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INVASION NOTE

Evidence for ongoing introduction of non-native earthworms in the Washington, DC metropolitan area

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Abstract Earthworm introductions and invasions are ongoing, with significant consequences for ecological characteristics and function where populations of invasive species reach high densities. In North America the influx of people, goods and materials to coastal cities has long been recognized to be related to introduction and establishment of many different invasive organisms. We conducted surveys for soil invertebrates in the Washington, DC area along the Potomac River corridor to examine the influence of historic soil profile disrupting disturbances on the composition of soil invertebrate communities. Here we report three earthworm taxa that either (1) had never been previously reported in North America (Lumbricidae: *Helodrilus oculatus*), (2) had never been reported from "wild" caught samples in forested soils (Lumbricidae: *Eisenia fetida*), or (3) represented a notable range expansion for an introduced species (Lumbricidae: *Murchieona muldali*). All three species reported here have attributes that give reason for concern over their expansion into North American soils, not least of which is their potential for competitive interactions with the remaining native earthworm species.

Keywords Earthworm invasion · Soil macroinvertebrates · Soil disturbance · Native species conservation · Public land management

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Introduction

The problem of earthworm invasions has received increasing attention in North America and world-wide in recent years (Hendrix et al. 2008; Frelich et al. 2006; Eisenhauer et al. 2007; Marichal et al. 2009), but many species occurring in North America have been recognized as originating from Europe or Asia for more than a century (Eisen 1900). Further, the presence of these non-native earthworms has been suggested by a few workers as having potential ecological significance for many decades (Stebbings 1962; Gates 1972). The first earthworm introductions from Europe to North America are hypothesized to have occurred as early as 1620, at Jamestown, Virginia, as English trading ships dumped ballast

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when docked at the first permanent colony on the Atlantic coast (Mann 2007). Thus, the mid-Atlantic colonies were among the first to engage in intercontinental commerce, and the surrounding soils have likely long played host to earthworms from around the world. Nevertheless, as international commerce has only increased over the past four centuries, and likely has not yet reached a peak level, the influx of people and materials from international sources continues unabated, potentially bringing with it new species of animals previously not known in North America, including earthworms.

Several workers involved in research on earthworm distributions have hypothesized that human-related disturbances are related to, and partly responsible for the introduction and establishment of non-native earthworms (reviewed in Hendrix et al. 2008), and this is thought to be particularly important in soils where native earthworm species are, or should be, present (Hendrix et al. 2006). Disturbances range from intense and profile-disrupting (such as agricultural tillage or urban development) to more diffuse perturbations such as road construction in wildland areas (Kalisz and Dotson 1989; Fragoso et al. 1995; Cameron and Bayne 2009), or even recreational use of otherwise undisturbed areas for fishing (e.g., Tiunov et al. 2006; Callaham et al. 2006; Holdsworth et al. 2007).

Methods and findings

We sampled soil invertebrates in the Washington DC metropolitan area along a chronosequence of known profile disrupting disturbances ranging in age from >200 to <1 year, with additional sampling paired at nearby relatively undisturbed sites (Table 1). The criteria for designating a site as relatively undisturbed included having no historical record of known soil profile disruption, and the presence of mature vegetation, in particular large trees of apparent >200 year age. All of the earthworms collected at disturbed sites were introduced species, but three of the disturbed sites contained species of particular interest. First, from the samples collected at Dyke Marsh, we found 15 individuals of the species *Helodrilus oculatus* Hoffmeister 1845, from the Family Lumbricidae. This is the first known occurrence of this species in North America. Next, we report for the first time outside of cultures (i.e., first specimen collected in the wild) collection of a single specimen of the widely used compost worm, *Eisenia fetida* (Savigny 1826), from the Family Lumbricidae. Finally, we report a range expansion for the lumbricid species *Murchieona muldali* (Omodeo 1956) (nine specimens collected at Great Falls Park) which had previously only been known from Illinois, Indiana, Michigan, and Tennessee (Reynolds and Wetzel 2011).

Discussion

Continued introduction and spread of non-native earthworm species could have dramatic impacts on soil communities in undisturbed areas of North America. The three species reported on in this paper are of particular concern.

The home range of *Helodrilus oculatus* is thought to be southern Europe, spanning the Iberian Peninsula to the Caucasus (Szederjesi et al. 2014), where it is considered uncommon, but this may be due to lack of sampling in its preferred habitat. The species has a semi-aquatic habitat preference, usually occupying saturated soil along the margins of rivers, lakes, and streams, and has been reported to inhabit wet caves in southern Europe (Szederjesi et al. 2014). Indeed, the species' range may also be expanding in Europe as the first reports of the species in Denmark were in the late 1980s (Clasuen 1987), and its range is now reported to include southern Sweden (T. Decaëns, personal communication). The occurrence of this species in North American soils is of particular concern due to its occupation of the same habitat as species in the native earthworm genus *Sparganophilus* which has so far enjoyed a lack of competition from introduced earthworms. If *H. oculatus* proves to compete effectively with *Sparganophilus* spp. for space or other resources, then this suggests that the remaining diversity of native North American earthworms may be further imperiled.

The impacts of earthworms on leaf litter horizon in forests is dramatic, and these effects are particularly pronounced for epigeic species (Snyder et al. 2011; Greiner et al. 2012; Frelich et al. 2006; McLean and Parkinson 2000; Eisenhauer et al. 2007). These epigeic species are known to cause reductions in the depth and mass of leaf litter, and in turn to have

Table 1 Locations where specimens representing new distribution records were collected

Sample location	Lat/long[a]	Disturbance history	Earthworm species collected	Notes
Arlington House	38.8817 −77.0730	Contemporary construction—2010s		
Dyke Marsh	38.7698 −77.0471	Construction with unconsolidated till—1970s	*Helodrilus oculatus*	First North American record
Turkey Run Park	38.9594 −77.1427	Early twentieth Century construction—1910s		
Fort Marcy	38.9251 −77.1156	US Civil War entrenchment—1860s	*Eisenia fetida*	First record outside cultures
Great Falls Park	38.9914 −77.2504	Revolution Era canal construction—1780s	*Murchieona muldali*	First report for Eastern Seaboard

Sites were distributed along the George Washington Memorial Parkway, in Virginia. Paired disturbed and undisturbed sites were sampled at each location. Sites were selected to span a range of known disturbance ages

[a] Latitude and Longitude coordinates provided represent an approximate centroid for the disturbed plots at each location

negative effects on organisms living in the litter layer either by destroying habitat (McLean and Parkinson 2000) or directly competing with native detritivores for food resources (Snyder et al. 2013). The composting earthworm species, *Eisenia fetida*, is just such an epigeic species. Its reported home range is nearly pan-European (Sims and Gerard 1985). In North America, although sold for composting in all 50 states (Reynolds and Wetzel 2011), the species has not been known to survive in "natural" environments outside composting bins (or areas with abundant animal manure) prior to our collection. This inability of *E. fetida* to survive in the wild has been attributed to its apparent requirement of warm temperatures. However, our collection of the species in natural soils of the Washington, DC area suggest that it can survive outside compost bins, and that it may have the potential to become established in wild populations. The epigeic behavior of *E. fetida*, and its preference for feeding on fresh organic matter suggests that it may pose particular problems to the maintenance of O-horizons in forested ecosystems where it invades.

Another European lumbricid, *Murchieona muldali* (Sometimes called *Murchieona miniscula*, or *M. miniscula muldali*) has been rarely reported in North American soils, with reports only from Michigan, Illinois, Indiana and Tennessee (Reynolds and Wetzel 2011). However, the species may currently be in an expansion phase globally, as it has also been recently reported in New Zealand soils (Blakemore 2012). This small, apparently endogeic species (little pigment, and collected from soil pits in our survey) may pose additional threat to the predominantly endogeic native genus *Diplocardia*. *Murchieona muldali* was collected in close proximity to the only location where *Diplocardia* specimens (also, small endogeic species) were collected in our survey, and this may once again suggest the potential for negative competitive interactions between native and introduced species. Future surveys in the area should shed light on the question of whether the two groups are in competition, the European species is expanding, or if the current distributions are stable.

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