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Original article

Earthworms and mesofauna from an isolated, alkaline chemical waste site in Northwest England

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ABSTRACT

Post-industrial sites across Europe may have developed over periods in excess of a century, often leading to poor nutrient soils with noxious constituents and extreme pH values. One such site, Nob End (Bolton, UK), a toxic tip created in the 1800s from a sodium carbonate factory, represents an "island of alkalinity in an acidic sea" where the weathering process (from pH 12) has provided a suitable environment for a rich alkali-loving flora and hence, deserving its designation as a Site of Special Scientific Interest. Despite their importance, the belowground communities have not been investigated and for this reason, in this study, we explored how soil macro- and mesofauna communities respond to extreme pH values in a system that has also experienced recent changes in management practices. As expected, earthworms, mites, insects and woodlice numbers were significantly higher and the community diversity enriched at the (now pH 8) alkaline sites, whereas in areas where acidic boiler waste was historically deposited, enchytraeids, collembolans and dipteran larvae populations dominated the soil communities. Surprisingly, site management (cutting back of scrub) in the alkaline soil areas had a significant positive effect on soil macro-fauna by promoting numbers and biomass, but severely reduced the microarthropod populations. A transect investigation across an increasing pH gradient (from 4.5 to 8.0) was mirrored by a rise in earthworm numbers and species richness. Earthworms were further investigated surrounding the site, seeking potential sources of colonisation, with the majority of species at Nob End also present in adjacent non-industrially-influenced areas. This work demonstrates that soil fauna can ultimately colonise extreme edaphic conditions and these extreme environments have not prompted the development of specific faunal communities. As management of above-ground communities significantly influenced soil invertebrate communities, this could represent an important restoration practice to improve soil structure and fertility at this polluted site.

1. Introduction

The northwest of England has an historic connection to industrial processes resulting in industrial wastelands with heavily contaminated soils. Many of these areas were despoiled during the working life of the given industry, with a large number of derelict sites now rehabilitated to some degree [1,2]. However, some sites were not reclaimed, but following ecological survey were deliberately left relatively untouched as they proved to be floristically rich and offered distinct edaphic conditions compared with more natural surrounding soils. During the nineteenth century, at Nob End (near Bolton, UK), Leblanc waste from the chemical synthesis of sodium carbonate (washing soda) was often dumped close to the production site to depths of 10 m or more. This process was in operation at a number of sites in the northwest of England to service the local cotton industry [3]. However, this site is now the only one that remains in England, and has been designated a Site of Special Scientific Interest (SSSI) for its nationally rare plant species, including a rich variant of a tall fescue-coltsfoot community and several species of orchids, [4,5]. Little attention, however, has been paid to invertebrates, except for unpublished investigations of molluscs [6] and brief mention of Lepidoptera by Shaw and Halton

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[7], with no known records of soil-specific fauna. In addition, Richardson [8] suggests that grassland sites derived from urban developments, with e.g. soils of extreme pH, cannot be defined using botanical criteria alone and that survey of invertebrates is required for any selection as priority habitat for conservation. So, investigations of soil fauna were undertaken, focusing specifically at ecosystem engineering groups [9,10] that might have direct actions on soil development through provision of ecosystem services [11].

The aim of this work was therefore to document soil fauna in the grass-covered, weathered Leblanc waste at Nob End. Specific objectives were: (i) to describe earthworm and mesofauna communities at areas of varying pH values; (ii) to link invertebrate community composition and structure to known site history and current management practices; (iii) to seek potential areas that could represent the most likely pool for earthworm colonisers of this heavily contaminated soil.

2. Materials and methods

2.1. Study site

Nob End, Farnworth, is located 4.5 km from Bolton, within Moses Gate Country Park (53° 33' 08″ N, 02° 22' 47″ W) and owned and managed by Bolton Metropolitan Borough Council. This 8.8 ha site, lying at the confluence of the Rivers Croal and Irwell, consists of a plateau with 20 m high steep sides [5], has been extensively surveyed floristically for its orchid-rich flora [7,12].

On site, the soil-forming substrate (wastes from the Leblanc process), known locally as “galligu”, was originally caustic when dumped, with a pH of 12 and largely consisted of calcium sulphide mixed with calcium oxide and unburned coal. Deposition of the waste material continued for a period of around 50 years until the 1880s, after which the site was abandoned due to its extremely noxious nature.

Over the intervening years, weathering from the surface has occurred to provide a novel substrate in this locality. The uppermost organic-rich horizon of the soil extends to a depth of 5–10 cm. Below this, there is an orange-coloured mineral soil developed from the weathered Leblanc waste, extending to a depth of 1 m in places. The orange colour of the sub-surface horizon is derived from iron impurities of unknown origin [7]. Deeper down, un-weathered grey/blue galligu is present – this colour derived from reduced iron compounds.

2.2. Soil fauna communities in selected areas under contrasting vegetation and different management

Three areas were selected for sampling (Fig. 1) based on relevant material available [5,7,13] and consultation with the Site Manager from Bolton Council, with respect to historical events and specifically more recent management:

UNMAN: An unmanaged base-rich area where scrub (Hawthorn - *Crataegus monogyna* - in particular) had encroached over the open calcareous vegetation. Ground flora was diverse, herb-rich with a reduced grass presence. Examples included carline thistle (*Carlina vulgaris*), purging flax (*Linum catharticum*) and common centaury (*Centaurium erythraea*).

MAN: A managed base-rich area that had a similar flora to the unmanaged area, except that scrub had been cut back and removed (since the 1990s) to leave more open grassland. Some herbicides had also been applied here, and work between 2004 and 2007 involved applying Tricloyr, diluted with diesel, directly to cut hawthorn stumps by paint brush and one area of bramble *(Rubus fruticosus)* (of approx. 10 m^2) was weed-wiped in 2005 using glyphosate [14].

CAL: A *Calluna*-rich grassland area where boiler waste was historically dumped above the alkaline Leblanc waste [4,7] and resulting acid soils provided conditions where ling heather (*Calluna vulgaris*) is able to grow. Other typical vegetation here is mat-grass (*Nardus stricta*) and wavy hair-grass (*Deschampsia flexuosa*) – National Vegetation Classification - U2a [15]. In some of the acidic areas, no vegetation is present above a grey, granular substrate.

In October 2008, at each of the 3 locations (Fig. 1) soil samples were collected from any distinct horizons, organic (0–10 cm) and mineral (10–20 cm). Samples from the upper horizons were analysed [16] in the laboratory for moisture content, organic matter content (loss on ignition) and pH. Samples of the orange-coloured mineral material (in the alkaline sites) had pH determined.

Earthworms were collected by a combination of hand-sorting and chemical expulsion from an area of 0.1 m^2, delineated by a quadrat. Firstly the soil was dug out to 0.2 m and the material was hand-sorted for earthworms and thereafter, 5 L of a mustard vermifuge (5 g L^{-1}) were poured into the resulting hole and monitored for emerging earthworms [17]. Five replicates were sampled at each location to minimise damage to the area. In the laboratory, collected earthworms, preserved in 0.4% formaldehyde, were identified to species, following the nomenclature of Sims and Gerard [18], and had biomass determined.

Soil samples for mesofaunal extractions were collected using an auger (diameter 10.5 cm) to a depth of 0.15 m. These were extracted from the corer and carefully sealed in plastic bags to prevent any chance of escape and kept intact for mesofauna extraction ($n = 10$ replicates per location). Each sample was divided into two and each half used to extract either enchytraeids and dipteran larvae using a modified wet funnel method [19] or microarthropods (i.e. mites, collembolans, millipedes, spiders, etc.) using Tullgren [20] extraction. The extracted animals were allocated to groups using a stereoscopic microscope and reported as total numbers m^{-2}.

2.3. Change in soil community composition along a pH gradient

Further sampling for earthworms was undertaken in September 2009 along a line transect laid between the two “unmanaged” areas representing two extreme pH values, i.e. the *Calluna*-rich (CAL) and the scrub-rich area (UNMAN) from the previous year (see Fig. 1). Earthworm samples ($n = 3$, as in section 2.2) were collected every 10 m over a distance of 110 m. This line transect was across a grass-dominated area, but intercepted a patch of bramble and some hawthorn scrub. It traversed an area that was historically the location of the Prestolee Alkali Works [13], where the ground was broken and contained elements of rubble.

2.4. Earthworms from surrounding unaffected habitats

Additional soil sampling for earthworms was performed at positions labelled 1–5 on Fig. 1 in October 2009. These were located across the “necks of land” that attach Nob End directly to the surrounding countryside, as the River Croal to the west, the River Irwell to the SE and the disused Manchester, Bury and Bolton Canal to the north make this site a near-island. Site 1 was a sycamore (*Acer pseudoplatanus*)-dominated woodland, with areas of dressed stone providing evidence of past industrial use; site 2 was immediately beside the River Irwell with some willow (*Salix* spp.) present; site 3 was within path-side mown grass, adjacent to the canal; 4 was in hawthorn and elder (*Sambucus nigra*) woodland adjacent to a weir on the River Croal; and 5 was path-side, close to a stand of invasive Japanese Knotweed (*Fallopia japonica*).