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Size spectra of soil nematode assemblages under different land use types

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ABSTRACT

Although the slopes of size spectra (plots of abundance on organism size) have been widely used to assess aquatic and terrestrial communities, size spectra have not been used to assess soil nematode communities. Two forms of size spectra (one based on the average biomass of nematode genera and another based on the average biomass of nematode size classes were used to assess the soil nematode communities in managed forage land and cropland, and in naturally developed grass-shrubland and secondary forests in a karst peak-cluster depression area. R^2 values were larger for size spectra based on nematode size classes than on genera. The slopes of the size spectra for total nematodes were more negative in forage land and cropland than in grass-shrubland and secondary forests, which was consistent with disturbance of the soil nematode community by agricultural management. The results suggest that size spectra analysis is applicable to soil nematodes; they can reveal different land use types and may reveal the degree to which the soil nematodes in particular and the soil community in general have been disturbed. Size spectra may be more useful if based on nematode size classes rather than on genera.

1. Introduction

Size spectra, also known as body size distributions, have long been used to assess aquatic and terrestrial communities (White et al., 2007; Petchey and Belgrano, 2010). The ‘size spectra describe the relationship between organism size and abundance and can be predicted from the expected joint change in abundance and organismal mass’ (Petchey and Belgrano, 2010). The most common pattern of size spectra, i.e., of log–log plots of abundance on body size, is a linear curve with a negative slope (White et al., 2007; Clauset and Erwin, 2008). These slopes are common compared in ecological studies involving size spectra (Petchey and Belgrano, 2010). In general, a smaller value of the slope (i.e., a more negative slope) indicates a more disturbed community (Shin et al., 2005; Petchey and Belgrano, 2010) because large organisms are more sensitive to disturbance than small ones (with disturbance, the curve becomes more negative because the abundance drops faster for large than for small organisms).

Species of soil nematodes vary greatly in body size, and nematode tolerance to disturbance is inversely related to body size (Bongers and Bongers, 1998; Bongers, 1999; Ferris et al., 2001). Therefore, the analysis of size spectra for soil nematodes could enhance our understanding of soil ecology (Turnbull et al., 2014). Size spectra for soil nematodes, however, have not been studied. In the present research, we investigated the soil nematode assemblages (e.g., total nematodes, bacterivores, fungivores, etc.) under four land use types in a karst peak-cluster depression area in southwest China. The objective was to determine whether nematode size spectra reveal the differences among land use types or ecosystems.

2. Materials and methods

2.1. Site description

This study was conducted at the Huanjiang Observation and Research Station for Karst Ecosystems (107°51′–108°43′E,

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24°44′–25°33′N), Chinese Academy of Sciences (CAS), Guangxi Province, China. The climate is subtropical monsoon with a distinct wet (from April to September) and dry season (from October to March). The watershed is a peak-cluster depression area typical of karst regions. The mean annual temperature and precipitation are 18.5 °C and 1389 mm, respectively. The calcareous soil developed from a dolostone base (Zhao et al., 2014b).

Four land use types were selected: forage land, cropland, grass-shrubland, and secondary forest. Although other land use types (e.g., a sugarcane field, a vegetable field, and a burned site) were present, they were not represented by four replicate sites and so were not included in the study. The forage lands were hybrid napiergrass (*Pennisetum hybridum*) monoculture fields; two sites were located on the sides of different hills, and two were located in the depression and were separated by two roads and a cropland. The croplands were used for maize–soybean rotations and were separated by roads and other land use types; three sites were located in the depression area, and the fourth was located on a hillside. Both the forage lands and the croplands differed in the level of management practices, such as fertilization, harvest, tillage, weed control, and irrigation. The grass-shrublands and secondary forests were located on the sides of four hills surrounding the watershed. The grass-shrublands had naturally developed for >20 years on sites where croplands had been abandoned. The secondary forests were also located on sites where croplands had been abandoned but where tree saplings had been planted; after trees were planted, the secondary forest sites had been allowed to recover naturally for >20 years.

2.2. Soil sampling and analysis

Soil was sampled on 17 April 2014. Soil cores (2.5 cm diameter) were taken at 0–10 cm depth from 15 randomly selected locations at each of the 16 sites (four replicate sites × four land use types). The fifteen cores were combined to form one composite sample per site. Nematodes were extracted from 50 g of moist soil using the Baermann funnel method. After fixation in 4% formalin solution, nematodes were counted with an inverted microscope (Eclipse Ts100, Nikon) and then measured and identified with a differential interference contrast microscope (ECLIPSE 80i, Nikon). Body length and greatest body diameter of each of the first 150 specimens encountered were measured using a microscope imaging system (DS-U3/L3-Vi1/Fi1/Fi2, Nikon) and image analyzer (Iworks, Korea); the feeding type (bacterivore, fungivore, herbivore, and omnivore–predator) of each of these 150 nematodes was deduced from the morphology of its mouth and pharynx (Supporting information 1). The data for body length, greatest body diameter, feeding type (trophic group), and total nematode abundance and abundance of each trophic group constituted dataset1. The encountered nematodes were also identified to genus according to published keys (Bongers, 1988; Jairajpuri and Ahmad, 1992; Mai and Mullin, 1996; De Ley et al., 2001) and were assigned to functional guilds (Yeates et al., 1993; Bongers and Bongers, 1998; Ferris et al., 2001). The functional guild is defined by the nematode's trophic behavior and by its ecological life strategy as a colonizer or persister (as indicated by its "*cp*" value). The data for abundances of each genus, abundances of trophic groups, body lengths, greatest body diameters, and *cp* values constituted dataset2. These two datasets were used to construct two forms of size spectra as described in the following section. The trophic group compositions in the two datasets are somewhat different. In particular, specimens of *Filenchus* and *Ditylenchus* are considered herbivores and those of *Dorylaimellus* are considered omnivore–predators in dataset1 but are considered fungivores in dataset2; specimens of *Achromadora* are considered omnivore–predators in dataset1 but are considered bacterivores in dataset2.

2.3. Data analysis

Nematode body size was represented by biomass. The biomass (fresh weight, μg) of each specimen in each sample was calculated as follows:

$$B = \left(D^2 \times L\right) \times \left(1.6 \times 10^6\right)^{-1}$$

where B is the biomass per individual, D is the greatest body diameter (μm), and L is the body length (μm) (Andrassy, 1956). As noted in the previous section, nematode communities were characterized by two forms of size spectra. The first, which was abbreviated SSC for 'size spectra classes', allocated nematodes into ranges of body size classes and plotted nematode abundances in the classes against average biomass of the classes; each size class had a range of 0.5 μg. The second form of size spectra, which was abbreviated SSG for "size spectra genera", plotted the abundances of the nematode genera against the average biomasses of the genera. Dataset1 was used for SSC, and dataset2 was used for SSG.

Before analysis, data for the abundances and biomasses of total nematodes, free-living nematodes (i.e., all nematodes except herbivores), and four trophic groups were $\log(x+1)$ transformed. Linear regression, which was performed with SPSS software (SPSS Inc., Chicago, IL), was used to describe the relationship between log-transformed nematode abundance and log-transformed nematode biomass for both SSC and SSG. One-way ANOVA was employed to determine the effects of land use type on the calculated slopes for individual soil samples of the SSC and SSG for total nematodes, free-living nematodes, and omnivore–predators. Statistical significance was determined at $p < 0.05$.

3. Results

Table 1 lists the ranges of body length, greatest body diameter, and biomass of the nematode genera in this study. The body sizes of most genera, as indicated by all three variables, varied substantially. The linear regressions differed between SSC (Fig. 1) and SSG (Fig. 2). The adjusted determination coefficients (R^2) for total nematodes, free-living nematodes, and omnivore–predators in the four land use types were larger with SSC-generated linear curves (Fig. 1A, B, and F) than with SSG-generated curves (Fig. 2A, B and F). In addition, only the SSG for total nematodes, free-living nematodes, and herbivores in the forage land generated statistically significant linear curves (Fig. 2A, B, and E). Although the SSG for total nematodes and free-living nematodes in the grass-shrubland also generated linear curves ($p < 0.05$), their R^2 values were relatively small (0.07 and 0.113, respectively) (Fig. 2A and B). Neither the SSC nor the SSG for bacterivores, fungivores, and herbivores generated well-fitted linear curves except the SSC for bacterivores in the secondary forest and the SSG for herbivores in the forage land (Figs. 1C–E and 2C–E). In addition, abundance and biomass of bacterivores, fungivores, and herbivores were positively correlated for both the SSC and SSG in some land use types (Figs. 1C–E and 2C–E).

For SSC among land use types, the slope values were in the following order: for total nematodes, cropland < secondary forest < forage land < grass-shrubland (meaning that the negative slope was steepest in cropland and least steep in grass-shrubland) (Fig. 1A); for free-living nematodes, secondary forest < forage land < cropland < grass-shrubland (Fig. 1B); and for omnivore–predators, secondary forest < cropland < forage land < grass-shrubland (Fig. 1F). For SSG among land use types, the slopes were in the following order for both total nematodes and free-living nematodes: forage land < secondary forest < grass-