe and North America in comparatively recent times, over the most northerly part of the Atlantic, is, I think, well attested on geological grounds: it accounts for the presence of endemic lumbricids in the eastern United States" (Stephenson, 1930: 688). The word "endemic" of that previous sentence requires emphasis. Only because of the presence of endemics on both sides of that ocean was that bridge at first thought to be necessary.

Omodeo's contribution (1963) involved: Lumbricid origin in Eurasia. Migration of existing European species across the north Atlantic to Greenland and America. Survival there, morphologically unchanged, on nunataks, during the glacial period. Migration of American worms along the same bridge to Europe at the same time the European species were crossing to America.

The only genus that could be mentioned in that reverse direction was *Sparganophilus*. It is truly American, but is represented in Europe only at two sites in England and one in France, and there by the same species that in America (Jamieson, 1971: 814) extends from Central America to the Canadian shores of the Great Lakes. In marked contrast, European lumbricids reach all the way across North America both in the United States and Canada.

The author of the "hypothesis" attributed to Gates cannot now be mentioned. It may never have been developed in a formally logical way but was merely expressed as a probability (of high degree), as by Beddard in his monograph (1895: 155). With the inclusion of such geographical names as present knowledge permits, the "probability" of Beddard can be stated as follows: Presence of lumbricids invariably identical with those of Europe, in South Africa, the hills of south India, Australia, New Zealand, North and South America and oceanic islands such as St. Helena, Bermuda, St. Paul's Rock (Indian Ocean), Hawaii, etc., resulted from transportation; and by man. One attribute all such areas have in common is that Europeans have taken to each of those places live plants with their roots surrounded by earth. Before 1895 as well as subsequently, Beddard and others had commented on the earthworms often contained in such earth. Thousands of earthworms were intercepted by the U.S. Bureau of Plant Quarantine during the last 25 years in unsterilized materials associated with the roots of live plants. Often included in such interceptions were 18 of the 23 European lumbricids now domiciled in North America.

Both Ball and Omodeo derogated the evidence in support of Beddard's "probability" that has been accumulated by the present author (*cf.* Gates, 1966, 1967, 1972a: 62, 1972b, 1976, etc.). Ball (1976) for instance, while admitting "that some earthworms have been transported

by man," states, "we cannot from this logically infer that the entire distribution is a result of such transport." Fifty years study of earthworm literature never once revealed any such claim for even one species of earthworm. Indeed, the author often has emphasized the need to determine the original home of various widely distributed anthropochores. Also, observations of farmers (Ball, 1976: 410) seemingly are regarded as unimportant, although farmers who make their living through regular turning of the soil seem unusually well qualified to speak with authority on the absence of worms in the fields they tilled. However, persons other than farmers, including anglers as well as qualified natural history observers, have recorded again and again the absence of earthworms in various glaciated parts of Canada as well as the United States. Also noteworthy is the absence of a single endemic earthworm anywhere in Canada. That of course could have been predicted by anyone really familiar with the necessities of earthworm life as well as with conditions prevailing during the Quaternary glaciation and subsequently. Indeed that is what the present author almost did long ago (Gates, 1929).

Omodeo not only claimed that European earthworms were restricted to an eastern part of the United States (New England was specifically mentioned) but also that 200 years was insufficient to enable the present distribution. Actually more than 400 years is known to have been available for modern man to provide the present distributions. Columbus, on his second voyage to America, brought with him live plants. The English fishermen had been dumping earthen ballast in Newfoundland before there was any British settlement on the continent. Cortez returned live plants from Spain after his conquest of Mexico. Early English and Dutch settlers in New England and New York brought over pear trees, whose history has been followed, in large wooden tubs of earth. Eisen had found European lumbricids common as far west as California during the latter half of the 19th century. Finally, institutional and commercial as well as individual activity has been shown (Gates, 1966, 1967, etc.) to be adequate to have produced the present distribution of the European species on this continent.

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