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Distribution of earthworms across the Sefton Coast sand dune ecosystem

Kevin R. Butt and Emma J. Chamberlain

School of Natural Resources, University of Central Lancashire,
Email: krbutt@uclan.ac.uk

Abstract

An investigation of earthworms at the Sefton Coast sand dune system examined species distribution and abundance with respect to soil conditions and management across areas of vegetation succession. Laboratory work examined growth, maturation and survival of one species in soils with increasing proportions of sand (0-100%). Nine earthworm species were found on the dunes, but not where soil organic matter content was <1%. *Dendrobaena octaedra* and *Lumbricus rubellus,* found 300m from the strand line, were considered pioneering species. In areas of human disturbance a greater number of species was present. Earthworm distribution was influenced by dune successional stage and management.

Key words

Earthworms, Sand dunes, Sandy soils, Succession, Sefton Coast.

Introduction

Ecological investigations across coastal ecotones formed by sand dunes are common and vegetation succession observed in floral species is well documented (Smith 1999, Rodwell 2000). Despite this, little research has been undertaken on the soil fauna of such ecosystems, although recently some soil-dwelling invertebrate groups have been examined in detail (Goralczyk 1998, Verhoeven 2002). However, few specific studies of earthworms have been conducted and earthworm distribution in dunes has only been addressed by Boyd (1957) on Scottish Islands. It is often, perhaps incorrectly, assumed that earthworms cannot exist in soils with a high sand content and the current study grew from initial observations of earthworm surface-casting beside a car park within the sand dune ecosystem at Formby.

The aims of this work were to obtain baseline data on distribution and abundance of earthworms across the sand dune ecosystem on the Sefton Coast and to seek to relate findings to physico-chemical soil properties and human influences.

Materials and Methods

Transects

Following English Nature guidance to avoid the protected nests of sand lizard (*Lacerta agilis*), two transect lines of 700m, were established at 90^{o} to the sea shore on the Sefton Coast sand dune system (European designation as a Special Protection Area). These were located at Ainsdale Sands (AS): National Grid Reference SD292120 (Site of Special Scientific Interest), and Lifeboat Road (LR): SD269065. Each transect crossed from the sea shore (strand line) over yellow mobile dunes, through grey fixed dunes to scrub and planted pine shelterbelt trees (Smith, 1999). Marram grass (*Ammophila arenaria*) dominated the high yellow dunes, whereas the grey dunes had a more diverse flora but were dominated by red fescue (*Festuca rubra*). In wetter areas of dune slack, creeping willow (*Salix repens*) was the dominant species.

Sampling took place during April 2005. Three replicated quadrats of 0.1m^2 were dug to 0.4 m every 50m along the given transects. Earthworms were hand-sorted (Plate 1) from soil on plastic sheeting in the field and preserved in 4% formaldehyde. A mustard powder vermifuge (50g in 10 litres water) (Butt, 2000) was also applied to the given area to extract any deeper burrowing earthworm species. Soil samples from visible horizons were collected at the same locations, for loss on ignition (organic matter), pH determination and sand content calculation. Earthworms were identified following the nomenclature of Sims and Gerard (1999) and were subdivided into major ecological categories of epigeic (litter dwelling), endogeic (shallow burrowing) and anecic (deep burrowing), as decribed by Bouché (1977). On completion of the initial transects a more detailed section at AS (250-350 m) was sampled every 10m.

Plate 1: (a) (left) Hand-sorting for earthworms 450m from the strandline in the car park at Lifeboat Road, Sefton Coast.
(b) (above) View looking inland (east), across the car park and towards the pine shelter belt, from the yellow dunes at Lifeboat Road, Sefton Coast.

Laboratory experiment

To assess the effects of the proportion of sand in soil, juvenile *Aporrectodea longa* (Ude) were collected using a mustard vermifuge from the site of the original earthworm cast observations (450m on the LR transect) in spring 2005. These were washed and returned to the laboratory along with sand collected from yellow dunes at LR. This sand was mixed with commercially available Kettering Loam (Boughton Loam Ltd, UK) to create five sand : loam ratios i.e. 100:0, 75:25, 50:50, 25:75, 0:100. Mixtures were put in 0.6 litre pots (n=3 replicates) and fed with excess dried and rewetted horse manure, a proven food for earthworms (Lowe and Butt 2005). Two juvenile *A. longa* (mean mass 2.05g) were weighed and then put in each pot and incubated at 15 ± 1ºC. Every 4 weeks, earthworms were inspected, weighed and food and water added to pots as required. At 8 weekly intervals, the pot contents were wet sieved to locate any cocoons, with substrate in all containers renewed as per treatment

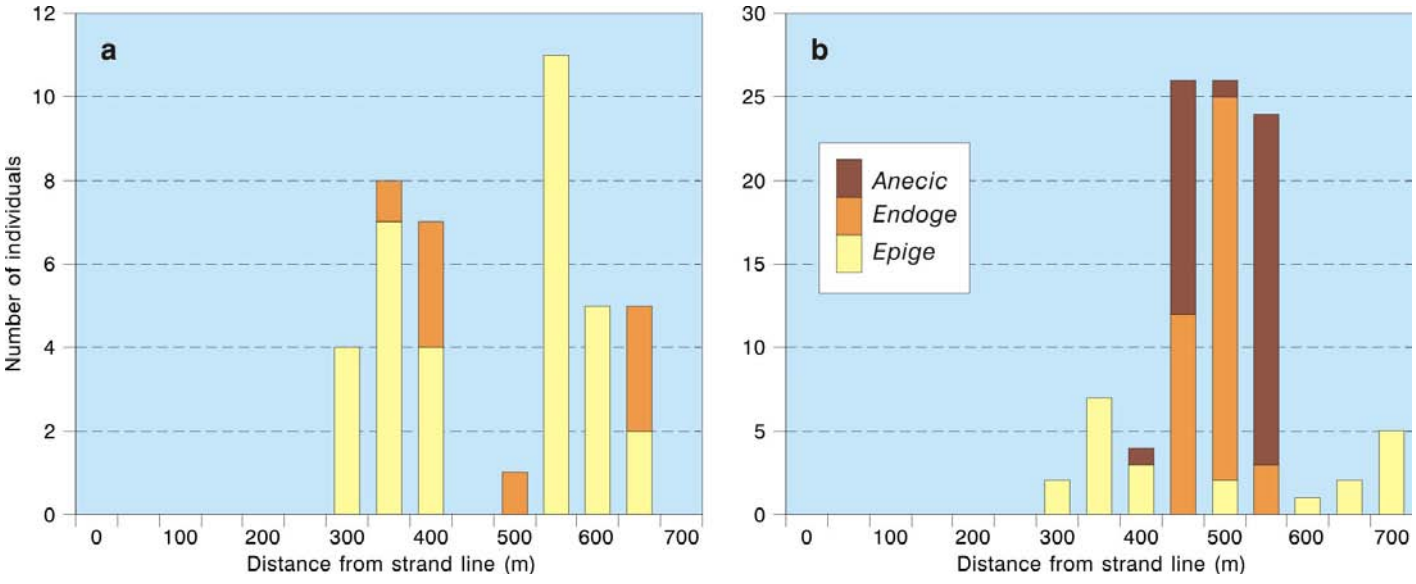

Figure 1: Earthworms assigned to ecological grouping located along transects running from the strand line (sea shore) across sand dunes at (a) Ainsdale Sandhills and (b) Lifeboat Road, Sefton Coast.

at this stage. The experiment ran for 24 weeks. A one way analysis of variance (ANOVA) was applied to laboratory results derived from changes in earthworm biomass related to sand: soil treatments.

Results

Transects

Figure 1 (a & b) shows the distribution of earthworms, with respect to ecological grouping (Bouché 1977), across the sand dune system at AS and LR respectively. On both transects, the first earthworms were encountered at 300m within a grey dune area. At AS, epigeic species, dominated by *Dendrobaena octaedra* (Savigny), but including *Lumbricus rubellus* (Hoff.) and endogeic species represented only by the green morph of *Allolobophora chlorotica* (Savigny) were present to 500m. Thereafter the species found were again dominated by *D. octaedra* but with small numbers of *Murchieona minuscula* (Rosa) and *Octolasion tyrtaeum* (Savigny). At LR epigeic species similar to those at SA were found with the addition of *Lumbricus castaneus* (Savigny) At 450-550m on the LR transect, intersection with a recreational car park took place. Here, developments have created sandy soils in raised areas which were found to be earthworm-rich (74 g m^{-2}) and contained those species previously encountered plus *Aporrectodea caliginosa* (Savigny) and *A. longa* (predominating) with smaller numbers of *Lumbricus terrestris* (L.). *L. castaneus* and *L. rubellus* were also present in and under litter of a pine shelterbelt at 700m. Biomasses of earthworms along the AS transect were low, ranging from 1.4-3.2 g m^{-2} at 300m and 700m respectively.

Earthworms (*D. octaedra*) were first encountered at 320m on the detailed transect at AS. At 340m, sampling occurred in a large dune slack, where *A. chlorotica* and *O. tyrtaeum* were found. These more detailed results did not extend the distribution of earthworms any closer to the strandline than previously found.

No significant correlations ($p>0.05$) were found between number of earthworms and measured soil properties. However no earthworms were found where the organic matter content of soil was less than 1% (across the yellow dunes, 0-300 m, on both transects).

Laboratory experiment

Growth of *A. longa* in different proportions of sand is shown in Figure 2. Growth rates over 24 weeks were significantly different ($p<0.05$). In 25, 50 and 75% sand, all earthworms survived, but 2 died after 16 weeks at 0% and 5 (of 6) by 24 weeks in 100% sand. Of the survivors at 24 weeks, all were fully mature except 3 in 75% sand and the surviving individual in 100% sand. During the final 16 weeks a total of 11, 12, 9 and 5 cocoons were produced by *A. longa* in the soils containing 0, 25, 50 and 75% sand respectively.

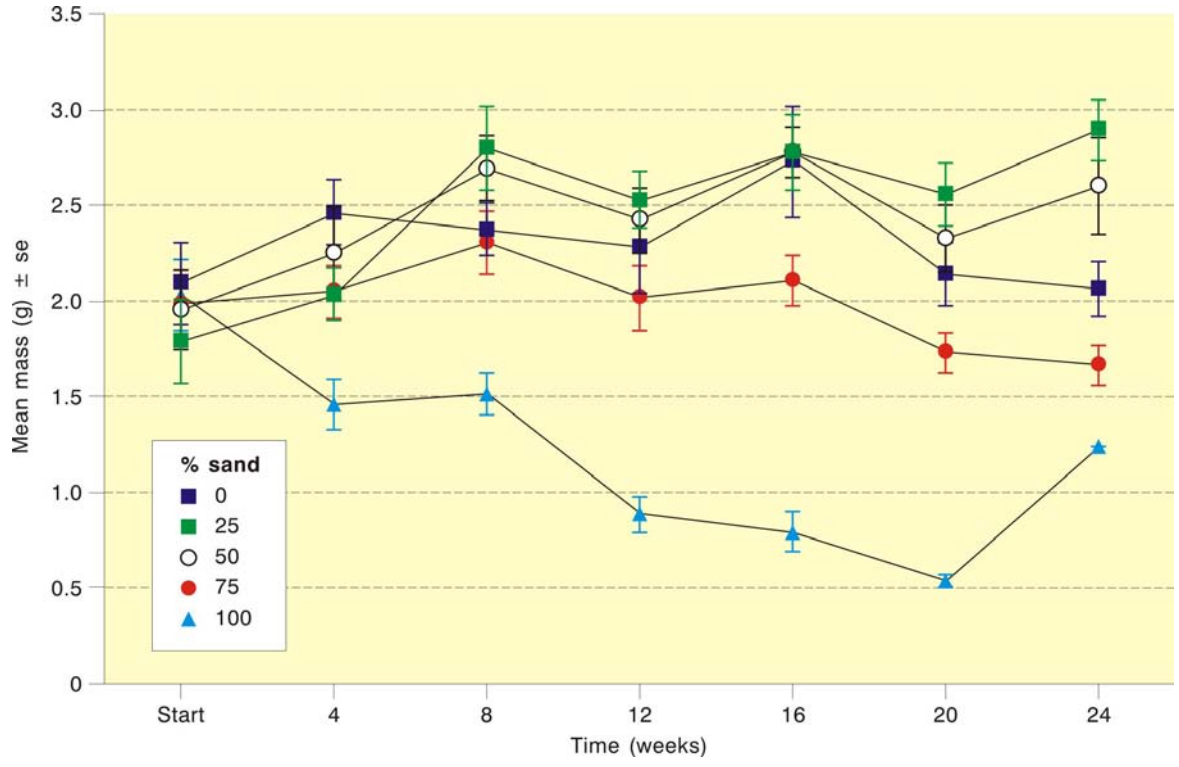

Figure 2: Mean growth of Aporrectodea longa, collected from the Sefton Coast sand dune system, at 15°C in a sand/loam substrate.

Discussion

Earthworms were located in the sand dune system but only where some stabilisation had occurred and organic matter was present, giving the soil a darker (grey) appearance. Boyd (1957) recorded a total of eight species from dunes in Scotland, which are very similar to those reported here. Exceptions are mainly derived from the anthropochorous species (*sensu* Enckell and Rundgren 1988) at Lifeboat Road, where natural dynamics of soil and vegetation development have been disrupted. Generally, a predictable succession of epigeic and endogeic species was observed, which was similar to records from the Hebrides (Boyd 1957) with *L. rubellus, D. octaedra* and *D. rubidus* dominating, but percentage contribution of these species differed across islands as it did here in the grey dunes of the two main transects.

In a sand dune system earthworm community development is strongly linked to soil development and the type of primary succession observed is similar to that of abandoned industrial areas (Pižl 2001). On Hebridean dunes, Boyd (1957) found that moisture content in slacks or more particularly below dung pats, with added organic matter, was a critical factor in what he described as "an austere environment" for earthworms. Colonisation of sand dune ecosystems by earthworms may be a lengthy process and one mediated particularly by soil organic matter and soil moisture content. Human disturbance, as detected here within the car park area at Lifeboat Road, disrupts successional development and permits existence of deep burrowing species and may have even led to their direct introduction. Stochastic events may also be important and be a function within survival strategies of pioneering epigeic earthworms.

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