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Earthworm databases and ecological theory: Synthesis of current initiatives and main research directions

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ABSTRACT

Earthworms are a key group of detritivores and ecosystem engineers in many ecosystems worldwide, yet we have a limited understanding of how their diversity varies globally. Synthesis of global data on earthworms would allow a range of important ecological, evolutionary, and applied questions to be addressed. We conducted a survey on global earthworm data at the 10th International Symposium on Earthworm Ecology (ISEE10) and sent an electronic survey to additional earthworm researchers. Respondents were asked about existing databases, research interests, required data, and research locations. Most researchers were aware of at least one database with earthworm data, with a total of 19 current databases being identified. Most of the top questions listed by researchers related to distributions and diversity at global scales, but traits, evolution, genetics, taxonomy, invasions, ecosystem functioning/impacts, ecotoxicology, and bioindicators were also key themes of interest. Correspondingly, distributional, environmental, and trait data were the primary data types required. Global data coverage was poor, with research being especially concentrated in Europe and the United States. Encouragingly, all researchers who currently had data indicated they would be willing to contribute it to a global database. While there are a number of key challenges associated with synthesis of earthworm data on a global scale (data limitations, taxonomic inconsistencies, logistical issues), the wide range of questions involving global data listed by researchers, and their willingness to contribute their own data, suggests there is strong interest in developing a comprehensive global database on earthworms.

1. Introduction

Global distributions of soil organisms, and the factors driving these distributions, are poorly understood as compared to broad-scale patterns of aboveground biodiversity (Bardgett, 2002; Decaëns, 2010; Wardle et al., 2004). The complex and heterogeneous nature of soil allows for high levels of niche partitioning and local diversity, but how this biodiversity varies over temporal and spatial scales is not clear especially at large scales (Bardgett, 2002; Decaëns, 2010). Very few studies have systematically examined global patterns of belowground diversity and community structure (Nielsen et al., 2014), despite increasing recognition of the importance of aboveground–belowground feedbacks in controlling ecosystem processes (Wardle et al., 2004). In general, there is a need for hypothesis-driven and synthesizing research in soil ecology to allow an improved understanding of the major factors driving dynamics of belowground systems (Powell et al., 2014).

Earthworms are an important group of soil organisms for which global synthesis is needed. They are essential components of many terrestrial ecosystems and function as key detritivores (Edwards, 2004) and ecosystem engineers (Lavelle et al., 1997). Earthworms often dominate the biomass of invertebrates and initiate decomposition processes by incorporating surface litter into the soil, fragmenting leaf litter, and paving the way for further microbial decay (Edwards, 2004). Furthermore, earthworms

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structure the environment for other soil invertebrates (Brown, 1995; Eisenhauer, 2010) and plants (Scheu, 2003; Van Groenigen et al., 2014). They also have substantial effects on ecosystem functions and services, including greenhouse gas fluxes (Lubbers et al., 2013).

Synthesis of global earthworm data would allow many fundamental questions to be addressed relating to ecology, evolution, ecotoxicology, and conservation. For example, basic macroecological patterns, such as effects of elevational and latitudinal gradients on diversity could be examined with such a dataset. As well, factors that have been demonstrated to determine earthworm distributions at local and regional scales, including climate, habitat type, species' interactions, and anthropogenic activities, could be compared across broad spatial extents. Synthesis of earthworm data available worldwide would also allow identification of regions where little data currently exists and which would greatly benefit from increased research effort. This knowledge would allow research in data-poor regions to be prioritized.

Despite the wide range of research questions that could be examined using global earthworm data, synthesis is likely to be challenging for a number of reasons. Assembling data will be complicated by the fact that sampling techniques are not standardized across different studies, with various extraction methods and sampling plot sizes being used. The taxonomic level to which individuals are identified also varies among datasets, and there are issues with unresolved taxonomies, the use of multiple names for the same species, and the use of the same name for multiple species (i.e., cryptic species). Finally, practical difficulties exist with linking databases that have different formats and data types, or with transferring data from one database to another.

In this paper, we summarize currently available data on earthworms at broad spatial scales and discuss future directions for synthesis of global data. We surveyed earthworm researchers attending the 10th International Symposium on Earthworm Ecology (ISEE10) in Athens, Georgia and also sent a survey to additional earthworm researchers via email. As well, we conducted a workshop on global earthworm data at ISEE10, which informs some of the discussion in this paper.

2. Materials and methods

Paper copies of our questionnaire were distributed to the approximately 113 attendees at the ISEE10 in June 2014, who were asked to return the survey by the end of the day. In August 2014, we also emailed an electronic version of the questionnaire to 174 earthworm researchers, which represents the majority of the international research community, but likely excludes a non-negligible number of Chinese and Russian scientists. A total of approximately 235 unique individuals were contacted, as there was some overlap between conference attendees and the email list, and thus some people received the survey twice. Respondents were also asked to forward the survey to other interested researchers, but there appear to have been very few, or no, responses from other researchers not on our list, as most respondents included their email address on the survey form. The survey consisted of six open-ended questions (see Table 1 for survey questions). Respondents were asked to indicate any global databases they were aware of that contain information on earthworms, as well as up to five key questions that could be addressed with a global earthworm database and the types of data that should be included in such a database. In addition, we asked where their research was conducted and if they would be willing to contribute their data to a global database or to collect additional data.

Responses to the survey were used to compile a list of current databases (Table 2), which we examined to determine whether they were still being updated and contained publicly available information. To identify major areas of research interest, we divided the key questions listed by respondents into six major categories (listed in Table 3). We then selected the top one to three questions in each of these categories (depending on the overall number of questions within each category). We also grouped the types of data that respondents thought should be included in a database into ten major categories (listed in Table 4). Locations where researchers reported their data from were mapped using ArcGIS 10.0 (ESRI, Redlands, CA).

3. Results

A total of 77 earthworm researchers responded to our survey, including 31 at ISEE10 and the remainder via email. This represents a response rate of 33%, given that approximately 235 individuals received surveys. From the survey, we identified 16 currently existing databases that contain publicly available earthworm data and two databases that do not currently have data freely available online (Table 2). Some respondents also listed citizen science projects, most of which do not presently have data available but might in the future (Table 3). All of the databases included data at the species level and most focused on the global level (75%) rather than on specific countries or regions (25%). The databases included data on large-scale distributions, genetics, taxonomy, traits, and abundance/biomass within plots, with most including only one type of data. More than half of the respondents were aware of at least one database (56%).

A wide range of key research questions were suggested by survey participants, on topics such as distributions, genetics, invasions, ecotoxicology, traits, and ecosystem functioning/impacts (Table 4). Most of the research questions listed concerned large-scale distributions and biodiversity (45%), followed by traits (17%). Consistent with the types of questions that were of greatest interest, the data types most frequently listed as being important to include in a global database were trait, environmental, and distributional data (Table 5). Our question about desired data types

Table 1
List of questions from the survey conducted at ISEE10 and online. In the online survey, we specified that answers to question 1 should include only databases that participants were aware of before reading our email asking for responses, because one database (Drilobase) was discussed in the email.

Questions
1 Before reading our email, what databases did you know of that contain information on earthworms? Please indicate the type of data included in each database: (a) Large-scale distributional/geographical; (b) Quantitative plot-level data (density/biomass); (c) Genetics/phylogeny; (d) Traits
2 List up to 5 key questions that could be addressed with a global dataset on earthworms
3 Which data would you like to be able to extract from a global earthworm database (e.g., morphological traits, behavioural traits, environmental data, . . .)?
4 Would you be willing to contribute your data to such a database?
5 What country or region(s) do you work in/is your data from?
6 In the future, would you be willing to collect more data about additional variables at your sites in order to inform key resaerch questions (e.g., data on pH, soil moisture, body size, etc.)?

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