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Clonal diversity and morphometry in the parthenogenetic earthworm *Eiseniella tetraedra* (Sav.) as affected by habitat characteristics including radioactive pollution

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ABSTRACT

Eiseniella tetraedra (Sav.) is a cosmopolitan earthworm reproducing by obligate parthenogenesis. Here, we examined whether habitat characteristics affected the clone pool diversities and morphometric variability of the stenotopic riparian species *E. tetraedra* along a west–east transect from the Scandinavian mountains to lowland habitats of the Swedish east coast through Finland and to Russia (the Komi Republic) near the Ural Mountains. The transect comprised a geographical distance that cuts through the maritime to continental climatological zones within the boreal forest belt. It terminated in the Komi Republic, thus adding habitat (soil) characteristics to the factor of radioactive pollution. We found that mountain brooks in Sweden hosted the lowest numbers of clones, but in the lowland samples the clone pool diversities decreased in general from Sweden through Finland and Russia, i.e. from west to east. Nevertheless, high levels of clonal variability were observed within the countries, so that even monomorphic pools were found. However, no clones were shared between the countries. The fresh body weights and posterior body lengths of adult earthworms decreased from west to east. The numbers of posterior segments did not, however, differ between the countries, due to decreased segment size. The location of the clitellum, tubercula pubertatis and male pores showed no clear-cut morphometric clines along the W–E gradient, but the tubercula pubertatis and male pores were more clearly demarcated in adults of the Russian material than in those from the West. *Eiseniella* adults from the Swedish mountains carried spermatophores considerably more often than those from the other localities. *E. tetraedra* from localities with radioactive pollution in Russia (the Komi Republic) showed no clear-cut clone pool diversities in comparison to the clone pools of the other sites within the area. Monomorphic clone pools were recorded in localities with low as well as high levels of long-term ionizing radiation and exposure to heavy metals. We found no morphological malformations, such as dislocations of characters, in comparison to individuals from sites with lower levels of environmental radiation.

Introduction

Eiseniella tetraedra (Sav.) is a tiny earthworm reproducing by obligate parthenogenesis (e.g., Casellato 1987). Most populations, including those in our study, are comprised of tetraploid individuals (Omodeo 1952; Vedovini 1973; Terhivuo et al. 1994). *E. tetraedra* is a stenotopic species most often found in riparian or even underwater habitats (Terhivuo 1988a). It is a cosmopolitan species widely distributed both in the Old and New World countries (Stephenson 1930). *E. tetraedra* is not directly linked with human culture and is not intentionally transported by human activity.

We previously surveyed several aspects of the ecology and morphology of *E. tetraedra* in the Baltic Sea basin, such as clone pool affinities (Terhivuo and Saura 1997, 1999, 2006), the effect of free-running and regulated rivers on the dispersal of clones (Terhivuo and Saura 2002), the role of fugitive clones in an archipelago (Terhivuo and Saura 1999) and its clone pool diversity in northern Norway and southern Finland (Terhivuo et al. 1994). Here, we focus on the extent of clonal diversity and morphological characters along a transect across Northern Europe at the same general latitude. The transect extended from the Scandinavian mountains close to the Atlantic Ocean through Sweden, then across the Baltic Sea to Finland and then to Russia close to the Ural Mountains. The transect included several ecological variables, such as different glaciation histories through the Pleistocene (Forman et al. 1999), altitudinal differences, a dispersal barrier caused by the Baltic Sea and another geographic gap due to long distances across northern Russia. We

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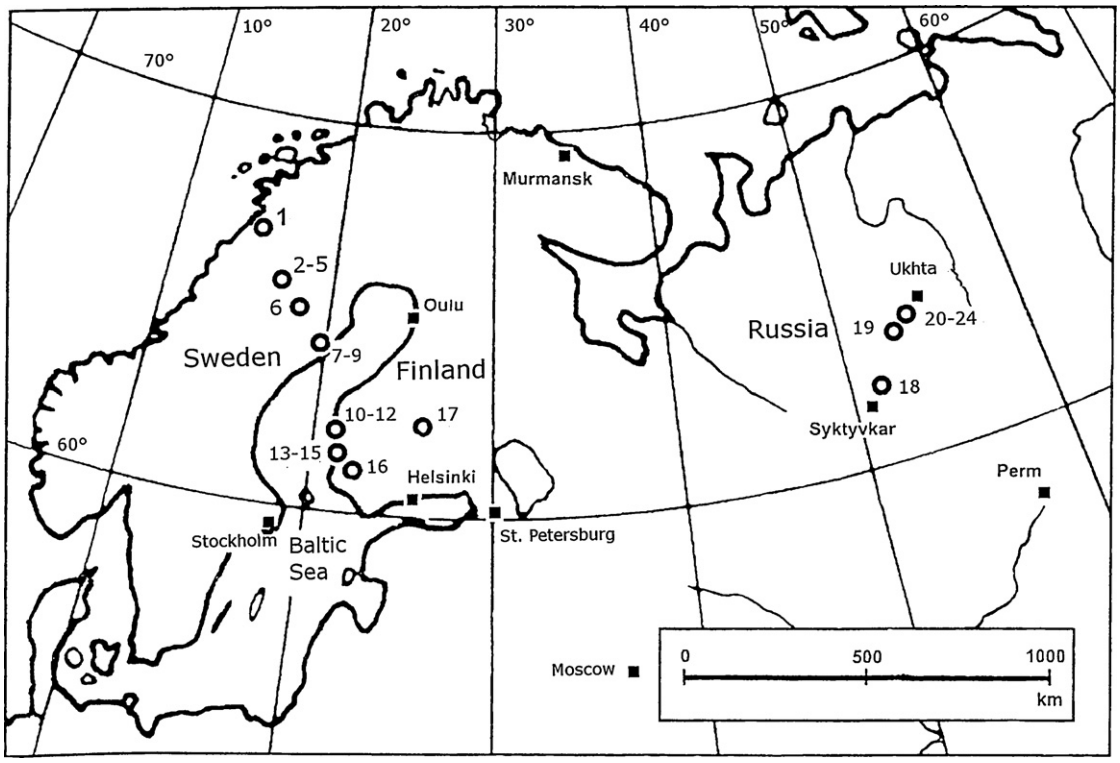

Fig. 1. Sample localities.

also sampled *Eiseniella* from sites with old and heavy radioactive pollution. We wanted to explore whether these factors can affect clonal diversity and species morphology over a wide geographical area.

In parthenogenetic *E. tetraedra*, the genetic constitution of the mother earthworm is restored by premeiotic doubling of the entire chromosome set (Terhivuo et al. 1994). Accordingly, genetic variability in a population originates from mutations and invasion of individuals, and is also exposed to variability in habitat characteristics. Hence, our hypothesis were that: (1) geographical trends can be found in clone pool diversities and morphological characters along a west–east sampling line representing a climatological gradient from maritime to continental climates, as well as geographical barriers within the coniferous taiga belt of Northern Europe and (2) local clone pools and morphological characters of individuals are affected in populations occupying soils exposed to long-term ionizing radiation at Vodnyi (Russia, the Komi Republic).

Materials and methods

Localities sampled

We hand-sorted *Eiseniella* individuals from each sample site (Fig. 1). The localities were given serial numbers from west to east, i.e. from Sweden to Finland and Russia. In Sweden, we sampled *E. tetraedra* in subarctic mountains (locs. 1–6) as well as in lowlands (locs. 7–9), whereas in Finland and Russia only lowland sites were sampled. We indicated the samples according to the country, because the countries are separated by geographical barriers and climatological differences. The Bothnian Bay of the Baltic Sea separates Sweden and Finland, while the Russian samples originate from sites far from the Finnish and Swedish sample sites (Fig. 1).

The list of locations is as follows (serial numbers refer to Fig. 1). Our sample number 1 came from Norway but was situated close to the northern Swedish border, illustrating why we included it in the Swedish sample material.

Sweden: (1) Norway, Umbukta (year of sampling is 2000), under mosses and stones near a small mountain brook with gravel bottom; (2) Storuman, Klippen (2000), under stones and among mosses and plant detritus on the shoreline of a small mountain brook with gravel, sand and clay at the bottom; (3) Storuman, Forsbäck (2000), among gravel, sand and liverworts on the shoreline of a mountain brook; (4) Storuman, Tärnaby, Hemavan, Umfors, Dulkojukke (2002), under the stones and mosses of a mountain river with sand and clay at the bottom; (5) Storuman, Kåtaviken, Mjölkfjället (2002), under stones and gravel near a small mountain brook; (6) Norrlunda, Lycksele (2000), boggy riverbank, among plant detritus deposited on the shoreline of the Ume River; (7) Umeå, the Sävar River (by the bridge 1996–1997), under stones on the shoreline; (8) Umeå, the Sävar River mouth (1996–1997), under stones and among detritus on the shoreline; (9) Umeå, Holmen (2000), among dead plant material and hay turfs on the shoreline of the Ume River mouth with gravel and clay at the bottom. Samples 1 through 6 came from subarctic mountains from about 410 to 800 m above sea level (see also Terhivuo and Saura 2008), whereas locs. 7–9 represented lowland samples. More details of the material from Sweden are given in Terhivuo and Saura (1997, 2008).

Finland: (10) Malax (1995), under leaf and reed (*Phragmites*) litter on a shore with clay and sand underneath; (11) Kristiina (1995), on the shore among hay, reed and alder (*Alnus*) with leaves and clay underneath; (12) Merikarvia, Tuorila, the Tuori River (1995), under hay and leaf material, to depths of 2–3 cm under water; (13) Pori, Ahlainen, the Eteläjoki River (1995), under dead leaves close to the waterline; (14) Pori, Ahlainen, Sandö, the Ahlainen River (1995), under stones at the waterline; (15) Pori, Anttoora, Kemianranta (1995), among dead plant material at the shoreline; (16) Kokemäki, Järilä (1995), on the bank of a small pool, among dead plant material; (17) Konnevesi, biological station (lake shore, 2001), under stones and among dead plant material at the shoreline with sand and clay underneath.

Russia: (18) the Komi Republic: the Vydhayzy River, about 40 km from Syktyvkar to Ukhta (2001), in a ditch with muddy bottom;