Soil Biology and Biochemistry 122 (2018) 71–80

Contents lists available at ScienceDirect

Soil Biology and Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

EGrowth: A global database on intraspecific body growth variability in earthworm

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ARTICLE INFO

Keywords:
Body size
Life history traits
Interspecific variability
Intraspecific trait variability (ITV)
Database
Allometry

ABSTRACT

Earthworms play a key role in soil and ecosystem functioning. Predicting their abundance and spatial distribution is required to understand their ecological role. There is growing evidence that mechanistic models of earthworm population dynamics are promising tools to tackle this issue. However, this approach requires a fair amount of data because it explicitly integrates the three fundamental biological processes: growth, reproduction and mortality. Hitherto, the lack of comprehensive databases on life history parameters related to these three processes hampered the widespread development of mechanistic earthworm population dynamics models. As a consequence, predicting earthworm abundance in a variety of conditions across species is still difficult.

The clear bottleneck for making progress is the lack of databases on the intraspecific variability of earthworm life history traits in response to environmental conditions. Data related to body growth and body size are critical because body size largely determines reproduction and mortality rates. Body growth is therefore the backbone of mechanistic models of earthworm population dynamics.

Here I present EGrowth, the first comprehensive database on intraspecific variability of earthworm body growth in relation to environmental conditions. The EGrowth database contains 1073 growth curves of 51 species of earthworms, representing 16002 measures of body mass. It covers publications on earthworm body size from 1900 to 2016. The environmental conditions in which the growth curves were produced are also reported. The database is open access and can be browsed from a graphical user interface. EGrowth will be updated regularly in the future as new studies are published. I propose a standardized framework for reporting future data on body growth of earthworms.

1. Introduction

Earthworms play an important role in soil functioning (Lavelle, 1988). For instance, they modify soil structure, bulk density and aggregate stability, with direct consequences for water infiltration rates and hydrological conductivity (Blanchart, 1992; Bossuyt et al., 2005; van Schaik et al., 2014). They also affect nutrient and carbon fluxes through their effect on decomposition and microbial activity (Pashanasi et al., 1996; Richardson et al., 2016). These modifications impact vegetation (De Deyn et al., 2003; Hattenschwiler and Gasser, 2005; Laossi et al., 2009) and climate dynamics (Lubbers et al., 2013; Zhang et al., 2013). A number of studies have shown that all these effects quantitatively depend on earthworm abundance and traits, which are themselves constrained by environmental conditions (e.g. Jouquet et al., 2008; van Schaik et al., 2014). Understanding how the environment impacts earthworm abundance and traits in a quantitative way is therefore a key requisite for a better grasp of their role in soil functioning. However, predicting earthworm abundance and traits in a specific context is very challenging because soils are extremely heterogeneous even at fine scales. In addition, ecological preferences vary among species. A major challenge is thus to develop a quantitative understanding of earthworm ecology for predicting earthworm abundance and traits in relation to ecological conditions.

A promising approach for tackling this issue is the development of process based models (Jager et al., 2006; Kooijman, 2010). They have been used for a variety of purposes such as understanding the spatial structure of earthworm populations, the impact of earthworms on infiltration rates, or the effect of pesticides on earthworm population dynamics (Barot et al., 2007; Baveco and De Roos, 1996; Schneider and Schroder, 2012; Vorpahl et al., 2009). These models mimic growth, reproduction and death of individuals or cohorts, in order to predict population dynamics. They require a fair amount of data to parametrize the modelled processes, which has been identified as the primary bottleneck for the development of such approaches (Schneider and Schroder, 2012). Data on body growth variability, and thus on intraspecific body size variability (IBSV), are critical because body size

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https://doi.org/10.1016/j.soilbio.2018.04.004
Received 12 December 2017; Received in revised form 29 March 2018; Accepted 4 April 2018

determines the rate of reproduction and life span (Brown et al., 2004). Indeed cocoon production, cocoon hatchability, food consumption, and longevity all depend on the body size of earthworms (Daniel, 1990; Michon, 1954). In turn, the population dynamics and ecological effects of earthworm are also related to their body size (Brown et al., 2004).

In order to build mechanistic models of body growth, we need to estimate the effects of the environment on growth patterns. For this we need databases that document the respective effect of a variety of environmental factors. This kind of data is typically available from experiments in controlled conditions, where only the factor(s) studied vary. A large number of studies have reported this type of experiments on earthworms. However, as far as I am aware, there is no comprehensive database compiling data on the effect of the environment on intraspecific body size variability in earthworms.

Building a database on IBSV that covers a wide spectrum of earthworm species is challenging in several aspects. The first inherent difficulty is that the shape of body growth curve varies among studies (Grimm et al., 2014). In particular, growth curves can be non-monotonic because body size can regress, present oscillations or can follow a staircase shape (Lakhani and Satchell, 1970; Michon, 1954; Tondoh and Lavelle, 1997). Hence, data on body size without reference to the shape of growth pattern have limited utility for modelling the effect of the environment on body size. The ideal structure of a global database should include this diversity of growth patterns, and should enable generalization to species for which growth form has not been measured so far. A simple way to achieve this is to build IBSV databases on body growth curves – i.e. ontogenetic growth. Body growth curves are measures of body mass at different times on the same individual or on the same population. This approach allows the modelling of body growth and the calculation of a variety of body growth parameters that can be compared among ecological conditions and across species (West et al., 2001).

A second difficulty for building databases on IBSV is the retrieval of the conditions during growth. Having this information is critical for identifying the drivers of IBSV, and to quantify their effect on body size. This information also allows parametrizing reaction norm functions, which are mathematical models that predict body growth in relation to environmental conditions such as temperature (Angilletta et al., 2004; Gillooly et al., 2001; Ray, 1960). Retrieving environmental conditions in reports on body growth of earthworm is however challenging because there are no standardized guidelines to present this type of information. As a result, these data are often missing or dispersed within the documents.

Lastly, the data by themselves are difficult to access because they are scattered in many articles, in different journals and in different kind of reports. The title and summary of the documents often do not reveal the presence of data on body growth. Growth curve data were often published in early articles that are not recorded in search engines and not available in electronic format. Data are usually difficult to reuse because they are presented only in graphical form, without the corresponding raw data. This implies a manual digitalization of the figures to reuse the data. Furthermore, centralizing existing data on body size and growth of soil animals is necessary, not only for making these data easily reusable, but also to ensure that these data will not be definitively lost in the future.

In this paper, I present the EGrowth database. The database compiles existing data about body growth of 51 species of earthworm. It actually contains more than 16000 body mass measures, representing more than 1000 growth curves. The database is open access and can be accessed in a variety of manner. It can be downloaded or accessed through a Graphical Interface (GUI) from R or from internet. This database will be updated in the future with new studies. In order to facilitate this process, I propose a standardized framework for reporting future data on body growth of earthworms.

2. Material and methods

2.1. Database construction

Data were searched in articles published in peer reviewed journals and in PhD theses from 1900 to 2016. Articles were searched in different ways, with the goal to be as exhaustive as possible. An intensive internet search was carried out through different databases, mainly Web Of Science, Scopus, Google Scholar and Researchgate. References cited within the articles were also searched for online and in various libraries in France (MNHN and IRD Bondy) and USA (UCSB and Stanford). Key words such as earthworm growth rate, body size, and ones related to earthworm ecotoxicology - a field which offers a large amount of data-were used to retrieve publications. In addition, all issues from the most relevant journals – Pedobiologia, Soil Biology & Biochemistry, Biology and Fertility of Soils, Applied Soil Ecology and Megadrilogica were checked manually through table of contents for articles containing data about earthworm growth rate. Articles that were not available in a digital format were scanned, and the text was extracted through an OCR process (Optical character recognition). Then figures and tables with relevant data were extracted, digitalized with the software DataThief, and exported into spreadsheets. Point data from figures were reported with their associated error bars when available. Error bars were converted to Standard Error bars. Metadata such as the number of measures per point, temperature and treatments were searched for manually in the text and included in the database, when available. The authors of the articles with missing data were contacted in order to complete the database. All articles were stored as pdf files in an online folder and can be accessed upon request.

Overall, 414 publications were analysed, from which only the ones with at least four monitoring dates were retained. As a consequence, many articles, in particular the ones that used Instantaneous Growth Rate (IGR) - the difference of (log) body mass between two dates -, were not considered. Studies that used adults at the beginning of the experiments were also discarded. At the end 162 publications were used to build the database. The list of articles is given in supplementary material.

2.2. Database structure

The database is organized in three tables (Fig. 1), which are described in detail in supplementary material.

2.2.1. File “curves.txt”

This table stores the growth curve data points (16002 entries, 4 columns). Each entry is the individual or average biomass of a batch of earthworms at a given time in a given experiment, with the standard error of the mean of the biomass, when available. Each growth curve has a unique identifier called “CURVE_ID”. All points with the same CURVE_ID belong to the same growth curve. Be aware that the column “time” is in most cases not the age of animals but the time since the beginning of the experiment.

2.2.2. File “curves_md.csv”

This table (1073 entries, 30 columns) describes the environmental conditions in which each growth curve was produced. This table is linked to the “curves.txt” file through the CURVE_ID field. This field allows the user to retrieve the environmental conditions in which each curve was produced. For each curve the name of the species studied, the types of factors that were tested in the experiment, the level of the factors, the intra and eventually interspecific earthworm density in the container, the room temperature, the soil moisture, the geographic origin of the individuals, the food and the substrate can be obtained. In experiments with fluctuating temperature, the average temperature was reported. There is also a “REF_ID” field that indicates the source of the data. This field is used to join this table to the file “references.csv”.