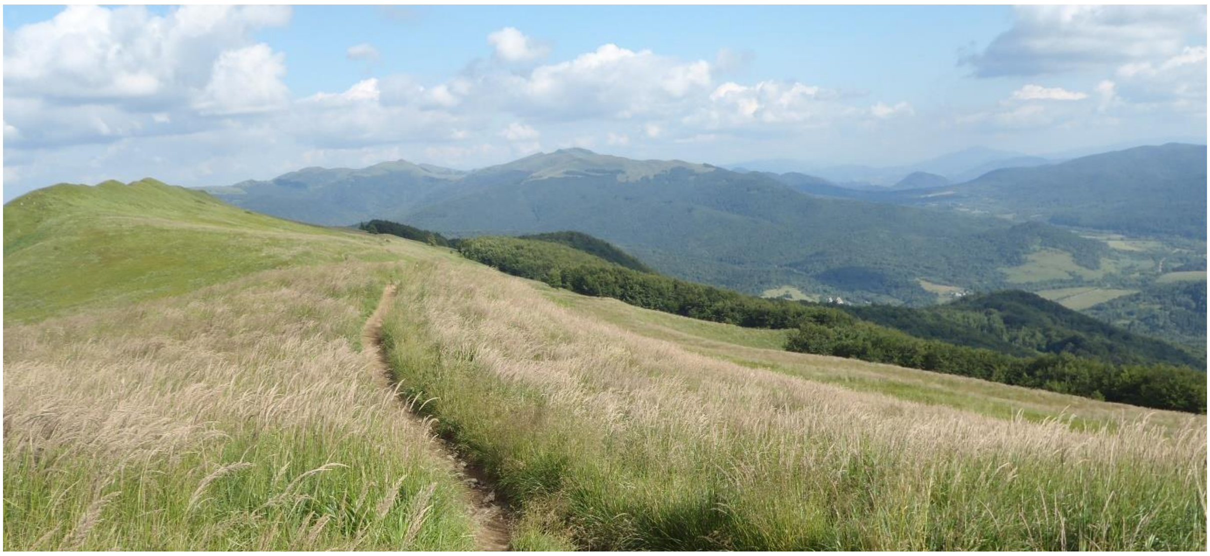
BIESZCZADY EARTHWORM CONFERENCE



University of Rzeszow, Poland
University of Central Lancashire, UK
Bieszczady National Park

Ustrzyki Górne, 3 - 4. 09. 2018

Contents

1.0 INTRODUCTION

Bieszczady is a mountain range that runs from the extreme south-east of Poland through Ukraine and Slovakia. It forms the western part of the Eastern Beskids (*Beskidy Wschodnie*), and is more generally part of the Outer Eastern Carpathians. The mountain range is situated between the Łupków Pass (640 m) and the Vyshkovskyi Pass (933 m).

Frequently Bieszczady refers only to the Western Bieszczady or even only to the part of the range lying within Poland. The highest peak of Bieszczady is Mt. Pikuy (1405 m) in Ukraine. The highest peak of the Polish part is Tarnica (1346 m).

History

Settled in prehistoric times, the south-eastern Poland region that is now Bieszczady was overrun in pre-Roman times by various tribes, including the Celts, Goths and Vandals (Przeworsk culture and Puchov culture). After the fall of the Roman Empire, of which most of south-eastern Poland was part (all parts below the river San) of Hungarians and West Slavs invaded the area.

The region subsequently became part of the Great Moravian state. Upon the invasion of the Hungarian tribes into the heart of the Great Moravian Empire around 899, the Lendians of the area declared their allegiance to the Hungarians. The region then became a site of contention between Poland, Kievan Rus and Hungary starting in at least the 9th century.

This area was mentioned for the first time in 981, when Volodymyr the Great of Kievan Rus took the area over on the way into Poland. In 1018 it returned to Poland, 1031 back to Rus, in 1340 Casimir III of Poland recovered it.

Bieszczady was one of the strategically important areas of the Carpathian mountains bitterly contested in battles on the Eastern Front of World War I during the winter of 1914/1915.

Up until 1947, 84% of the population of the Polish part of the Bieszczadzkie Mountains was Boyko. The killing of the Polish General Karol Świerczewski in Jabłonki by the Ukrainian Insurgent Army in 1947 was the direct cause of the replacement of the Boykos, the so-called Operation Vistula. The area was mostly uninhabited afterward. In 2002, then president Aleksander Kwaśniewski expressed regret for this operation.

In 1991, the UNESCO East Carpathian Biosphere Reserve was created that encapsulates a large part of the area and continues into Slovakia and Ukraine. It comprises the Bieszczady National Park (Poland), Poloniny National Park (Slovakia) + Uzhansky National Nature Park (Ukraine). Animals living in this reserve include, among others, black storks, brown bears, wolves and bison.

Fauna and flora

The characteristic feature of the Bieszczady natural environment is – different than in the neighbouring mountains – the layering of the altitudinal zonation. In the Bieszczady mountains there are three layers:

- lowland layer of foothills and valleys of up to 700-800 m above the sea level
- montane level reaching a height of up to 1150 m above the sea level
- alpine level, which is a pasture, i.e. the accumulation of subalpine and alpine flora, spread from the upper line of the forest to the highest peaks.

The flora of Bieszczady has about 900 species, including 300 species of lichens, around 250 species of mosses, 20 species of slime molds and a large number of fungi species. There are 27 species of endemic plants here, too.

The Bieszczady fauna boasts 25 species of fish, many species of amphibians (including the fire salamander and Alpine Newt), and reptiles (including the sand lizard, *Vipera berus* or the common *European viper*, smooth snake and *Aesculapius* snake), about 200 species of birds (including *Alpine accentor*, water pipit, golden eagle, black vulture, eagle owl (species threatened with extinction), rock thrush, and increasingly more common near the rivers – the black stork), and finally, 51 species of mammals (including brown bear, bison, lynx, wolf, wildcat and red deer).

The region of Bieszczady consists mainly of forest, which covers over 70% of the area. The predominant species is the beech, which accounts for approximately 48% of all trees, followed by fir, grey alder and pine, the latter mostly planted artificially.

Other species that can be found here are the spruce, hornbeam, sycamore, larch and birch.

What proves the uniqueness of the Bieszczady nature are the many forms of the legal protection of these areas. The Bieszczady mountains are a part of the International Biosphere Reserve “Eastern Carpathians”, and a lot of the area was incorporated into the Bieszczady National Park. Additionally, in the National Park’s buffer zone there is the San Valley Landscape National Park and Cisna-Wetliński Landscape National Park.

Bieszczady National Park

Bieszczady National Park is the third largest national park in Poland, located in the podkarpackie voivoideship, near the borders with Slovakia and Ukraine. It is the only place amongst the Polish mountains with such unusual altitudinal zonation where montane level transforms into subalpine zone, called pastures.
Main qualities of the Park are:

- the natural forms of landscape of the Eastern Carpathians
- the parts of the Carpathian primeval forest
- unique plants on the pastures
- well-preserved raised bogs
- East-Carpathian and Alpine plant species
- rare and endemic species of invertebrates
- conservation areas of large mammals and birds of prey
- the traces of material culture

Bieszczady National Park is relatively frequently inhabited by the species that are now considered endangered or rare in other parts of Europe. Native populations of large predatory mammals: bear, wolf and lynx are particularly valuable elements of the local environment. Among the large herbivores the deer beats other species in terms of numbers. Its population was estimated to be 5-7 individuals per 100 ha.
In the late 1960s, the bison was reintroduced in Bieszczady. This species easily adapted to the local conditions and currently the bison numbers in Bieszczady reach 300.
In Bieszczady there are also roe deer and wild boar. And the unequivocal success of the Park was reintroduction of the beaver to the area. The Park also carries out the conservation breeding of the old, now dying out Hutsul horses.
Bieszczady are characterised by a specific altitudinal zonation. It lacks the alpine level's spruce forests and mountain pine. This is why three zones have been distinguished: the foothills (up to 500 m above the sea level), lowland layer (up to 1150 m above the sea level) and the pastures level. The highest peak of the Polish Bieszczady is Tarnica (1346 m above the sea level). The Park is located over 600 m above the sea level and because of that it contains the greater land of valleys, lowland layer and the pastures level, spreading at 1150 m above the sea level to the highest peaks. Lowland layer is occupied mainly by the forests of beech and fir, beech and sycamore, alder spruce and fir. Above the upper limit of the forest the pastures are spreading, ending with very picturesque smaller rocks and large rocks rubble fields.
Bieszczady National Park protects the parts of the East-Carpathian wildlife in the Polish Bieszczady. Following a detailed valuation of natural resources, the Park zone and its buffer zone were established. Strict protection zones cover approximately 70% of the Park, and the rest is a zone of active/ buffer and/or landscape conservation. Landscape National Parks in the buffer zone are a natural barrier protecting the Bieszczady National Park. It is a vast area of high natural value, where the extensive human management is allowed.
The current mission of the Park is – except the protection of the most precious natural resources – the creation of a policy for sustainable development on a much larger area, including the Slovak and Ukrainian parts of the International Biosphere Reserve "Eastern Carpathians".
Bieszczady National Park is located on the Eastern external border of the EU, and thanks to its unique beauty it attracts growing interest from the citizens of the entire European Union, which in its natural resources has no such interesting areas.

San Valley Landscape National Park

San Valley Landscape National Park covers an area of 28 718 ha and protects the picturesque valley of the river San between its source and the Solina lake. Natural richness of the park is due to the high level of forestation – approximately 80%. The Park is dominated by the lowland layer because most of the land is located over 500 m above the sea level.
The Park was created to protect one of the most beautiful Polish rivers – San. The forest area is mostly made up of large montane complexes of Carpathian beech, of which half is hundred years old (and older) forest wilderness.
The forest landscape is also diversified: beautiful meadows and raised bogs, as well as areas of the spontaneous vegetation succession in the abandoned Boyko villages add to the variety of the region.
The Park protects seven nature reserves: Zakole (5,25 ha), Tarnawa (34,40 ha), Litmirz (13 ha), Łokieć (10,28 ha) Dźwiniacz (10,51 ha), spring Śnieżyca in Dwerniczek (4,94 ha), S. Myczkowski Hulskie and the Krywe (511,73 ha). Within the Park are preserved numerous relics of the past, including Boyko Orthodox church in Smolnik near the San river, Orthodox church in Chmiel, ruins of the Orthodox churches in Hulskie and Krywe, and the remains of the graveyards with historic gravestones.

Nature reserves

„Dźwiniacz" Nature Reserve - this bog nature reserve's total area equals 10,51 ha. It is located near the upper San river, in the former Dźwiniacz village, near another nature reseve: "Łokieć". It is a well-developed raised bog with a closed ecosystem, 55 plant species and 11 species of moss. The peculiarity here is a few patches of bog forest with a dominant spruce and rare plants, such as sundew and clumps of marshes.

„Litmirz" Nature Reserve - bog nature reserve with a total area of 13 ha, located near the Litmirz stream, where it meets the river San, in the former village of Tarnawa Wyżna. The raised bog is protected, along with richness of plants and spruce-beech forest, where the phenomena of vegetative reproduction of the spruce occurs. Great landscapes and wilderness replacing the depopulated villages after the World War II dominate in this area.

„Łokieć" nature reserve – peatbog nature reserve of total area of 10,28 ha, located in the upper bend of the river San in place of the former Łokieć village (now Dźwiniacz Górny). In the area of the raised bog there are 56 vascular plant species, and 7 species of mosses are under protection. Additional attraction are the sedges formed into rings, and a belt of haircap moss of high density, surrounding the bog.

„Tarnawa" nature reserve – of total area of 5,25 ha, it consists of two peatbogs divided by the stream on the meadows, near the upper San river, in the former Tarnawa Niżna village. The smaller bog has no trees, but the larger one, beautifully raised, has the only natural accumulation of the Scots pine in Bieszczady. In the swamp forest there is a rich peatbog flora with birch and spruce, and the real curiosity here is a round-leaved sundew.

„Zakole" nature reserve – of total area of 5,25 ha, it is located in a narrow bend of the upper San river, floating around Łysania, near the Smolnik village. From here one can start a trip around the peatbog reserves located in the upper San valley in the San Valley Landscape National Park. Raised bog owes its charm to the picturesque surroundings and precious flora that can be found here – the latter includes tussock cottongrass, marsh, bog bilberry, cranberry and bog rosemary.

„Hulskie" nature reserve – total area of 189,87 ha; it is one of the most interesting forest reserves in Bieszczady. It protects the best-preserved old trees of the Carpathian beech. The nature reserve is named after Stefan Myczkowski.

„Krywe" nature reserve – its total area is 511,73 ha. The landscape reserve with a partial ban of entering, to protect and preserve a part of the San valley in the Otryt mountain range with many plants' accumulations and rare species of plants and animals, including Aesculapius snake – the rarest of the Polish reptiles and the biggest snake species in Poland.

„Spring Śnieżyca in Dwerniczek" nature reserve – the nature reserve's total area is 4,94 ha. A very rich growth of the spring snowflake of the Carpathian variety has been set up under the legal protection here. Spring snowflake grows on the meadows. The main protection reason for this nature reserve is this being a floral reserve of herbaceous plants and shrubs, and the type of environment here is of coniferous forests and mountain foothills.

By arranging this conference, with researchers from the University of Rzeszow (UR) and University of Central Lancashire (UClan), a synergy should be discovered. We have the opportunity to interact and discuss our different research avenues and see if these can (re)cross so that we may be able to develop existing areas, or explore new topics that utilise our expertise in the field of earthworm research. Much has already been achieved with respect to basic earthworm biology and ecology, plus specific topics examining the actions of earthworms on organic materials or in soil-related situations. However, we are sure that in formal sessions, and in less formal settings, we will have the chance to envisage new ways of bringing the PERG from UR and the ERG from UCLan closer together (potentially in Bieszczady and perhaps further afield).

Thanks are offered to the University of Rzeszow and Bieszczady National Park (BNP) for help in hosting costs of this conference and providing assistance with logistics.

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2.0 CONFERENCE PROGRAMME

02.09.18 Day I

Visit to the campus of the Faculty of Biology and Agriculture at Rzeszow University;
Visit to the Natural History Museum in Ustrzyki Dolne;
Presentation of the dark sky in Ustrzyki Górne (depends on cloud conditions);
Integration evening.

03.09.18 Day II

(Chaired by Joanna Kostecka and Kevin R. Butt)

Generic Presentations

Representative of the Management of Bieszczady National Park: Chosen aspects of biodiversity protection.

Joanna Kostecka: Polish Earthworm Research Group (PERG) - chosen activity from field studies to sustainable waste management and taking part in the Preparatory Committee for International Earthworm Industry Alliance.

Kevin Butt: UClan's Earthworm Research Group (ERG) – background, current projects and future directions.

Specific Presentations

Mariola Garczyńska: Vermicomposting of chosen agricultural organic wastes.

Grzegorz Pączka: Effect of vermireactor's modifications on the welfare of earthworm *Eisenia fetida* (Sav.) and the efficiency of vermicomposting of selected organic waste.

Anna Mazur-Pączka: Community structure of earthworms in four types of beech wood *Fagetum carpaticum* in the Bieszczady National Park (south-eastern Poland).

Agnieszka Podolak: Comparison of body masses and fecundity of *Eisenia andrei* and *E. fetida* cultured in isolation or in pairs; from hatchlings to yearlings.

Christopher Nathan Lowe: The use of earthworms in chronic soil ecotoxicity testing: Developing ecologically relevant and sensitive test methods.

Frank Ashwood, Kevin Watts, Kirsty Park, Elisa Fuentes-Montemayor, Sue Benham, Elena I. Vanguelova: Afforestation effects on soil quality and earthworm populations.

Posters

Garczyńska, M., Podolak, A., Pączka, G., Mazur-Pączka, A., Szura, R., Kostecka, J.: Effects of Dimilin25 WP on the earthworm *Allolobophora chlorotica.*

Krempa, M., Miazga, N., Kołodziej M.: Our adventures with *Lumbricidae.*

Kostecka, J., Baran, A., Majerski, A., Augustyn, K.: Educational project „Appeal – us for earth".

Ashwood, F., Benham, S., Butt, K.R., Vanguelova, E. I.: Trialling a systematic sampling protocol for earthworms in deadwood.

Bentley, P. R., Butt, K. R., Lowe, C. N., Elphinstone, D.: The action of anecic and endogeic earthworm species on incorporation of wheat straw into agricultural soils.

Brami, C., Pérès, G., Menasseri, S., Jacquet, T., Lowe, C. N.: Effects of the energy crop *Miscanthus x giganteus* on soil properties and earthworm communities across a pollution gradient.

Butt, K.R., Lang, F., Ehrmann, O., Kobel-Lamparski, A., Lamparski, F., Nuutinen, V.: Black Forest Giants: Preliminary field and laboratory investigations of *Lumbricus badensis* (Michaelsen) behaviour and ecology.

Lampert, M., Butt, K. R., Vanguelova, E. I., K. Doick, K., Ashwood, F.: Reclaiming landfill to woodland – Using trees, earthworms, and composted green waste for enhanced ecosystem service provision.

Lupton, K., Lowe, C.N. Butt, K.R.: The use of earthworms in OECD / ISO standardized ecotoxicity tests.
Quigg, S and Butt, K.R.: Earthworm community development at the restored Hallside steelworks.

Discussion Session
General points arising from all presentations:-
Potential avenues for future joint research:-

04.09.18. Day III
Field trip - to Połonina Caryńska- an outdoor laboratory.

3.0 ABSTRACTS OF PRESENTATIONS AND POSTERS

ORAL PRESENTATIONS

Joanna Kostecka

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Polish Earthworm Research Group (PERG) - chosen activity from a field studies to a sustainable waste management and taking part in a Preparatory Committee for International Earthworm Industry Alliance

Research on earthworms began in Rzeszow in the last century. Most of our research and publication deals with the issues related to the Lumbricidae family in soils of natural and anthropogenic ecosystems (also their protection) and applications of the earthworm *Eisenia fetida* (Sav.) (also now *Dendrobaena veneta* Rosa) in biotechnology of vermiculture (with determination of technology of organic waste vermicomposting and using vermicomposts in agriculture and horticulture).

In the 1980s research focused on the ecology of earthworms in the natural ecosystems of the Bieszczady Mountains [e.g. 1,2,3,4]. In the early 1990s experiments on using *E. fetida* for vermicomposting organic waste started. In a farm belonging to the Regional Development Fund for Rzeszow Area run by Agricultural Secondary School in Miłocin, near Rzeszow, about 30 m^2 of vermiculture was set up. At first this was in a bed limited by wooden walls and the base covered with wire netting. Then the walls were made of hollow bricks and the base of concrete [5,6]. The farm specialised in breeding cattle and horses, hence the first waste given to the earthworms was cow and horse manure. Testing the principles and technology of vermicomposting, a lot of cow manure vermicompost was produced with high quality parameters [7]. This allowed for numerous experiments which compared fertilising vegetables with vermicompost with balanced doses of mineral fertilisers. The research showed a positive influence of the manure vermicompost on the size and quality of carrots, tomatoes, cucumbers, potatoes, celeries, leeks and cabbages [e.g. 8]. The high quality of the crops was defined by a lower content of some heavy metals (Pb, Cd) and nitrates in vegetables grown on vermicomposts as compared to those grown on mineral fertilisers. Studies on the use of the second product of vermiculture, i.e. earthworm's biomass were also carried out [e.g. 9].

The research conducted by us in this field, gradually attracted other scholars of the Faculty, mainly from the Department of Agroecology. The research results were also known of and used in the educational area (in contact with teachers, pupils, farmers, students and local government representatives).

Vermicomposting was also conducted on a large scale in selected sewage treatment plants [e.g. 10,11,12,13]. In 1996 the first tests took place aiming to use earthworms for utilising kitchen organic waste on the spot, in "ecological earthworm boxes" [14,15]. During those tests, a number of educational projects were realised including promoting zooedaphone biodiversity [e.g. 16].

Some research of PERG (also in cooperation with ERG from UCLan) still consists of further study for Lumbricidae populations in various ecosystems [e.g. 17,18,19] and using them in biotesting [20]. PERG and ERG from UCLan are now starting to be connected further, also by publications in the field of education for sustainable development [21].

Promoting the importance of Lumbricidae for soil fertility and organic waste management, conferences entitled „Ecological and economic significance of earthworms" were organized in Rzeszów. They played a remarkable role for the exchange of information and expanding research in Poland. So far, five such conferences have been held [Conference „Ecological and economic significance of earthworms" 1994, 1996, 1998, 2001 and 2003- published at Zeszyty Naukowe AR w Krakowie *no 292/41* /1994- 150 pp; *no 310/47* /1996-180 pp; *no 334/58* / 1998- 202 pp; *no 372/75* / 2001- 292 pp; Zeszyty Problemowe Postępów Nauk Rolniczych *no 498*/ 2004- 230 pp].

As part of the European community, Poland has to follow European law and directives concerning municipal waste. By the year 2020 our country is supposed to retrieve up to 75% from the municipal waste dumped in landfills. The proper use of *E. fetida* populations might help to achieve that goal.

With sustainable development and sustainable organic waste management, there should be more than enough space for protection of such important soil animals [16] and a use of such versatile biotechnology [13,22].

In the period between the first meeting of both research groups (ISLE OF RUM EARTHWORM CONFERENCE, May 2014) research and publications in Rzeszów were aimed at further recognition and propagation of the place of vermiculture in the system of sustainable waste management and the circular economy [1a, 2a, 5a, 6a, 8a, 10a, 12a]. Field and laboratory studies of a few new earthworm species were also examined and published [3a, 16a].

Research topics of dr. Mariola Garczyńska focus on the pro-environmental disposal of segregated organic waste with the use and improvement of on-site vermicomposting technology [13a]. The influence of various xenobiotic substances (chemical plant protection agents - anti flies preparations, neonicotinoids) on the earthworm population [9a, 17a] is also examine.

Dr. Grzegorz Pączka is conducting research on vermicomposting of potentially hazardous organic waste. They focus on the development of methods to optimize the processes occurring in vermireactors [14a]. One of the aspects of this research are modifications of habitat conditions in vermireactors, for effective processing of organic plant waste and the welfare of earthworms. Research and publication to explore further aspects of the ecology of earthworm's species has also been carried out [4a, 11a].

Dr. Anna Mazur-Pączka recognizes the species composition of earthworms in selected areas of the Podkarpackie Voivodeship: natural areas, used for agriculture and degraded by industrial human activity [7a, 15a]. These are basic research in the field of biodiversity of soil organisms. They are intended to illustrate the current state and directions of changes in the population of earthworms occurring due to the growing anthropopressure.

Dr. Agnieszka Podolak currently leads research on the distinction between coexisting hybridisation and self-fertilization phenomena in closely related model earthworm species, *Eisenia andrei* and *E. fetida*, widely used in biomedicine and ecotoxicology [18a, 19a].

During the "1st International Earthworm Congress" held on June 23-29, 2018 (at the School of Agriculture and Biology, Shanghai Jiao Tong University - Shanghai, China), the Preparatory Committee for the International Earthworm Industry Alliance was established. Its task is to take action to revive world cooperation in the field of creating an international market for vermiculture products. The vermicomposting system for organic waste is now a need of the moment and can very significantly contribute to building sustainable development and a circular economy. The group that created this International Union was invited to prof. dr. hab. Joanna Kostecka and dr. Kevin R. Butt. This gives us hope not only to participate in global activities, but also in a few thematic cooperation between our research groups.

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Keywords: subjects of research, field research subjects, vermicomposting, vermicomposting and sustainable development.

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UClan's Earthworm Research Group (ERG) – background, current projects and future directions.

The ERG at UCLan has existed for 2 decades and is based on research that began back in the 1980s. It grew from work begun at the Open University, where KRB undertook his PhD – a project initially conceived by Clive Edwards, when still based at Rothamsted in the UK. Early work focused on mass production of soil-dwelling species (such as *Lumbricus terrestris*) for soil amelioration. This required investigation of basic life cycle parameters (growth; reproduction; cocoon development) and how these were affected by abiotic (e.g. temperature; moisture) and biotic (population density; food quality) factors. At this point numerous organic materials (e.g. dung; bio-solids; paper pulp; straw) were investigated. However, it must be stressed that the focus of this group has been mainly on soil dwelling (endogeic and anecic) earthworm species.

Thereafter, interactions between different species (within and between ecological categories) were examined in the laboratory, and as field trials began to put the "Earthworm Inoculation Unit" (EIU) to the test, mainly on restored sites. Then, and with CNL as a permanent member of the group, we began to expand our horizons and become involved with more projects which examined further aspects of earthworm biology both in the UK and further afield. This involved collaboration with numerous researchers from different countries, including Joanna Kostecka from Poland (some 20 years ago – with the British / Polish Joint Research Collaboration Programme – which brought KRB to Poland and took JK to the UK (twice each). This was the start of our fruitful research work which saw KRB in Bieszczady National Park and *Allolobophora carpathica* grown in the ERG lab in Preston and further collaborative work at Manchester Airport, on the Isle of Rum, in the Yorkshire Dales and in Devon!

More recently, the ERG has expanded its numbers by inviting individuals to join – mainly those who have worked and published with us. Numerous investigations have been undertaken and included work at Down House – the home of Charles Darwin. Our numbers are kept up by a rolling programme of PhD students who have examined/are examining a variety of topics, with links to Forest Research and Myerscough College helping secure funds (see other presentations). In addition, we encourage undergraduates to investigate areas of ERG interest, which have resulted in publications, and also encourage Internships, with Masters by Research students who have also proved to be very successful.

One of the ERG's strengths is our broad approach to research, enabling us to investigate numerous topics and address a variety of research questions, often developing novel techniques to do so. Future projects will continue current trends within soil restoration, ecotoxicology, life history investigations and ecosystem service provision, but may also seek to move into further realms, with earthworms acting as the focal group. This talk will explore all of the above by way of illustration.

See www.uclan.ac.uk/erg for further details.

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Vermicomposting of chosen agricultural organic wastes

Waste remaining after corn harvest (corn straw) can be used as animal feed in agricultural farms or may be applied for field fertilization, but it is better to compost these residues and other types of organic waste. This results from the fact that without composting, the ploughed corn residues stay in soil for years and are decomposed mainly in anaerobic conditions. The processes of decay that occur there, favour diseases and inhibit normal plant growth

The article presents results of studies on using dense populations of *Eisenia fetida* (Sav. 1826) and *Dendrobena veneta* (Rosa 1893) earthworms for neutralization of post-harvest maize (*Zea mays ssp. Indurata)*) waste. The experiment was conducted in climatic chamber conditions in various variants (bedding I – pure maize stems, bedding II – maize stems with cellulose (2:1), bedding III – maize stems with horse manure (2:1)). In earthworm cultures on the above-mentioned beddings, changes in their populations were analysed, assessing biomass and the number of laid cocoons. The obtained organic fertilizers were subjected to chemical analysis. It has been demonstrated that waste was neutralized by both earthworm species and the obtained vermicomposts had beneficial properties as beddings for plant cultivation. Vermicomposting of this type of waste provide plants with valuable nutrients in an available form. The addition of cellulose and horse manure to maize stem waste did not significantly differentiate the content of principal nutrients ($p>0.05$) in the produced vermicomposts.

Differences in biomass growth of both earthworm species in the studied waste and the number of cocoons laid by them indicate that *E. fetida* preferred maize waste with horse manure. *D. veneta* preferred pure maize waste.

Differences in the composition of waste vermicomposted by earthworms had a significant effect on the number of cocoons laid by *E. fetida species.*

Keywords: Vermiculture, *Eisenia fetida*, *Dendrobena veneta*, post-harvest maize waste.

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Effect of vermireactor's modifications on the welfare of earthworm *Eisenia fetida* (Sav.) and the efficiency of vermicomposting of selected organic waste

Thirty percent of the world sugar production is manufactured from sugar beet (Roper 2002). From one ton of this raw material, approximately 150 kg of sugar and 250 kg of sugar beet pulp results (Spagnuolo et al. 1997). In 2016 in EU countries, approximately 17 million tons of sugar were produced, and thus over approximately 28 million tons of sugar beet pulp. In the same period in Poland, during the production of 2.17 million tons of sugar, over 3.6 million tons of sugar pulp were produced (www.stat.gov.pl).

Sugar beet pulps can be used as a feed for farm animals (Journal of Laws No. 16, item 137) on condition that they meet the quality requirements (Regulation EC No. 183/2005). When the standards are not met, in accordance with the regulation of the Minister of Environment of 9 December 2014 on waste catalogue (Journal of Laws of 2014, item 1923), sugar beet pulp are classified as waste. The increasing amount of this waste generates a growing problem concerning its management (Bhat et al. 2015).

The studies present results of application of various technologies of the process of vermicomposting of waste biomass of sugar beet pulp using earthworms *E. fetida*. A possibility of using *E. fetida* for quick utilization of sugar beet pulp in vermireactors with different characteristics of initial beddings was observed. During waste utilization in vermireactors* (BAGS and SGS) it was noted that the population of earthworms persisted, but earthworm count insignificantly decreased. Significant differences in the mean biomass of specimens from BAGS and SGS groups were also observed. The greatest differences (22 and 21%, $p<0.05$) were observed on the 10th and 40th day of the experiment. Earthworms multiplied that has been proved by the mean number of laid cocoons which was significantly increasing during the experiment conducted using both technologies (on average by 36%; $p<0.05$). Significant differences in the mean cocoon weight between the technologies used were noted only on the 10th day of the experiment.

The obtained vermicomposts were characterised by higher N, P, K, Ca and Mg content compared to the initial waste biomass.

(*Vermireactors BAGS - biologically active garden soil was used as the initial bedding
Vermireactors SGS - the same bedding was applied, but it had been sterilised at 105°C
The sterilised bedding was used to show the simulation of using in the vermiculture a soil degraded as a result of anthropopressure (low biodiversity)).

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Regulation of the Minister of Agriculture and Rural Development of 19 January 2005 on feed materials intended for marketing (Journal of Laws No. 16, item 137).

Regulation of the Minister of Environment of 9 December 2014 on waste catalogue (Journal of Laws of 2014, item 1923).

Regulation (EC) No. 183/2005 of the European Parliament and of the Council of 12 January 2005 laying down requirements for feed.

Keywords: vermiculture, *Eisenia fetida*, *vermireactor,* earthworm's welfare.

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Community structure of earthworms in four types of beech wood *Fagetum carpaticum* in the Bieszczady National Park (south-eastern Poland)

Lumbricidae play a key role in the soil environment as "the ecosystem engineers". They participate in all the categories of services provided by ecosystems. They are involved in developing soil structure, in circulation of nutrients, primary production, climate regulation, reduction of pollution, and culture-related services; they are a source of nutritious food for animals and, in some cultures, for people The factors linked with geology, climate and biology, as well as human operations based on excessive exploitation lead to soil environment degradation. In recent years, it has also been pointed out that due to a decreased biological diversity of soil fauna, these resources are also at risk.

In this study, we attempted to characterize community structure of earthworms in four types of beech wood *Fagetum carpaticum* in the Bieszczady National Park.
The study was carried out in the Western Bieszczady (Poland) near the village of Ustrzyki Górne in 2009–2010 in four phytosociologically varied locations within the Carpathian forest (*Fagetum carpaticum*): I – *F. c. festucetosum drymejae*, II – *F. c. typicum*, III – *F. c. lunarietosum*, IV – *F. c. allietosum.* At each investigated site, eight samples of soil (0.25 x 0.25 x 0.25 m) were taken and examined by hand sorting. From the deeper layers, earthworms were expelled using weak formalin solution (0.4%). The extracted specimens were purified from soil and mucus residues and bathed in water for 15 minutes. They were put down by submerging in 30% ethyl alcohol, and then transferred to preservation solution (4% formalin). The collected specimens stored this way were identified and weighed in the course of a few days.

A total of 11 species of earthworms were found: 7 species at Site I, II, and III. The highest abundance, i.e. 11 species was found on site IV. The numbers of earthworms identified at Site I amounted to 33 ± 9 ind. m^{-2}; at Site II there were 48 ± 11 ind. m^{-2}, Site III had 42 ± 9 ind. m^{-2} and Site IV with 66 ± 12 ind. m^{-2}. The total earthworm biomass measured at Site I amounted to, 17.18 ± 4.55 $g{\cdot}m^{-2}$, Site II was found with 25.88 ± 6.17 $g{\cdot}m^{-2}$, Site III had 56 ± 4.74 $g{\cdot}m^{-2}$, and Site IV presented with 112.55 ± 28.34 $g{\cdot}m^{-2}$.

The research shows that there is a growing anthropogenic impact negatively affecting the biological diversity, including earthworms. A comparison of research findings acquired at present and in the 1980s may suggest a decrease in the diversity of earthworm communities in the course of twenty-five years. The reasons for this, despite the statutory operations conducted in that period (the investigated sites I, II and IV are located within the Bieszczady National Park), may include the direct and/or indirect impacts caused by human activity in this area.

Keywords: Lumbricidae, Bieszczady National Park, beech wood.

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Comparison of body masses and fecundity of *Eisenia andrei* and *E. fetida* cultured in isolation or in pairs; from hatchlings to yearlings

Earthworms (Lumbricidae) as an experimental model find wide application in many research fields like agriculture, vermicomposting, ecotoxicology or biomedicine, some of them requiring precise species delimitation. The composting species *E. andrei* (Ea) and *E. fetida* (Ef) were originally described as pigmentation morphs of one species spelled as *Eisenia foetida*, then as its subspecies, and only since 2005 as two independent species with reproductive isolation forming two distinct clades on phylogenetic tree based on species-specific DNA sequences. They are simultaneous hermaphrodites capable to self-fertilization, cross-fertilization, and also asymmetrical hybridization. In the light of recent achievements, it is crucial to re-examine some basic phenomena on precisely defined Ea/Ef species and their hybrids. The aim of present investigation was to follow the body mass gain, cocoon production and reproduction, from hatchling to yearlings, in progeny of Ea and Ef earthworms originally derived from laboratory stocks in Lille University and then cultured in the laboratories of Jagiellonian University and Rzeszów University, and genotyped by species-specific sequences of mitochondrial COI gene and nuclear 28S rRNA gene.

Freshly hatched specimens Ea (A) and Ef (F) were cultured in Rzeszów laboratory over one year at the same laboratory condition either individually as A or F virgin specimens, or in intraspecific pairs (AA or FF) or interspecific pairs (AF). Their body masses, cocoon production, and hatchlings were recorded in the selected time intervals.

Body mass gain was fastest in A and F earthworms living in isolation, reaching 3.30 g and 1.70 g, respectively, on week 54 after hatching; only few of them produced sterile cocoons. On week 54, body masses of specimens from AA, FF, and AF pairs reached 1.0 g, 0.9 g, and 1.1 g, respectively; Cocoon production was very high in all these pairs, but numbers of hatchlings were highest in AA, lower in FF, and very low in AF pairs. Moreover, among hatchlings of interspecific pairs both pure Ea and Ef specimens and hybrids are expected; this will be discerned by genotyping using DNA samples from amputated posterior segments (in progress). In conclusion, body mass of earthworms depends on the energy expenditure needed for reproduction. The results from various stages of life cycle will be presented.

Keywords: *Eisenia andrei, Eisenia fetida,* body mass, cocoon production, hatchlings, life cycle.

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The use of earthworms in chronic soil ecotoxicology testing: Developing ecologically relevant and sensitive test methods.

Earthworms have played a major role in soil toxicity testing, with a strong emphasis placed on lethal endpoints. This has seen the development of standardised acute toxicity tests (ISO 11268-1 and OECD 207 filter paper contact and artificial soil test), which still have value particularly in the initial screening of new chemicals. However, it is now widely recognised that chronic toxicity tests designed to measure sub-lethal endpoints, such as fecundity (ISO Reproduction toxicity test 11268-2), growth rate, cocoon viability and behavioural traits provide more sensitive and ecologically relevant data allowing assessment of a contaminant at population and community levels.

The protocols used in acute toxicity tests are well established and rely on the use of standardised conditions to ensure reproducibility (i.e. a standard artificial soil and test species). The epigeic earthworm *Eisenia fetida* (Savigny) has been widely adopted as a test species in both acute and chronic tests (e.g. ISO reproduction toxicity test). However, continued use of this species, particularly in chronic studies, is questionable as it does not inhabit mineral soil and is uncommon in the natural environment. As duration of acute tests is relatively short (14 days for the OECD artificial soil test), maintenance of optimal abiotic and biotic conditions for earthworm production is not a priority however, in more sensitive chronic tests (usually longer in duration), abiotic (e.g. soil type, temperature, moisture and food) and biotic (e.g. earthworm density, species choice/origin) can have a significant influence on measured endpoints. Nevertheless, experimental design is often adapted from acute protocols.

The Earthworm Research Group has sought to identify suitable soil-dwelling earthworm species for use in toxicity testing alongside development of a sensitive behaviour-based chronic standardised test. Experience of culturing temperate soil-dwelling species has been influential in advocating *Octolasion cyaneum* as a candidate test species. *O. cyaneum* are relatively easy to identify and have a widespread temperate distribution. This species reproduces by parthenogenesis allowing for the production of genetically homogenous populations with the ability to exist in a wide range of environmental conditions making them ideally suited as subjects in comparative ecotoxicology. Further collaborative research is seeking to validate the use of *O. cyaneum* as a test species via an amendment to the standardised reproduction toxicity test.

Ongoing research has sought to develop and evaluate an avoidance test utilising soil-dwelling earthworms in linear pollution gradients. Experiments were established to determine the relative sensitivities (in terms of associated avoidance behaviour) of *O. cyaneum*, *Lumbricus rubellus* and *Allolobophora chlorotica* to soils polluted with heavy metals and silver nanoparticles. Results have suggested that the use of a linear pollution gradient system has the potential to assess earthworm avoidance behaviour and could provide a more ecologically relevant alternative to the ISO 17512: 2008 avoidance test. However, further work is required to establish the effectiveness of this procedure, specifically in initial chemical screening and assessment of single contaminant bioavailability, where uptake of pollutants by earthworms could be measured and directly related to the point of introduction and retrieval.

Keywords: Ecotoxicology, Chronic toxicity tests, *Octolasion cyaneum,* Pollution gradient.

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Afforestation effects on soil quality and earthworm populations

New woodland expansion targets in England must be undertaken strategically in order to ensure conflicting demands for land (such as agriculture) are managed, whilst also ensuring the sustainability of valuable soil resources. This study aimed to identify the effects of afforestation of agricultural land and the impact of woodland age on soil quality and earthworm populations. Soil sampling took place across 21 sites, representing a chronosequence (n = 7 of each class): agricultural (pasture and arable) land, secondary woodlands (60 to 110 years old), and ancient semi-natural woodlands (>400 years), all on deep clay soils in the English Midlands. Soil quality results included ancient woodland significantly increasing the soil organic carbon stock (t C/ha) in comparison to arable farmland. In terms of earthworm results, afforestation led to a significant decrease in earthworm abundance and biomass from pasture land. However, woodlands were more earthworm diverse and species rich, with young (50-60 years) secondary woodland having highest species richness and significantly higher species diversity than arable land. Clear changes in earthworm community structure followed afforestation, with an increase in the relative density of anecic and epigeic species, and a decrease in endogeic species.

Conclusions include afforestation leading to ecologically meaningful improvements in earthworm diversity and gains in soil carbon and nitrogen within 50 to 100 years. Specifically, the afforestation of arable land is likely to be more beneficial to soil quality and biological value than on pasture land; which is already a biologically and organic carbon rich soil habitat. Alongside the importance of site history, the choice of tree species is crucial for maintaining diverse and healthy soil fauna populations and maintaining mull humus and therefore a stable and diverse broadleaf forest system.

Keywords: Soil Carbon, Soil Nitrogen, Oak, Afforestation, Soil Fauna

POSTERS

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Effect of Dimilin 25 WP on the earthworms *Allolobophora chlorotica*

Earthworms are an important group of inhabitants of the soil ecosystem. They can contain up to 70% of biomass, which is why they are commonly used in ecotoxicological tests to assess the impact of chemical substances on the environment. Chemical stress affects the zooedophon representatives differently, even in the so-called environmentally safe doses recommended by the producers.

The aim of the present studies was to check the effect of Dimilin 25 WP on the earthworms *Allolobophora chlorotica*. Adult (*clitellum*) earthworms *A. chlorotica* were collected by hand sorting method from the experimental garden of the Institute of Zoology of the Jagiellonian University (Kraków). To the containers filled with 300 ml soil (Kronen Universalerde –garden soil; pH ($CaCl_2$) 5,5-6,5; N –200-450 mg/l; P_2O_5–200-400 mg/l; K_2O –300-500 mg/l; ISO 9001 2000) contaminated before respectively 0.078 g and 0.0078 g Dimilin 25 WP introduced 5 adult (*clitellate*) earthworms *A. chlorotica* (0.379 ± 0.091 g). Dimilin 25WP belongs to the inhibitors of chitin biosynthesis from the group of acylurea (benzylurea) preparations (active substance –diflubenzuron). Soil samples were allowed it equilibrate for 24 h before. The experiment was performed in four replicates in comparison with the control group. Soil in the containers checked by hand -sorting method after 3, 6, 9 and 12 weeks. At this time survival, body weight and reproduction were checked. At the end of the experiment, the surviving earthworms were stimulated for 1 minute with 4,5V electric current to expel coelomic fluid with coelomocytes (3 ml PBS with 2g/l EDTA 1 min; 2% formalin 24h) and counted in a Burker haemocytometer. Experiment carried out for 12 weeks in laboratory conditions (18± 2 ^{o}C; 24 light), fed on horse manure. Application of Dimilin 25 WP in both studied concentrations significantly decreased the biomass of the population and the individual body mass. Insecticide reduced the total number of coelomocytes *A. chlorotica* and reduced the probability of survival of the earthworm population compared to the control group.

Keywords: *Allolobophora chlorotica*, Dimilin 25WP, ecotoxicology, population characteristics, coelomocytes.

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Our adventures with *Lumbricidae*

Earthworms (Lumbricidae), belonging to the type of Annelidae, are currently the subject of various studies. They play an important role in many processes occurring in ecosystems. They affect the physical and chemical properties of soils and participate in their functioning, as well as in the functioning of the broadly understood environment as "ecosystem services". Thanks to the tunneling of their underground corridors they contribute to the improvement of air and water circulation in the soil. Complexes created by earthworms are a component of humus. Lumbricidae take part in the distribution of organic matter and its even distribution in the soil profile, they also participate in the circulation of matter and energy flow through ecosystems (Morgan 2004, Jura 2007). Earthworms are also of great practical importance, because they can be used, for example, to neutralize organic waste. This biotechnology is called vermiculture. Vermicomposting with the appropriate species of earthworms can be one of the most effective methods of waste disposal at their place of origin (Domínguez and Edwards 2011). Vermiculture can be carried out on a small or large scale, technical or semi-technical, as well as in "earthworm ecological boxes" (Kostecka 2000). Although vermicomposting is an effective method, often used in the world it is still the object of many multi-directional research (Pączka and Kostecka 2012). It still requires updating solutions to many problems.

Lumbricidae are for some people repulsive. But not for us. Thanks to them, we could start our adventure at the university. We familiarized ourselves with the principles of scientific research, we participated in activities that disseminated their significance, we learn how to transform organic fertilizers into valuable waste fertilizers. We agree fully with Cleopatra that these precious animals should be respected and used in a sustainable way.

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Keywords: education, interest, concern, Lumbricidae.

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EDUCATIONAL PROJECT „APPEAL – US FOR EARTH"

An invitation to you

Do not procrastinate
close your eyes
and extend your hand to birds
whenever you wish
they will serve you with their wings
and while soaring with the flock
you will see the real world

Joanna Kostecka

In the space of 4 billion years our planet has shaped its current forms of life. Followers of anthropocentric philosophy may summarise this fact as if life evolved in order to prepare conditions for the appearance of human beings. Thanks to strength of mind, humans have subordinated the planet's resources, its processes as well as inconveniences of functioning. This was and is being done at the expense of other forms of life – here a follower of biocentrism may feel certain resentment. A growing number of people from different professions are currently engaged in voicing their views regarding the defence of living organisms on Earth. They are able to reach their audiences via different activities, such as short, yet very accurate films portraying reality [see e.g. Cutts], and to make them pause for even a moment of thought to answer the question: where are you going and why are you rushing so much [Carley, Spapens 2007]?

The purpose of this project is to present a selection of facts regarding human dependence on a correctly functioning environment [Millenial Ecosystem Assessment 2005, Popkiewicz 2013] and also to emphasize the threat emerging from an under-appreciation. Further principles of the educational project "Appeal – us for Earth" will be brought in future publications. Together, these will attempt to set out poetry, art, sculpture and music to emphasize the necessity of maintaining positive relationships between human beings and the environment.

Currrent actions aim at stimulation, shaping, and preservation of positive emotions and bonds in this field. This project was created at the University of Rzeszow in collaboration with members of the Polish Ecological Engineering Association, and Group of Creators Golden Line [see Creators Group]. Our project is set to move and positively form a concerted effort aimed at changing everyday behaviours and habits to pro-environmental and pro-humanist ones, with the aid of poetry, art, sculpture and music.

MESSAGE

To sensitize people towards the beauty of Gaia, in order to make them feel responsible for her.

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Keywords: biodiversity, awareness, concern.

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Trialling a systematic sampling protocol for earthworms in deadwood

Fallen branches, logs, stumps and standing dead trees (termed 'Coarse Woody Debris' or CWD) are a key habitat in forest ecosystems; providing juvenile and adult earthworms with refuge from predators and a food resource. There is increasing evidence that earthworm species which live in alternative habitats to soil (such as CWD) can be missed by traditional quantitative sampling methods. For example, *Eisenia lucens*, common in the *Fagus*-dominated forests of the Bieszczady mountains, would be under-recorded, as it lives predominantly in deadwood during the times when earthworm sampling normally occurs. Such under-sampling can lead to false classifications regarding species distributions and conservation status. Resolving the current lack of a systematic and quantitative methodology for surveying earthworms and other invertebrates in microhabitats such as CWD may therefore lead to valuable insights into earthworm species ecologies, distributions and diversity in forest ecosystems. More information on the ecological importance and benefits of CWD to forest health may also help to promote a balance between intensive and low-impact forest management practices. This poster summarises a novel project which aims to develop a systematic method for surveying deadwood-associated earthworms in an unmanaged woodland habitat. The success of the method will be evaluated by comparison to results gathered through standard soil-pit earthworm sampling, in terms of earthworm species richness and diversity, abundance, biomass and ecotypes collected. The results from these surveys will be used to determine the influence of soil and CWD environmental factors and woodland age on the earthworm populations of oak-dominated broadleaf woodlands.

Keywords: Coarse Woody Debris, Microhabitat, Deadwood, Deciduous Woodland, Oak.

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The action of anecic and endogeic earthworm species on incorporation of wheat straw into agricultural soils

Anecic earthworms such as *Lumbricus terrestris* may play a pivotal role in reduced tillage agricultural soils, where their feeding behaviour enables incorporation of surface applied organic matter into the soil profile, enhancing degradation and nutrient cycling. This study is part of a wider project exploring the incorporation of organic matter into agricultural soils by earthworms. An experiment was designed to explore the behavioural relationships between *L. terrestris* and the endogeic *Aporrectodea caliginosa* to determine influences on the incorporation of wheat straw into soil. Three straw treatments were used with lengths of 40, 20, and 1 cm, plus a control with no straw applied. These lengths were chosen to reflect measurements taken from a harvested field. This experiment had 3 earthworm treatments (*L. terrestris* and *A. caliginosa* monocultures and a mixed culture of these two species) and incorporation of wheat straw into soil. Mature earthworms were set up in 3 L polyethylene-bound units of soil (diam. 10 cm; height 18 cm). Air-dried wheat straw (10 g) was cut to the selected particle sizes, and surface applied (n=5 replicates per treatment). Units were incubated at 15 ºC in 24 h darkness for 8 weeks. At experimental end, remaining surface straw was removed, dried at 105 ºC and had mass determined. Soil samples were taken at 3 depths (0-6, 6-12, and 12-18 cm) and nutrient concentration and C/N ratio analyzed. Recovered earthworms had their masses determined and soil was checked for cocoons.

L. terrestris monocultures incorporated the largest straw mass into soil (6.36 ± 0.60 g of 1 cm particle size), had 100% survival rate and produced cocoons. Although *A. caliginosa* incorporated straw into soil under all treatments (2.20 ± 0.14 g of 40 cm; 1.71 ± 0.16 g of 20 cm; 1.39 ± 0.69 g of 1 cm lengths), survival rates were lower (80, 60 and 93% with 40, 20 and 1 cm respectively). Straw incorporation under mixed species treatments was low (<1 g), however *A. caliginosa* survival was higher and average mass loss was lower over the period of study. This suggested a positive interactive effect between *L. terrestris* and *A. caliginosa*.

Statistical analysis of the straw removal, particle size and earthworm species indicated a significant difference between straw removal and particle size under *L. terrestris* monocultures ($p<0.05$), however there was no relationship between particle size, straw removal and earthworm populations in the other treatments. Nutrient levels increased under earthworm treatments compared with controls. Analysis of nutrient concentration against soil depth indicated that there was a significant difference between nutrient concentration and depth within *L. terrestris* monocultures ($p < 0.05$), where nutrient concentration decreased with depth. The nutrient concentration under *A. caliginosa* treatments did not change with soil depth. This could imply that earthworm species interactions and/or earthworm numbers influence nutrient concentration in agricultural soils.

This experiment suggested that the presence of *L. terrestris* increased the incorporation rate of wheat straw and may provide some positive benefits with *A. caliginosa*; however, this requires further exploration in field settings, to explore the implications of this on sustainable agricultural soils.

Keywords: Agriculture, *Aporrectodea caliginosa*, *Lumbricus terrestris*, Organic matter incorporation, Particle size.

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Effects of the energy crop *Miscanthus x giganteus* on soil properties and earthworm communities across a pollution gradient

Due to increasing human activities, many sites are contaminated. Conventional restoration techniques exist but are expensive and may disturb the environment [1, 2]. A more economical and environmentally friendly alternative is phytoremediation [3]. Miscanthus is a perennial rhizomatous grass native to Southeast Asia [4]. Once planted, the rhizome system can recycle nutrients from the soil and above ground biomass allowing continuous biomass production for up to 20 years [5] with low tillage and nutrient inputs and without crop rotation. Moreover, Miscanthus exhibits high levels of disease and pest resistance [5] and plant cover associated with rapid growth rates limit the need for pesticides [6]. Previous work has shown that low tillage increases invertebrate diversity, the number of birds and the presence of small mammals [7, 8]. The ability of Miscanthus to grow on polluted sites and to phytostabilize trace elements allows its use in a phytoremediation context [4]. The cultivation of Miscanthus offers the possibility of economically developing marginal lands through biomass production and commercial use in different sectors such as horticulture (e.g. mulch) and biomaterials production (e.g. bio-based plastics and building blocks) as well as thermal energy production (biomass boiler).

The work presented here is part of a broader project that seeks to evaluate the entire Miscanthus thermal chain from cultivation, through energy production, to the production and reclamation of ash as a fertilizer or in of aided phytostabilization of contaminated sites. The objective of this first step is to study the impact of Miscanthus crops (*Miscanthus x giganteus*) on soil quality in polluted and unpolluted sites through multi-criteria soil quality analysis. For this purpose, soil samples were collected from three sites with varying levels of soil pollution. Site 1 (Bioferme) is an agricultural unpolluted site. Site 2 (Marne & Gondoire) is a moderately polluted site located near a motorway. Site 3 (Chanteloup) has received sludge for over a century and is the most polluted site. *Miscanthus x giganteus* cultures were established at each site in 2013 as part of the "Biomass for the Future" (BFF) project. Soil and earthworm samples were taken from the Miscanthus plots and nearby grasslands to allow the study of biological (earthworm community, microbial biomass), chemical (pH, organic matter, C/N ratio, available and total metal trace element concentration, total PAH and PCB concentration) and physical (soil structural stability, bulk density) parameters. Analysis of results will allow for inter-site and Miscanthus-grassland comparisons through the implementation of a soil quality index and, will be presented during the conference.

Keywords: *Miscanthus giganteus*, Soil quality, multi-criteria analysis, polluted land, Metal Trace Element, Energy crop, Earthworm communities.

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Black Forest Giants: Preliminary field and laboratory investigations of *Lumbricus badensis* (Michaelsen) behaviour and ecology

An investigation was undertaken to look at specific aspects of the ecology and behaviour of the little studied, large anecic earthworm *Lumbricus badensis*, endemic to the Schwarzwald area of SW Germany (Kobel-Lamparski and Lamparski, 1987). An appropriate *Fagus*-dominated forest site was located close to Belchen (at c. 1160 m altitude), where survey of the soil surface of largely vegetation-free ground layer areas, indicated the presence of *L. badensis* middens. Records of behaviour at the soil surface were made in the field using six web-cams, each monitoring an area of approx. 0.25 m^2 from dusk until dawn (21.30 - 05.30) over 5 nights, in early June 2015 (30 days after snow-melt). Results showed that *L. badensis* was very active at the soil surface during the hours of darkness, maintaining tail-contact with the burrow at all times. During filming, one mating event was recorded, lasting more than 3 hours, but soil surface behaviour was mainly concerned with foraging and movement of materials (such as spruce cones) close to the burrow entrance. Population density of adult *L. badensis* was approximately 7 m^{-2}, based on finding individual burrows within carefully examined 0.1 m^2 areas. Webcam data showed that some burrows had multiple entrances at the soil surface. The mean diameter of burrow entrances (± se) was 10.4 ± 0.9 mm (n = 7; max. 13 mm). Partially emerged adult individuals were captured at night and pulled out from their burrows. They had a mean mass of 25.1 ± 2.2 g (n = 14; max. 41 g). Based on hand-sorting of soil samples, other earthworm species present at the site (and percentage of total) were *Aporrectodea icterica* (65), *Lumbricus rubellus* (9) and *Octolasion tyrtaeum* (26), with total density of 90 earthworms m^{-2} and a total mass of 28.1 g m^{-2}. Three lemon-shaped cocoons of *L. badensis* were collected at a depth of less than 30 cm from the field (size approx. 13 x 9 mm; mass 381 - 529 mg). These were taken to UCLan (Preston, UK) and incubated at 15 ^{o}C under laboratory conditions and each produced a single hatchling with mass of 322 - 392 mg. Growth to maturity took 10-12 months at 15 ^{o}C, with tubercular pubertatis present after 9 months at a mass of 12-14 g. These adults, plus a small number of field-collected individuals maintained at UCLan, were set up in soil-filled tubes (16 cm diam.; depth 50 cm) for closer scrutiny of feeding and potential reproductive behaviour by web-cam recording. The upper surfaces of the tubes were aligned within a soil-covered arena (55 x 45 cm), mimicking a forest floor, to permit potential interactions. Bouts of foraging and a single mating attempt, at the soil surface, were recorded.

Overall, this preliminary study on *L. badensis* suggests that much can be learned about the life and ecological significance of this remarkable species from combining conventional field and laboratory methods of earthworm ecology with behavioural observations.

Keywords: Burrow, cocoon, foraging, growth, mating, midden, observation, web-cam.

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Reclaiming landfill to woodland – Using trees, earthworms, and composted green waste for enhanced ecosystem service provision

Landfill operations involve complete destruction of soil habitats. When landfill operations cease, active restoration techniques including soil reconstruction, tree planting, and earthworm inoculation are used to re-instate soil structure and ecosystem function. These techniques promote tree and earthworm community establishment, helping deliver key supporting and regulating ecosystem services. Trees and earthworms produce and cycle soil organic matter (SOM), providing the carbon and nutrients needed to rehabilitate terrestrial ecosystems. However, reclaimed landfill soils are typically SOM-deficient. Waste-derived materials called 'organic amendments' (OA) are included during soil reconstruction to alleviate any deficiency. Composted green waste (CGW) is an OA with similar physical, chemical, and biological properties to natural SOM, used to enhance the structure, nutritional content, and habitability of reclaimed soils. From 1998 – 2012, a series of experimental trials emerged throughout the UK designed to test CGW impact on tree growth and soil fertility. These trials suggested CGW could improve tree growth in the short term, however knowledge regarding CGW long-term impacts is scarce. Furthermore, CGW ability to support a broad range of ecosystem services has never been investigated.

By re-visiting experimental sites in Scotland, Northern England, and Southern England, this research project will detail CGW's long-term contribution to primary productivity, soil formation, nutrient cycling, and carbon storage on landfill-reclaimed to woodland. Whether changing CGW quantity or application depth influences earthworm activity and long-term carbon storage will be closely examined. Earthworms' role in soil formation suggests their presence in reconstructed CGW-amended soils is crucial, however research indicates that earthworms also drive considerable carbon losses from soil. This conflict may be partly resolved by assessing earthworm contributions to multiple ecosystem services simultaneously, improving understanding of their net ecological contribution during reclamation. Earthworm re-colonisation via active and passive means will also be assessed. Active inoculation is resource and energy intensive, therefore understanding how, where, and why passive re-colonisation is most applicable can improve restoration efficiency.

To date, soil physical, chemical, and biological parameters have been partially analysed at 3 of 6 sites. Analysis of variance (ANOVA) between experimental treatments shows CGW has made lasting improvements in ecosystem service provision. Primary productivity (measured as tree growth), and nutrient cycling at depth (measured as available nitrogen) remain significantly higher after +5 years. *Alnus cordata* height increased by +0.5 m on average, whilst endogeic earthworm (*Allolobophora chlorotica)* density rose consistently through time, indicating their potential contribution to tree growth and soil fertility. An examination of soils in and around an active reclamation site also showed the earthworms *A. chlorotica, Aporrectodea longa* and *Aporrectodea caliginosa* survive on-site in stockpiled soils, providing an additional resource for passive earthworm re-colonisation.

Further data will now be collected from each site to provide comprehensive information on CGW and earthworm impacts on multiple ecosystem services. Finally, a visually-based tool for assessing the physical and biological quality of reclaimed soils is also being developed, whilst the ability of a smartphone app to accurately analyse leaf area for trees on reclaimed land is being tested.

Keywords: Restoration, Soil, Trees, Compost, Earthworms, Passive, Ecosystem Services, Carbon.

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The use of earthworms in OECD / ISO standardised ecotoxicity tests

OECD (Organisation for Economic Co-operation and Development) and ISO (International Organisation for Standardisation) tests have been developed to monitor and assess the impact of soil pollutants such as pesticides, heavy metals and nanoparticles worldwide. A number of these standardised tests use earthworms in a prescribed artificial substrate to assess the impact on survival, reproduction and/or behavioural responses.

Various aspects of the standardised tests have been questioned. The tests specify the use of epigeic earthworms *Eisenia fetida / E. andrei,* although these “compost earthworms” are not considered to be representative of typical earthworm communities which are comprised mainly of soil-dwelling species. The artificial substrate is not a “typical” soil and as such may well affect the bioavailability of pollutants as well as the behaviour of the test species. Moreover, the wording of the test protocols are somewhat ambiguous in places and this can lead to variability in test outcomes amongst researchers and commercial laboratories.

The aim of this PhD project is to develop test protocols which are practicable and more ecologically relevant in terms of test species and substrate type. In the early stages of the project the method specified in ISO 11268-2:2015 (reproduction test) has been followed and raised a number of questions regarding organic matter inputs and the sand particle size and water holding capacity of the artificial substrate. Initial experiments have assessed the responses of compost earthworms and *Lumbricus terrestris* (an anecic earthworm species) in OECD artificial substrates made up with two different grades of sand compared with a Kettering Loam soil. It is proposed that particle size of the sand used in the artificial substrate may affect earthworm behaviour and as such future work will look at comparative burrowing behaviour in Evans Boxes.

Keywords: OECD, ISO, artificial substrate, earthworm.

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Earthworm community development at the restored Hallside steelworks

In the early 1990s, an abandoned steelworks site at Hallside, near Glasgow in Scotland, was reclaimed in a scheme that sought to create a 35 ha "Energy Park", surrounded by community woodland. This aimed to produce biomass through Short Rotation Coppice (SRC) of *Salix* spp. After removal of structures and all contaminated substratum, a rudimentary soil was created on the brownfield site by spreading of a stone-rich material, derived from nearby piles of colliery spoil. This was then mixed with locally-derived bio-solids, to create a growing medium to 2 m in depth. Use of such inorganic and organic materials formed a functional substrate for tree growth, and freed up land for housing development. In 1996, trees were planted and to potentially assist their growth, earthworms were added to site using 2 techniques; (1) the Earthworm Inoculation Unit (EIU) technique – using 8,000 commercially-sourced *Lumbricus terrestris* in 3 litre units; and (2) incorporation of earthworm-rich turf discs (15 cm diam; 3 cm depth), supplied by a commercial operator. The latter were examined and found to contain a mixture of earthworm species, dominated (96%) by epigeics such as *Dendrobaena veneta* and *Eisenia fetida* with endogeic *Allolobophora chlorotica* also present. Success of each inoculation was investigated over the first two years. Results suggested that both techniques had been poorly implemented (with operational or seasonal deficiencies, respectively) and very few, if any, earthworms had persisted.

This poster reports on further monitoring events that show earthworms had begun to colonise the site and become established within the first 5 years, and had spread widely. In 2000, the initial community (n= 9 species) was dominated by the semi-aquatic species, *Eiseniella tetraedra* (67%), with epigeics accounting for 95% of all earthworms, with very few endogeics (2%) and rarely encountered anecic *L. terrestris* (<1%). Overall, community density was 188 ind. m^{-2}. After almost 10 years (2005), twelve species were found, still dominated by epigeics (63%) of which *Lumbricus rubellus* and *E. tetraedra* were well represented. *A. chlorotica* was the most frequent of endogiec species which accounted for 30% of earthworms located. At this point *L. terrestris* represented 2% of all earthworms. Overall community density was 133 earthworm m^{-2}.

After a period of more than 2 decades (spring 2018), further fieldwork continued this investigation. Some 1,500 earthworms were collected representing 16 species. Endogeics accounted for 74%, with *A. caliginosa*, *A. rosea* and *O. cyaneum* amounting to 34, 27 and 8 percent each. *A. chlorotica* (green and pink morphs) comprised 5% of earthworms. The major anecic species was *A. longa* (13%). Epigeics accounted for only 5% of all earthworms and were dominated by *D. octaedra*. Most of these species are thought to have colonised the site naturally. Earthworm diversity across site was characterised by a Simpson's Index of 0.789 and a Shannon (H) Index of 1.89 with Evenness of 0.68. Mean earthworm density was 208 m^{-2} across site. Habitat from which earthworms were collected significantly influenced community density and biomass. By comparison with an adjacent natural soil, grassland cover and presence of birch or willow trees on the made soil were positive, but conifers (Norway spruce and Scots pine) and particularly wet areas and areas of willow scrub had a negative influence. Community composition changed dramatically with time from reclamation of the site.

Keywords: British Land Reclamation Society, Bio-solids, Brownfield site, Colliery spoil, Colonisation, Inoculation, Pedogenesis, Rehabilitation, Short Rotation Coppice.