Institution: University of Central Lancashire

Unit of Assessment: 17 Geography, environmental studies and archaeology

Title of case study: Earthworm Applications: Harnessing ecosystem services

1. Summary of the impact (indicative maximum 100 words)

The applied use of earthworms in soil restoration, bio-monitoring, agro-ecosystems and organic waste management has had wide-reaching impact on the commercial sector and the public. A variety of commercial groups (such as the Forestry Commission and BAE Systems) have benefitted from this research in both the UK and abroad. In addition to this, earthworm research has also reached the public domain through outreach activities and media coverage. For example, this UoA was involved in a National Open Air Laboratories campaign. Our earthworm identification guide produced in collaboration with the Natural History Museum in London has now been widely distributed and used.

2. Underpinning research (indicative maximum 500 words)

This represents aspects of the Earthworm Research Group (ERG), comprising two full time staff (Butt and Lowe), alongside research students and collaborations from external associates. General earthworm survey work has been conducted across Britain and beyond, to address specific questions relating to habitat suitability but also linking with historical human activities, e.g. effects of agriculture and forestry on soils and earthworms. Focus has been on rapid recent changes and on longer term factors affecting soil properties and the influence of earthworms within these anthropogenic systems. The Island of Rum, Inner Hebrides, managed by Scottish Natural Heritage has been one focal location where the role of earthworms in soil rehabilitation has been a key element in our research.

Restoration ecology is an established research area, developed in this UoA since the mid-1990s with the specific focus of using earthworms in soil bio-stimulation. Use has been made of a patented technique (the Earthworm Inoculation Unit) to target earthworm-deficient soils such as landfill, post-industrial and ex-agricultural sites. This research utilises growth and reproduction data of soil-dwelling earthworms gathered from controlled laboratory experimentation. Once produced and inoculated into field soils, earthworms and their ecosystem service activities are monitored over time. Soil development and pedogenesis through burrowing and soil turnover are critical to biological soil restoration. The combination of earthworm species used and their interactions is also vital and soil-dependent. Water infiltration into soils is assisted through macropore (vertical earthworm burrow) creation and has been investigated using a novel technique for estimating burrow dimensions via resin-casting. Earthworm populations have also been monitored to assess their availability as food for legally protected vertebrates as a part of mitigation measures at sites where soil disruption has occurred (e.g. after development of Runway 2 at Manchester Airport).

The ability to maintain and produce (known exposure-rated) naïve earthworms is of considerable value and has led to a further research strand using earthworms to monitor bio-availability of soil contaminants. Ecotoxicology is a growing environmental concern and earthworms can act as a solution (bio-remediation) to some problems and as a monitoring tool to others. To further enhance their use, a technique was developed to permanently tag earthworms so that mark-release-recapture methods can be used to assess accumulation of contaminants. Management of organic waste materials through land spreading and the mode of incorporation into the soil by earthworms and effects on the soils are also studied. This links directly with ecotoxicological research to provide an overarching programme investigating earthworms in waste and environmental management. Equally, composting and vermi-composting have been investigated as methods for reducing volumes of organic wastes and producing useful by-products.

A further development, building on culture techniques of soil-dwelling species, has been a role within novel DNA analysis of earthworms to verify species identification and to collect data to assist construction of a “Barcode of Life Database” (BOLD).

Key researchers: Kevin Butt (Reader in Ecology) employed at UCLan since 1994; Chris Lowe (Senior Lecturer in Waste and Environmental Management): Research Fellow at UCLan (2005-2009), permanent since 2009.

3. References to the research (indicative maximum of six references)

Dupont, L., Lazrek, F., Porco, D., King, R.A., Rougerie, R., Symondson. W. O. C., Livet, A., Richard, B. Decaens, T., **Butt, K.R.** and Mathieu, J. (2011) New insight into the genetic structure of the *Allolobophora chlorotica* aggregate in Europe using microsatellite and mitochondrial data. *Pedobiologia* 54, 217-224.

Butt, K. R. (2008) Earthworms in soil restoration: lessons learnt from UK case studies of land reclamation. *Restoration Ecology* 16, 637-641.

Butt, K. R., Lowe, C. N., Beasley, T., Hanson, I. and Keynes, R. (2008) Darwin's earthworms revisited. *European Journal of Soil Biology* 44, 255-259.

Butt, K. R. and **Lowe, C.N.** (2007) A viable technique for tagging earthworms with visible implant elastomer. *Applied Soil Ecology* 35, 454-457.

Lowe, C. N. and **Butt, K. R.** (2005) Culture techniques for soil dwelling earthworms: A review. *Pedobiologia* 49, 401-413.

Butt, K. R., Nieminen, M. A., Sirén, T., Ketoja, E. and Nuutinen, V. (2005) Population and behavioural level responses of arable soil earthworms to boardmill sludge application. *Biology and Fertility of Soils* 42, 163-167.

4. Details of the impact (indicative maximum 750 words)

Commercial impact

The introduction of earthworms into degraded or newly restored land is known to promote soil improvement. However, obtaining the most appropriate species in the large numbers required can be costly and time consuming. Development of the Earthworm Inoculation Unit (EIU) technique has proved successful and has led to long-term monitoring of sites in the UK and overseas, with on-going academic and commercial activity. Specific post-industrial work took place at Calvert Landfill site, Buckinghamshire in collaboration with the Forestry Commission (FC), including £24,000 funding (Short Rotation Forestry and earthworms: Impacts and responses). Here interactions between earthworms and trees were investigated and work established that earthworm communities could influence tree growth. This has led to further collaboration (0.5 funding of a PhD) with the FC, where work examined the effects of earthworms on short rotation forestry production. In the late 1990s at the rehabilitated Hallside Steelworks site, Scotland, earthworm inoculation was used to assist incorporation of sewage sludge and colliery spoil to build new soil. This was linked with a consortium of interested groups (including Scottish Natural Heritage) and the results from here and elsewhere have convinced managers of a large disused ordnance site in Scotland to investigate potential commercial applications. The EIU technique has also been employed by MTT, Agrifood Research in Finland to enhance soil fertility in heavy clay soils. This work is on-going and links with soil drainage, cereal production and further organic waste (boardmill sludge) use in an agricultural setting. In an urban setting, composting and vermi-composting (using litter-dwelling earthworms) has been employed and funded through Lancashire Environmental Fund (Landfill Tax). A current PhD, again jointly funded by UCLan and the FC, is examining effects of earthworms on tree establishment at Thames Chase in Essex. This project once more links trees, reclaimed land, organic wastes and earthworms.

Previous soil restoration operated primarily in terms of the physical and chemical constituents of the soil and did not consider the structure and function of biological components. Following major landform corrections, development of a living soil can proceed once the major components have been brought together. Constructing soils usually requires the use of a subsoil and addition of organic matter (OM) which is not new, but the UK National Building Specifications (2011) now dictate that consideration should be given to earthworm augmentation or inoculation to enhance topsoil function. This long-awaited recognition thus takes note of research undertaken by this group through the development of the EIU technique.

Funded earthworm monitoring has also been undertaken on translocated grassland at Manchester

Airport since 1998 (including £20,000 funding from Manchester Airport). This followed Runway 2 construction and relates to the presence of food (earthworms) for legally protected vertebrates (badgers and great-crested newts). Results from this work have also influenced the recently commissioned commercial work in Scotland, to be developed 2012-27, at the Bishopton ordnance development, managed by BAE Systems (including £3,500 Initial Earthworm Survey).

Public engagement
UCLan staff have been involved in increasing the reach of this research by involving the public wherever possible. For example, we were involved in a National Open Air Laboratories (OPAL) campaign. Here, the general public were encouraged to explore the outdoors and investigate biodiversity. This was assisted through production of a simple-to-use field identification guide for earthworms in collaboration with the Natural History Museum (NHM) in London. This earthworm identification guide has now been distributed to 50,000 individuals/groups, particularly school children, and is assisting in production of distribution maps of the more common species across Britain (something currently lacking). Over 4,200 individual public surveys have been conducted and recorded on line.

Furthermore, English Heritage (Down House in Kent) permitted the ERG to sample "Darwin's Garden" and have allowed long-term experiments to be established, replicating those of Darwin (relating to stone burial by earthworms in Great Puckland's Meadow). This has assisted English Heritage in providing material on their activities at Down House for public education. This has also (and will) received much media coverage and links historic scientific endeavours with current research. Members of the ERG have also contributed to numerous "Bioblitz" events, where the public are exposed to biodiversity at selected natural history locations across the country. These and further aspects of the ERG work have been disseminated to the public through the media. Most notably two television programmes have allowed the research to be widely appreciated. The BBC showed a section on research undertaken in "Darwin's Garden" and a French organisation (Gedion TV) featured even lengthier exposure of the group in a documentary entitled "Superworm".

5. Sources to corroborate the impact (indicative maximum of 10 references)

National Building Specifications Ltd, August 2011.
Topsoil and Soil Ameliorants (Q28). http://www.thenbs.com/
This document makes specific reference to earthworm enhancement and inoculation and the "earthworm inoculation unit" technique developed within this research group (section 2.23 on pages 4 and 5).

Natural History Museum/OPAL
http://www.opalexplorenature.org/node/2335 : In collaboration with David Jones from the Natural History Museum (NHM) in London and OPAL (Open Air Laboratory) an earthworm identification guide has been produced by **Lowe** (UCLan). This guide has been distributed free to the public in survey packs (n=50,000 packs) along with instructions on how to sample for earthworms. The information from these surveys is being collated by the NHM to enable distribution maps of common British earthworms to be created ((http://www.opalexplorenature.org/wormDistribution)**.**

Bioblitz events
Involvement in public awareness activities relating to rapid biodiversity assessment in Britain e.g. Lancashire Bioblitz (June 2011)
http://www.lancswt.org.uk/index.php?mact=News%2Ccntnt01%2Cdetail%2C0&cntnt01articleid=168&cntnt01returnid=15

Recent television coverage
1) http://www.open.edu/openlearn/body-mind/ou-on-the-bbc-jimmy-doherty-darwins-garden-apes-and-men
A 2009 BBC programme "Darwin's Garden" featured **Butt** relating recent findings from the ERG to Darwin's original work on earthworm Ecology, specifically the burying of large stones, at Down House, his home in Kent.

2) http://www.science-television.com/en/film/1184/super-worm/?producer=4889&PHPSESSID=6e3a9ff4d6416ec96df75f7c11faf1bc A French production "Superworm" which featured numerous research aspects of the ERG and extensively featured both **Butt** and **Lowe**.

BOLD (Barcode of Life Database)
http://www.barcodinglife.com/index.php/Taxbrowser_Taxonpage?taxid=25193 The Barcode of Life is a project to create a public collection of reference sequences from vouchered specimens of all species of life. The ERG has been instrumental in providing earthworm specimens for inclusion.

British Library Repository for web site
During 2009, a request was received from The British Library to archive the ERG website: http://www.uclan.ac.uk/erg for the Darwin 200 Collection. This has taken place and means the ERG will be remembered, for more than publications, beyond the life of the group.