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Original article

Does distance from the sea affect a soil microarthropod community?

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ABSTRACT

Coastal sand dunes are dynamic ecosystems characterized by strong abiotic gradients from the seashore inland. Due to significant differences in the abiotic parameters in such an environment, there is great interest in biotic adaptation in these habitats. The aim of the present study, which was conducted in the northern Sharon sand-dune area of Israel, was to illustrate the spatial changes of a soil microarthropod community along a gradient from the seashore inland. Soil samples were collected from the 0–10 cm depth at five locations at different distances, from the seashore inland. Samples were taken from the bare open spaces during the wet winter and dry summer seasons. The soil microarthropod community exhibited dependence both on seasonality and sampling location across the gradient. The community was more abundant during the wet winter seasons, with an increasing trend from the shore inland, while during the dry summers, such a trend was not observed and community density was lower. The dominant groups within soil Acari were Prostigmata and Endeostigmata, groups known to have many representatives with adaptation to xeric or psammic environments. In addition, mite diversity tended to be higher at the more distant locations from the seashore, and lower at the closer locations, a trend that appeared only during the wet winters. This study demonstrated the heterogeneity of a soil microarthropod community in a coastal dune field in a Mediterranean ecosystem, indicating that the gradient abiotic parameters also affect the abundance and composition of a soil microarthropod community in sand dunes.

1. Introduction

Sand dunes are accumulations of sand created by wind, and they are mostly common in deserts, seashores, and rivers. They are widely distributed across the globe, as today, about 10% of the land area between 30°N and 30°S is covered by sand deserts (Sarnthein, 1978). Sand-dune ecosystems are characterized by harsh conditions and are low in nutrients (Hesp, 1991; Willis, 1963; Willis and Yemm, 1961), causing physical stress on biotic components that limits biomass accumulation below and above the ground. In contrast to the relatively stable nature of soils, sand-dune ecosystems are dynamic and usually in the process of successional changes (Foster and Tilman, 2000). Dune ecosystems represent the earliest stages in the development of soil (Jones et al., 2008).

The most characteristic feature of coastal dunes is their connection to the seashore. This marine influence creates an environmental gradient across a coastal dunefield from the seashore inland due to physical stress caused by its proximity to the sea (McLachlan and Brown, 2006). The abiotic conditions are harshest near the shore due to winds that move sand particles and salt spray. Proceeding inland, the environmental conditions are more moderate, with a decrease in wind velocity and amount of salt spray (Hesp, 1988; Young, 1987), as well as a decrease in sand-particle transport rates (Goldsmith et al., 1990). Proceeding inland, these environmental features are assumed to cause a decrease in temperature extremes and alterations in the ratio between the coarse and finer particle fractions (Ranwell, 1972). These features affect the amount of organic matter, moisture levels, and sand movement, causing a decrease in pH, followed by changes in the composition of the plant community and its distribution (Kachi and Hirose, 1983; van der Valk, 1974; Wilson and Sykes, 1999).

Due to the harsh environment, the number of terrestrial inhabitants adapted to survive in sand-dune habitats, mostly without natural shelter, is relatively low and dominated by arthropods, particularly insects that are considered typical of embryo and consolidated dunes. Arachnids are very common in sands (Almquist, 1969; Barnes, 1953; Cooke and Cotton, 1961), but usually the insects are the dominant inhabitants of sandy areas (Callan,

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1964; Colombini et al., 2005; Ranwell, 1972; Russell, 2008; Spungis, 2002). Most of the research on arthropods focused on macroarthropods, while there is little information available on their smaller relatives – the microarthropods (Koehler et al., 1995; McLachlan and Brown, 2006), and much more research is needed.

The biomass of the living organisms beneath the soil is almost 20 times larger than that of the humans living on it (Balogh, 1970), illustrating the richness of the world under our feet. On most beaches, sandy soil fauna is rich and diverse, and may have greater biomass than macrofauna, even though we can find 25 species in the soil on sandy beaches for every species of macrofauna above it (Armonies and Reise, 2000). However, very little is known about the sand dune mesofaunal communities (McLachlan, 1991).

Soil microarthropods are one of the most important components of any terrestrial ecosystem (Santos et al., 1981; Steinberger and Wallwork, 1985) due to their role in controlling key functional processes, e.g., organic-matter decomposition and mineralization (Kaczmarek et al., 1995; Santos and Whitford, 1981; Wallwork, 1970; Whitford and Parker, 1989), soil formation (Persson, 1989), and nutrient cycling (Irmler, 1982; Powers et al., 1998). Many studies were conducted on soil microarthropod-community structure and composition in dry areas, but most of them were restricted to desert soils (Kamill et al., 1985; Steinberger, 1990; Steinberger and Whitford, 1985; Wallwork et al., 1985), without reference to sandy shore ecosystems. Information on the size and composition of mite populations in sandy shores was mostly restricted to cold and temperate climates (Kagainis and Eitminaviciute, 2011; Salmane, 1999, 2000), which are different in their features and soil biota from the dry Mediterranean region.

While the gradient's effects on the flora and macrofauna of sand dunes, from the shore inland, have been studied in detail (Heykena, 1965; Isermann and Cordes, 1992; Jungerius, 1990; Rose, 1988; van Heerdt and Morzer-Bruyns, 1960; Willis, 1989), information on its effects on a soil microarthropod community is scarce, and limited to specific taxonomic groups in cold climates (Koehler et al., 1992, 1995). Moreover, these studies did not provide any information on the changes within this community during the different seasons of the year. Our aim in the present study was to examine the seasonal and spatial shifts in the soil microarthropod community's size and composition along a sand-dune–ecosystem gradient, from the shore inland, on the eastern Mediterranean shore. In order to achieve this goal, we selected a study site that included a coastal sand-dune ecosystem consisting of shifting-to-semi–stabilized dunes. Soil samples were collected at five sites along a 4 km transect, from the sea inland, during a two-year period. The samples were collected from bare, open areas, in order to minimize the effect of different microhabitats, created by the different flora at each location, as many studies showed significant differences in soil microarthropod communities among diverse plant species and bare soil (Noble et al., 1996; Steinberger et al., 1990). We hypothesize that microarthropod-community size and diversity will be determined by its distance from the seashore. The microarthropod community will increase and will be more diverse as it proceeds inland, due to the expected improvements in soil physical and biochemical conditions, e.g., lower salinity, increase in amounts of organic matter, and decrease in sand movement.

2. Materials and methods

2.1. Study site

The study was conducted at the Caesarea coastal sand dunes located in the northern Sharon Plains, from the Mediterranean shore to four km inland, 32°48′N between 34°88′E and 34°93′E. The climate is sub-humid Mediterranean, with a multiannual mean rainfall of 580 mm, falling mainly during winter and early spring (November to February), and with maximum rainfall in December. The mean minimum daily temperature reaches 10.5 °C in January, while the mean maximum daily temperature reaches 28.5 °C in August. Winds in winter are intense and vary in their direction, while they are weaker in summer, with a stable regime.

The sand dunes at this site vary from shifting to semi-stabilized and stabilized dunes, with vegetation cover dominated by shrubs and herbaceous annuals. According to Danin (Danin, 2005), this system is a unique Mediterranean ecosystem in which we can find the whole psammosere.

2.2. Soil sampling

Soil samples were collected from the 0–10 cm depth at five locations (n = 5) across a west-to-east transect, i.e., 100, 200, 1000, 2500, and 4100 m from the shore inland. The soil samples were collected from open spaces on four dates, i.e., 8/1/13 (winter 2012/13), 19/8/13 (summer 2013), 16/1/13 (winter 2013/14), and 21/8/14 (summer 2014). A total of 100 soil samples were collected during the study period. Each soil sample was immediately placed in an individual polyethylene bag and transported in an insulated cooler to the laboratory, where it was stored at 4 °C. Stones, roots, and other organic debris were removed from the soils prior to physicochemical and biological analyses.

2.3. Soil analysis

Subsamples from each replicate were analyzed for soil parameters. Soil moisture (SM) was determined gravimetrically by drying the soil samples at 105 °C for 48 h and measuring the mass loss. Soil organic matter (OM) was detected by oxidation with dichromate in the presence of H_2SO_4 (Rowell, 1994). Salinity was measured by measuring electrical conductivity in a soil-water suspension (1:10 soil-water extract), and measured using an autoranging EC/temp meter (TH2400, El-Hamma). pH was determined using a combined pH electrode in the filtered supernatant of a mixture of 20 g soil and 40 ml tap water.

2.4. Microarthropod extraction and identification

A subsample of 150 g fresh soil was taken from each sample for microarthropod extraction within 48 h of field collection. Each subsample was placed separately in a modified Berlese-Tullgren funnel under standard 40 W light bulbs for 72 h for microarthropod extraction. The microarthropods were collected from the funnels, then counted and identified. A representative from each taxonomic unit was mounted on a slide and identified under a light microscope based on the available keys. Mites of the order Mesostigmata, suborders Prostigmata, Endeostigmata, and Oribatida, were identified to the family level using keys by Krantz and Walter (2009) and unpublished keys. Psocoptera (Insecta) and Collembola (Entognatha) were described at the order level. Acari feeding habits were determined for each family based on the feeding behavior reported in the literature (Krantz and Walter, 2009). Feeding behavior was divided into five groups: predators, algivores, fungivores, phytophages, and detritivores. When such information was not available, feeding habits were deduced based on that of closely related family.

2.5. Statistical analysis

All data were subjected to statistical analysis of variance (ANOVA) using the statistical analysis system model (GLM). Duncan's multiple range tests were used to determine differences