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SUSTAINABILITY OF EARTHWORM COMMUNITIES IN TRANSLOCATED GRASSLANDS: THE FIRST DECADE AFTER RUNWAY 2 CONSTRUCTION AT MANCHESTER AIRPORT

Construction of a second runway at Manchester Airport led to a £17 million environmental mitigation package concerned with habitat restoration, relocation of species and translocation of valuable habitat components. One major concern was for legally protected vertebrate species (Meles meles and Triturus cristatus) affected by these works. To this end, a monitoring programme was established to assess earthworm communities (potential prey for the protected animals) within areas of translocated grassland. Major upheaval of soils can have negative consequences on soil biota, so integration of translocated turf with receptor subsoil was essential. The work reported here relates to continued monitoring of 4 specific translocated grassland areas. Digging and hand sorting of soil from replicated plots of 0.1 m^2, followed by vermifuge (mustard) application was used to extract earthworms. Monitoring took place on an annual basis during the same week of October from 1998-2007. Twelve species of earthworm were located, representing three ecological groups. Recorded densities ranged from 4 to 427 earthworms m^{-2}. Similarly, biomasses ranged between 2 and 110 g m^{-2}. Significant differences can be ascribed to type of translocation undertaken (turf transfer or soil alone) and also between grassland sites (low lying, slopes, hillocks) and across years. Meteorological data suggests that the most significant environmental aspect during the decade of monitoring was rainfall, having its greatest negative effect on earthworms in 2003. Earthworm community composition has been dynamic over this time period.

Keywords: badgers, earthworms, great crested newts, habitat, translocation

I. INTRODUCTION

Development of a second runway at Manchester Airport led to a number of impacts on the locality, which included the loss of some existing hedgerows, trees and ponds within 210 ha of prime wildlife habitat of the River Bollin valley [Butt et al. 2003, Marshall et al. 1997]. However, the runway scheme also included environmental enhancement measures to mitigate for these and other developments. One such measure was the collection and translocation of topsoil and species-rich, grass turves to adjoining sites. One concern was for colonies of amphibians (including Great Crested Newts - *Triturus cristatus*), which

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were themselves re-located away from the runway area. In addition, several badger (*Meles meles*) clans were also moved during this operation [Kostecka and Butt 1999].

The major aim of this work was therefore to assess the density, biomass and species composition of earthworm communities within specific translocated grassland areas and assess sustainability over time, as earthworms form an important part in their diet of amphibians [Griffiths 1996] and badgers [MacDonald 1983] at certain times of the year.

II. METHODS

Each year 1998-2007, locations to the South of Runway 2 were sampled during mid-October. These areas had received grassed turves or soil from areas affected by construction activity and were ascribed a Grassland Translocation (GT) code; see below. Sampling employed standard digging and hand-sorting of soil from randomly selected areas of 0.1 m^2 followed by application of a mustard (50 g in 10 litres water) vermifuge [Butt 2000].

GT1 (Nat. Grid Ref. SJ 814 831) is located on a sloping roadside bank consists of two distinct parts. One where turves were brought intact and another where only loose soil was imported. (Replicates: n=5 for each half of the site.)

GT2/3 (Nat. Grid Ref. SJ 824 838) is close to constructed ponds and existing woodland and was created in two parts. One consists of "hummocks", raised to 3 m above the surrounding area, containing voids, which act as potential refugia for amphibians. The hummocks were covered with a layer of translocated grass turves. The second translocated area was lower lying and initially subject to inundation by water. These wet "hollows" were created with turves of similar origin (Replicates: n=10 for each of the 2 parts of this site).

GT4 (Nat. Grid Ref. SJ 812 823) is within the River Bollin valley and consists of species-rich translocated turves. As with the other sites, any soil on site was stripped away to the sub-soil level before translocation of turf occurred. (Replicates: n=10.)

On collection, all animals were preserved in 4% formaldehyde for laboratory-based identification. Earthworms emerging from deeper burrows after vermifuge application, were added to those collected by hand-sorting of soil. The soil was returned to the hole after inspection and the sampling point restored to as near pre-sampling conditions, as possible.

Specimens were examined and identified to species level, using the nomenclature of Sims and Gerard (1999). Earthworm masses were also recorded and each individual was allocated to an age category; simplified as "adult" (fully clitellate) or "juvenile". Numbers and masses of earthworms collected were compared using Mann Whitney tests at: (a) Sub-sites of GT1 where different methods of translocation had occurred; (b) GT2/3 where hummock and hollow areas had been created. Similar comparisons were also made with results obtained in 2007 with those from the initial sampling in 1998. Comparisons were also made of species contribution to the overall earthworm community.

III. RESULTS

Over the first 10 years of sampling, 12 species of earthworm were recovered across the sites representing all 3 ecological groups. These included surface dwelling (epigeic) species *Eiseniella tetraedra* (Savigny), *Lumbricus castaneus* (Savigny), *Lumbricus rubellus* (Hoffmeister*)* and *Murchieona minuscula* (Rosa); shallow working (endogeic) species *Allolobophora chlorotica* (Savigny) - both green and pink morphs, *Aporrectodea caliginosa* (Savigny), *Aporrectodea icterica* (Savigny), *Aporrectodea rosea* (Savigny)*, Octolasion cyaneum* (Savigny) and *Octolasion tyrtaeum* (Savigny); and two deep burrowing (anecic) species *Aporrectodea longa* (Ude) and *Lumbricus terrestris* (L.). The mustard vermifuge was successful at only extracting the earthworms *A. longa*, *L. terrestris and O. cyaneum*.

Earthworm densities at the given sites were initially (1998) in the region of 36-250 ind. m^{-2} (lowest levels at the soil only translocation) and after 10 years these were 85-236 ind. m^{-2} (see fig. 1). In 2003, a major crash in community densities was recorded across all of the GT areas (with figures of 4 – 151 m^{-2} recorded). The earthworm biomass results (not shown graphically) mirrored those of community density initially ranging from 10-58 g m^{-2} (1998) and rebounding to 37-105 g m^{-2} (2007) after a similar decline in 2003 (2-29 g m^{-2}).

The highest earthworm density (427 ind. m^{-2}) was recorded from GT4 in 2001 (with a corresponding biomass of 110 g m^{-2}). The lowest density recorded was 4 earthworms m^{-2} (2003) from GT1, but from an area where soil only was translocated. During sampling, generally more juveniles than adult earthworms were recorded across all areas.

After a period of ten years, combined figures for all sites were not significantly different from those initially recorded ($p>0.05$).

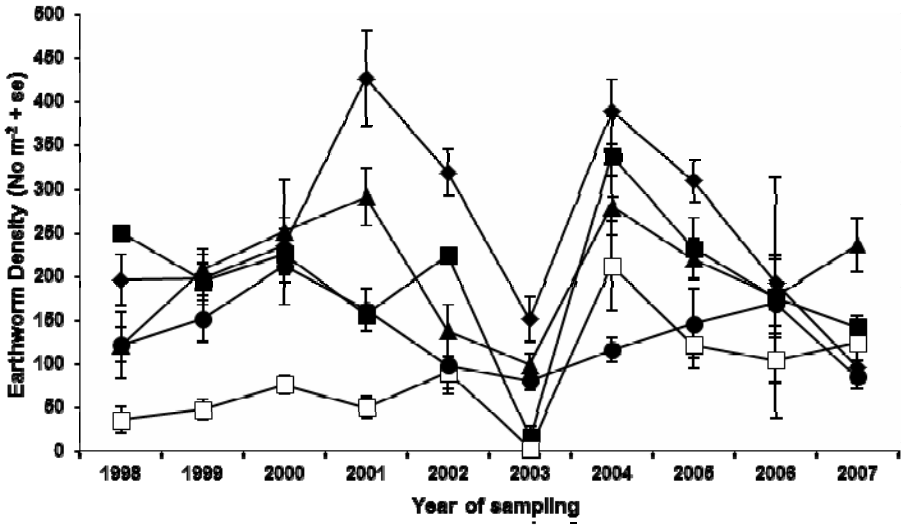

Fig. 1. Development of earthworm community densities in Grassland Translocation sites near Runway 2 at Manchester Airport: 1998-2007 (■- GT1 Turf; □- GT1 Soil only; ▲- GT2/3 Hummocks; ●- GT2/3 Hollows; ♦- GT4)

Rys. 1. Rozwój zgrupowania dżdżownic w odnowionych siedliskach łąkowych w pobliżu 2 pasa startowego lotniska w Manchester: 1998-2007 (■ - GT1 darń □ - GT1 tylko gleba, ▲ - GT2/3 wzniesienia; ● - GT2/3 obniżenia; ♦ - GT4)

Transfer of soil only to GT1 led to a low initial density of earthworms with an impoverished number of species (not shown), but this improved over the reported ten years, until numbers and biomasses with turf transfer at GT1 were almost undistinguishable.

To illustrate the way in which the earthworm community at any one of these translocation sites is dynamic, results over the given decade of recording are shown for the hollows of GT2/3 (Fig. 2). As depicted, the majority of earthworms were represented by 5 species: *A. chlorotica*, *A. caliginosa*, *A. longa*, *A. rosea* and *L. rubellus*. Some species such as *E. tetraedra* were only represented in 1999, 2000 and 2005 (this was the only GT site where this species was found). Equally, *L. castaneus* was only present in 1999. Although present throughout the survey period, the proportion of *A. chlorotica* (green morph) generally decreased over time at the hollows of GT2/3, whereas *O. cyaneum* and *O. tyrtaeum* were only found more recently.

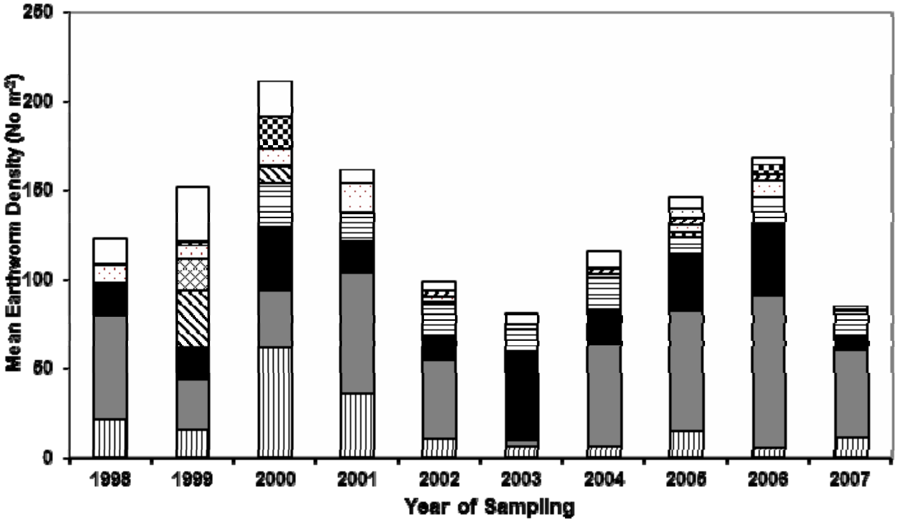

Fig. 2. Earthworm density and species composition at "Hollows" of GT2/3 over the monitoring period. The majority of earthworms are represented by 5 species: *A. chlorotica* (vertical lines); *A. caliginosa* (solid grey); *A.longa* (solid black); *A. rosea* (horizontal lines) and *L. rubellus* (stipuled). The solid white represents unidentified juvenile *Aporrectodea* spp. *E. tetraedra* was only represented in 1999, 2000 and 2005 (diagonal stripes).

Rys. 2. *Zagęszczenie i skład gatunkowy dżdżownic w "obniżeniach" z GT2/3, w okresie monitorowania. Dżdżownice są reprezentowane głównie przez 5 gatunków: A. chlorotica (paski pionowe); A. caliginosa (kolor szary); A. longa (czarny); A. rosea (paski poziome) i L. rubellus (kropki). Stałą biały reprezentuje niezidentyfikowany nieletnich Aporrectodea spp. i E. tetraedra reprezentowany był tylko w 1999, 2000 i 2005 roku (ukośne paski)*

L. terrestris was found at all of the GT sites during the given sampling period but was consistently represented by a low percentage of the total earthworm community (<5%). By contrast, the other deep burrowing species (*A. longa*) was well represented and often comprised a high percentage of the total earthworm community density and biomass. During the period of monitoring, more juveniles than adult earthworms were generally recorded from all GT areas.

Significantly more earthworms were found on the hummocks of GT2/3 than in the hollows ($p<0.05$). An equal number of species ($n=10$) was found at each site, with no *E. tetraedra* on the hummocks and no *M. minuscula* in the hollows. *A. icterica*, located more recently in both parts of GT1, was not found at GT2/3.

GT4, grazed throughout the monitoring period, revealed all species mentioned above except, *A. icterica*, *E. tetraedra* and *O. tyrtaeum.*

Sampling on the hummocks of GT2/3 in 2007, revealed a healthy, juvenile, Great Crested Newt (found unharmed) at the bottom of a sample pit. This animal was moved to the base of the hummock and crawled into an available opening.

IV. DISCUSSION

Monitoring results over the first decade of this programme suggest that the mitigation scheme has been a success in terms of translocating sustainable earthworm communities in grassland turves. Early results [Butt et al. 2003] showed numbers and masses had either increased or remained relatively stable after four years. Over the intervening six years, a further three earthworm species have been recorded: namely *A. icterica*, *M. minuscula* and *O. tyrtaeum*.

Promotion for the technique of intact turf translocation over soil alone is supported by findings from GT1, where the former initially led to significantly higher earthworm densities. However, it could be argued that after ten years, colonisation of the "soil only" areas have reduced the difference. Nevertheless, to successfully move deep burrowing earthworm species such as *L. terrestris*, turf transfer may well be required. These are one earthworm species that badgers specialise in feeding upon, with Kruuk [1978] reporting that when available, adult badgers can eat 130–200 per night.

Overall earthworm community density and biomass records in the translocated grasslands fall within the range of reported figures from pastures in temperate systems using similar collection methods [Edwards and Bohlen 1996]. However, results (such as those obtained in 2003) demonstrate that extreme weather events, such as the very dry conditions of that year can lead to catastrophic declines in community densities and biomasses. Marsh [2004] describes 2003 as a period when the UK registered its driest recorded February to October interval since 1921. Nevertheless, numbers did recover very rapidly (fig. 1) and the high proportion of juvenile animals suggested that healthy, reproductively active, earthworm populations were present.

Results from the hollows of GT2/3 (fig. 2) reflect the changing nature of the given habitat, which became drier over the monitoring period. Although nearby ponds were still present in 2007, the wet grassland once dominated by rushes (*Juncus*) was no longer present. Such a change was reflected by records of the semi-aquatic earthworm *E. tetraedra* [Sims and Gerard 1999] only occurring in three of the monitoring periods, with numbers falling each time. Equally the proportion of the green morph of *A. chlorotica*, another species to favour wet conditions [Satchell 1967] had decreased over the monitored decade.

Succession of grassland to birch (*Betula*)-dominated woodland was recorded as beginning at GT1 and scrubland, dominated by bramble (*Rubus*) and hawthorn (*Crataegus*) at the hummocks of GT2/3. During the monitoring period, active management was necessary to reduce this encroachment by woody species. At GT4, cattle grazing from 1999 led to an input of dung which was accompanied by the highest recorded increase in earthworm number. *A. longa*, not initially recorded there, appeared to have entered the area from adjacent pasture where this species was present in large numbers (evidenced by surface casting). Sheep grazing, more recently, led to lower organic inputs and may have been a factor in leading to reduced community densities.

As a part of the mitigation plan, monitoring of earthworm communities close to Runway 2 will continued and permit a more complete evaluation of the outcomes from this successful translocation programme.

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TRWAŁOŚĆ ZESPOŁOW DZDZOWNIC W ODTWORZONYCH UŻYTKACH ZIELONYCH: PIERWSZA DEKADA PO BUDOWIE PASA STARTOWEGO 2 NA LOTNISKU W MANCHESTER

Streszczenie

Podczas przygotowań do budowy drugiego pasa startowego na lotnisku w Manchester przenoszono cenne komponenty siedliskowe oraz gatunki a także odtwarzano całe siedliska, wykorzystując pakiet ochronny o wartości 17 mln £. Jednym z głównych problemów było zachowanie prawnie chronionych kręgowców (Meles meles i Triturus cristatus), zagrożonych rozbudową lotniska. W celu długotrwałego monitorowania ich stanu postanowiono także oceniać populacje dżdżownic (potencjalny pokarm tych zwierząt) w obszarze odtwarzanych użytków zielonych. Ponieważ prace inżynierskie mogą mieć negatywny wpływ na faunę gleb, przy budowie pasa zastosowano eksperymentalne przenoszenie darni z warstwą podglebia. Prezentowana publikacja opisuje efekty stałego monitorowania 4 konkretnych punktów/ stanowisk odtwarzanych użytków zielonych. Poszukując dżdżownic stosowano przekopywanie gleby kilku stanowisk o powierzchni 0,1 m^2 oraz sortowanie ręczne wybranych prób oraz wypłaszanie dżdżownic z głębszych warstw roztworem musztardy. Monitorowanie miało miejsce corocznie w tym samym tygodniu października, od roku 1998 do roku 2007.
Zlokalizowano 12 gatunków dżdżownic reprezentujących trzy grupy ekologiczne. Ich zagęszczenie wahało się od 4 do 427 dżdżownic na m^2 a biomasa od 2 do 110 g m^{-2}. Istotne różnice tych wartości stwierdzono przy porównaniu wymienionych cech dżdżownic na stanowiskach gdzie przeniesiona została cała darń i sama gleba a także między siedliskami w użytkach łąkowych (w zagłębieniach, na zboczu, na pagórkach) i w poszczególnych latach. Dane meteorologiczne wskazują, że w ciągu dekady monitoringu najbardziej istotny wpływ środowiskowy dotyczył opadów, mając największy negatywny wpływ na dżdżownice w roku 2003. Stan zgrupowania dżdżownic w badanym okresie był dynamiczny.

Słowa kluczowe: borsuki, dżdżownice, traszki, siedlisko, translokacja