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Anthropogenic biodiversity and geodiversity: investigating the potential for legacy anthropogenic substrate sites to help offset falling global biodiversity

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INTRODUCTION

Anthropogenic substrates are produced as waste materials and/or by-products of a variety of industrial processes. Blast furnace/steel slag, oil shale spoil, colliery spoil and paper mill sludge are just some of the anthropogenic substrates that can be found dumped in the natural environment in areas previously associated with industry (Thomas, 1930; Bradshaw, 1977; Allan *et al*., 1997; Saether *et al*., 2004; Courtney *et al*., 2009; Woods, 2012 ; Piatak *et al*., 2015; Butt & Briones, 2017; Di Carlo *et al*., 2019; Gomes *et al*., 2019).

Traditionally, brownfield land has been altered and/or viewed in the context of unsightly, derelict wasteland that ought to be developed or remediated, with no purpose for human wellbeing or biodiversity unless changed (Gemmell, 1976; Richardson *et al*., 2010; Mathey *et al*., 2018). For example, many anthropogenic substrate sites have been capped with clay or similar materials to try to increase plant cover on sites and potentially reduce the spread of contaminants from the substrate (Mayes *et al*., 2006, 2008; Gorman, 2009; Environmental Protection Agency, 2012). However, it has been found that, if left undisturbed, anthropogenic substrate sites can potentially provide relatively undisturbed spaces for wildlife due to variations in chemistry, surface texture, topography and other factors. In particular, unusual and/or important species communities can colonise and live on anthropogenic substrate sites. Anthropogenic substrate sites can act as refugia for many species and communities, as the chemistry of such substrates can often differ greatly from the chemistry of natural substrates in the surrounding area (Thomas, 1930; Ash *et al*., 1994; Allan *et al*., 1997; Bradshaw, 1997; Gibson, 1998; Hitchmough *et al*., 2001; Harrison & Davies, 2002; Batty, 2005; Bodsworth *et al*., 2005; Palmer, 2008; Buglife, 2009, 2012a,b; Courtney *et al*., 2010; Riding *et al*., 2010; Macadam & Bairner, 2012; Macadam *et al*., 2013; Robins *et al*., 2013; Tropek *et al*., 2013; Woch *et al*., 2013; Hodecek *et al*., 2015; Walmsley *et al*., 2017; Di Carlo *et al*., 2019; Gomes *et al*., 2019; Olds, 2019; Kupka *et al*., 2020; Macgregor *et al*., 2022).

My research, which began in 2019, involves the investigation of three important aspects of anthropogenic substrate sites: substrate chemistry and mineralogy; plant species and communities; and certain invertebrate species. Various analyses will be carried out to determine the minerals, elements and pH levels present in the different anthropogenic substrates. Various plant communities, as well as the species within them, were recorded in 2021 using quadrats in six study sites, three of these locations being in Scotland and three in northern England. I have been identifying the different species that were recorded, primarily bryophytes, grasses and wildflowers. A range of invertebrate species was recorded in 2021 throughout the three Scottish study sites. These invertebrates include butterflies and moths (Lepidoptera), true bugs (Hemiptera) and bees (Hymenoptera), as well as others from a range of taxonomic groups. In the context of the current biodiversity crisis, it is more important than ever before to record and assess the biodiversity of places, especially if such places tend to be overlooked in terms of biodiversity potential. Additionally, very few studies have investigated the relationships between plant species and the mineralogical and elemental composition of their growth substrates. This work will help with the investigation of plant establishment, survival and growth on anthropogenic substrates in a novel manner.

AIMS AND QUESTIONS

The primary aims and questions of my research are as follows:

1. What influence do substrate types have on plant species distributions?
2. How might anthropogenic substrates on field sites influence the invertebrate species and functional groups present?
3. How does substrate clay capping influence vegetation?
4. What is the influence of variability in steel slag substrate chemistry on plant species distribution?

These aims and questions concern different aspects of the substrate chemistry and wildlife present on brownfield sites. In particular, the investigation of steel slag sites is valuable as these areas are understudied compared with other types of wildlife sites in the U.K. (Ash *et al*., 1994; Skelcher, 2014; Gomes *et al*., 2019; Riding *et al*., 2020). It is expected that the investigation of substrates, plant species, plant communities and invertebrate species on anthropogenic substrate sites will yield information about these sites that will be valuable for a variety of researchers, conservationists and land managers, as well as members of the general public.

METHODOLOGY

Prior to fieldwork on anthropogenic substrate field sites, I acquired related and/or specific knowledge about relevant substrates, plant species and invertebrate species through literature searches, botanical and entomological training. This was done so as to make my independent fieldwork easier and better informed.

I carried out plant-related and substrate-related fieldwork at six study sites in the U.K., three in north-west England and three in central Scotland. The names and locations of these sites are listed in Table 1. Additionally, invertebrate-related fieldwork was completed at the three Scottish study sites; such surveys were not carried out on the English sites due to time and travel constraints. North-west England and Central Scotland have, historically, been centres of many types of industry (Price, 1983; Allan *et al*., 1997; Palmer, 2008; Warton Mourholme Local History Society Book Group, 2009; Skelcher, 2014; Riley *et al*., 2020). These sites were chosen to represent a wide range of substrate types and different geographies and topographies.

In preparation for plant-related fieldwork and data collection, a wooden 1 x 1 m quadrat, with 16 10 cm squares within the quadrat (marked out with rope), was made. This was used for the recording of plants at each of the six field sites. The fieldwork took place between 15th March and 31st July 2021. More specifically, plant-based fieldwork in the English sites took place between 10th and 21st July 2021, whilst Scottish plant-based fieldwork took place in March, May and July between 15th March and 31st July 2021. Field trips at the English sites were condensed into one visit due to time and travel constraints. Preliminary visits were carried out to scope each site and to determine the open plant communities, which would be surveyed, rather than the shrubby or forested plant communities, which have not been examined in the research. It is worth bearing in mind that this analysis did not determine plant communities using the traditional National Vegetation Classification (NVC) method, as I wanted to examine more specific species assemblages for the purposes of the study, and NVC communities are often a poor fit and not representative for many anthropogenic substrate sites (Maddock, 2010; Lush *et al*., 2013). In the field, the quadrat frame was placed on the ground once for each of the plant communities, with plant species recorded in that quadrat frame being deemed to be representative of the communities as a whole. Plant species, including bryophytes, ferns and angiosperms, were recorded. For each quadrat, plant species were recorded using videos captured on a mobile phone, which also included audio of plant community descriptions and lists of different species, as well as numbers of individuals. Certain specimens were also taken from the field and stored in scrapbooks on-site and off-site for later verification, identification and photography, where identification was not possible in the field with the limited time available.

Invertebrates were recorded at the three Scottish sites between the 23rd April and 19th September over 36 separate visits, twice each month (up to 14 for each site). This period of time was chosen to maximise the number of invertebrates that are likely to be recorded during the year. For every month, 2.5 h (±15 min) was spent looking for and recording invertebrates at most of the sites, including on the open plant communities that were also surveyed for plants, as well as the more shrubby and forested areas of the site. A mobile phone was used to record video, audio and location data relating to the different invertebrate records. Many invertebrate specimens were collected on-site to be more easily identified after fieldwork. These specimens were stored in a freezer shortly after each fieldwork trip. Additionally, during each two-monthly site visit, four pitfall traps were placed for 24 h (±15 min) in different parts of the site, placed in (1) different parts of the site and (2) differently shaded and exposed parts of the site. The specimens from these pitfall traps were also frozen shortly after fieldwork trips. The pitfall traps were very simple plastic pots, about 7 cm in diameter and 10 cm in height, which could be sealed with plastic screw-on lids. The bottom of each pot was filled with water and hand sanitiser (containing alcohol; see Simms, 2010; Laub

Site name	Location	Primary anthropogenic substrate/s
Addiewell bing (Scottish Wildlife Trust Nature Reserve) (Fig. 1)	Addiewell, West Lothian, Scotland	Oil shale spoil
Barrow slag bank	Barrow-in-Furness, Cumbria, England	Steel slag (natural clay cover is also present on part of the site)
Fallin bing (Fig. 2)	Fallin, Stirling, Scotland	Colliery spoil
RSPB Hodbarrow Nature Reserve	Hodbarrow, Cumbria, England	Blast furnace slag (much iron-rich sand is also present on-site)
South Bank Wood	Penicuik, Midlothian, Scotland	Paper mill sludge
Warton Slag Bank (part of the Morecambe Bay SSSI) (Fig. 3)	Warton, Lancashire, England	Blast furnace and steel slag

Table 1. Details of the six study sites.

Fig. 1. A view of part of the Warton slag bank, making up a cliff overlooking Morecambe Bay, Lancashire, England. (All photos: S. N. K van Mesdag)

Fig. 2. A view of part of the semi-open habitat on Fallin Bing, on top of the former Polmaise Colliery, Stirlingshire, Scotland.

Fig. 3. A view of a section of semi-open habitat, near scrub and woodland, on Addiewell Bing, West Lothian, Scotland.

et al., 2019) to help to immobilise trapped invertebrates. Unlike pitfall traps in many investigations, these were not covered with additional material in the field: this was partly for convenience but also considered satisfactory considering the fact that the pitfall traps were relatively small and operated for only 24 h, due to the time constraints of the fieldwork.

After fieldwork, specimens were observed and photographed using various equipment including simple microscopes. Soft-bodied specimens were primarily stored in ethanol after observation and photography, and hard-bodied specimens were primarily pinned and stored.

FURTHER WORK

Now that data and sample collection is complete, further work will include analysing the chemistry, mineralogy and elements of the substrate samples, and identifying the remaining unidentified invertebrates and plant specimens. These data will then be used for statistical analyses, primarily if not entirely on R Studio, to attempt to answer the research aims and questions . The results of this work will be presented as a Ph.D. thesis to the University of Glasgow and aspects submitted for publication to refereed journals. The intention behind this paper has been to outline the questions being addressed by the research and the methods being used.

REFERENCES

Allan, R.L., Dickinson, G., Dickson, J.H., Murphy, K.J., Pulford, I.D., Rogerson, R. & Watson, K. (1997). *The Natural Heritage Interest of Bings (Waste Tips) in Scotland: Inventory and Review*. Scottish Natural Heritage Review 48. SNH, Edinburgh.

Ash, H.J., Gemmell, R.P. & Bradshaw, A.D. (1994). The introduction of native plant species on industrial waste heaps: a test of immigration and other factors affecting primary succession. *Journal of Applied Ecology* 31, 74-84. https://doi.org/10.2307/2404600

Batty, L.C. (2005). The potential importance of mine sites for biodiversity. *Mine Water and the Environment* 24, 101-103. https://doi.org/10.1007/s10230-005-0076-0

Bodsworth, E., Shepherd, P. & Plant, C. (2005). *Exotic Plant Species on Brownfield Land: their Value to Invertebrates of Nature Conservation Importance*. English Nature Research Reports No. 650.

Bradshaw, A.D. (1977). Conservation problems in the future. *Proceedings of the Royal Society of London* 197B, 77-96. https://doi.org/10.1098/rspb.1977.0058

Bradshaw, A. (1997). Restoration of mined lands – using natural processes. *Ecological Engineering* 8, 255-269. https://doi.org/10.1016/S0925-8574(97)00022-0

Buglife (2009). *Planning for Brownfield Biodiversity: a Best Practice Guide*. Buglife, Peterborough. https://cdn.buglife.org.uk/2019/08/Planning-for-Brownfield-Biodiversity.pdf Accessed 4th November 2022.

Buglife (2012a). *Case Study: BP CATS, Teesside*. Buglife, Peterborough. https://cdn.buglife.org.uk/2020/01/BP-CATS-Teesside.pdf Accessed 4th November 2022. https://doi.org/10.1016/j.focat.2021.12.020

Buglife (2012b). *Case study: Untidy Industries, Basildon*. Buglife, Peterborough. https://cdn.buglife.org.uk/2020/01/Untidy-Industries-Basildon.pdf Accessed 4th November 2022.

Butt, K.R. & Briones, M.J.I. (2017). Earthworms and mesofauna from an isolated, alkaline chemical waste site in Northwest England. *European Journal of Soil Biology* 78**,** 43-49. https://doi.org/10.1016/j.ejsobi.2016.11.005

Courtney, R., Mullen, G. & Harrington, T. (2009). An evaluation of revegetation success on bauxite residue. *Restoration Ecology* 17, 350-358. https://doi.org/10.1111/j.1526-100X.2008.00375.x

Courtney, R., O'Neill, N., Harrington, T. & Breen, J. (2010). Macro-arthropod succession in grassland growing on bauxite residue. *Ecological Engineering* 36, 1666-1671. https://doi.org/10.1016/j.ecoleng.2010.07.006

Di Carlo, E., Chen, C.R., Haynes, R.J., Phillips, I.R. & Courtney, R. (2019). Soil quality and vegetation performance indicators for sustainable rehabilitation of bauxite residue disposal areas: a review. *Soil Research* 57, 419-446. https://doi.org/10.1071/SR18348

Environmental Protection Agency (2012). *A Citizen's Guide to Capping*. EPA 542-F-12-004. https://www.epa.gov/sites/default/files/2015-04/documents/a_citizens_guide_to_capping.pdf Accessed 4th November 2022.

Gemmell, R.P. (1976). The maintenance of grassland on smelter wastes in the Lower Swansea Valley. I. Blast Furnace Slag. *Journal of Applied Ecology* 13, 285-294. https://doi.org/10.2307/2401948

Gibson, C.W.D. (1998). *Brownfield: Red Data. The Values Artificial Habitats have for Uncommon Invertebrates*. English Nature Research Reports No. 273.

Gomes, H.I., Rogerson, M., Courtney, R., & Mayes, W.M. (2020). Chapter 7: Integrating remediation and resource recovery of industrial alkaline wastes: case studies of steel and alumina industry residues. In: *Resource Recovery from Wastes: Towards a Circular Economy*, pp. 168-191. Royal Society of Chemistry. https://doi.org/10.1039/9781788016353-00168

Gorman, S. (2009). *Proposal 1. Creation of New Carpark and Associated Infrastructure (6/09/9009) 2. Enhancement Works to Allow Public Access to Central Slag Banks (6/09/9010)*. Development Control and Regulation Committee 6/09/9009 & 9010. http://councilportal.cumbria.gov.uk/Data/Development Control and Regulation Committee/20091027/Agenda/(item 8) Planning Application No's 6-09-9009-10 New Car Park, Barrow Slag Bank, Barrow-in-Furness.pdf Accessed 4th November 2022.

Harrison, C. & Davies, G. (2002). Conserving biodiversity that matters: practitioners' perspectives on brownfield development and urban nature conservation in London. *Journal of Environmental Management* 65, 95-108. https://doi.org/10.1006/jema.2002.0539

Hitchmough, J., Kendle, T. & Paraskevopoulou, A.T. (2001). Seedling emergence, survival and initial growth of forbs and grasses native to Britain and central/southern Europe in low productivity urban "waste" substrates. *Urban Ecosystems* 5, 285-308. https://doi.org/10.1023/A:1025643929335

Hodecek, J., Kuras, T., Sipos, J. & Dolny, A. (2015). Post-industrial areas as successional habitats: Long-term changes of functional diversity in beetle communities. *Basic and Applied Ecology* 16, 629-640. https://doi.org/10.1016/j.baae.2015.06.004

Kupka, J., Svehlakova, H., Stalmachova, B. & Polacek, R. (2020). Botanical and zoological aspects of the shale post-mining landscape (Jakartovice village, Czech Republic). *IOP Conference Series: Earth and Environmental Science* 444, 012033. https://doi.org/10.1088/1755-1315/444/1/012033

Laub, C., Youngman, R.R., Love, K. & Mize, T. (2019). Using pitfall traps to monitor insect activity. *Virginia Cooperative Extension* 444-416.

Lush, M.J., Kirby, P. & Shepherd, P. (2013). *Open Mosaic Habitat Survey Handbook*. Exegesis Spatial Data Management, Talgarth, Brecon.

Macadam, C.R. & Bairner, S.Z. (2012). Urban biodiversity: successes and challenges: brownfields: oases of urban biodiversity. *The Glasgow Naturalist* 25(4), 29-32.

Macadam, C., Bairner, S., & Cathrine, C. (2013). *Open Mosaic Habitats on Previously Developed Land: Survey and Recommendations for Habitat Planning and Management in Scotland*. Scottish Natural Heritage Commissioned Report No. 606. https://www.nature.scot/doc/naturescot-commissioned-report-606-open-mosaic-habitats-previously-developed-land-survey-and Accessed 4th November 2022.

Macgregor, C.J., Bunting, M.J., Deutz, P., Bourn, N.A.D., Roy, D.B. & Mayes, W.M. (2022). Brownfield sites promote biodiversity at a landscape scale. *Science of the Total Environment* 804, 150162. https://doi.org/10.1016/j.scitotenv.2021.150162

Maddock, A. (2008, updated 2010). *UK Biodiversity Action Plan Priority Habitat Descriptions: Open Mosaic Habitat on Previously Developed Land*. BRIG, Joint Nature Conservation Committee, Peterborough.

Mathey, J., Arndt, T., Banse, J. & Rink, D. (2018). Public perception of spontaneous vegetation on brownfields in urban areas – results from surveys in Dresden and Leipzig (Germany). *Urban Forestry & Urban Greening* 29, 384-392. https://doi.org/10.1016/j.ufug.2016.10.007

Mayes, W.M., Younger P.L. & Aumônier, J. (2006). Buffering of alkaline steel slag leachate across a natural wetland. *Environmental Science & Technology* 40, 1237-1243.

Mayes, W.M., Younger, P.L. & Aumônier, J. (2008). Hydrogeochemistry of alkaline steel slag leachates in UK. *Water, Air & Soil Pollution* 195, 35-50. https://doi.org/10.1007/s11270-008-9725-9

Olds, L. (2019). *Invertebrate Conservation Value of Colliery Spoil Habitats in South Wales*. Colliery Spoil Biodiversity Initiative. https://collieryspoilbiodiversity.files.wordpress.com/2019/04/invertebrate-conservation-value-of-colliery-spoil-habitats-2019.pdf Accessed 4th November 2022.

Palmer, J. (2008). *Cumbria Species and Habitats Statements (With Habitat Targets, Planning Considerations and Enhancement Opportunities)*. Cumbria Biological Data Network.

Piatak, N.M., Parsons, M.B. & Seal II, R.R. (2015). Characteristics and environmental aspects of slag: a review. *Applied Geochemistry* 57, 236-266. https://doi.org/10.1016/j.apgeochem.2014.04.009

Price, W.A. (1983). *Industrial Archaeology of the Lune Valley*. University of Lancaster.

Richardson, P.J., Lundholm, J.T. & Larson, D.W. (2010). Natural analogues of degraded ecosystems enhance conservation and reconstruction in extreme environments. *Ecological Applications* 20, 728-740. https://doi.org/10.1890/08-1092.1

Riding, A., Critchley, N., Wilson, L. & Parker, J. (2010). *Definition and Mapping of Open Mosaic Habitats on Previously Developed Land: Phase 1*. ADAS UK Ltd. https://data.jncc.gov.uk/data/a81bf2a7-b637-4497-a8be-03bd50d4290d/UKBAP-BAPHabitats-40-OMH-2010.pdf Accessed 4th November 2022.

Riley, A.L., MacDonald, J.M., Burke, I.T., Renforth, P., Jarvis, A.P., Hudson-Edwards *et al.* (2020). Legacy iron and steel wastes in the UK: Extent, resource potential, and management futures. *Journal of Geochemical Exploration* 219, 106630. https://doi.org/10.1016/j.gexplo.2020.106630

Robins, J., Henshall, S. & Farr, A. (2013). *The State of Brownfields in the Thames Gateway*. Buglife, Peterborough. https://cdn.buglife.org.uk/2019/07/Summary-The-state-of-brownfields-in-the-Thames-Gateway.pdf Accessed 4th November 2022.

Saether, O.M., Banks, D., Kirso, U., Bityukova, L. & Sorlie, J.E. (2004). The chemistry and mineralogy of waste from retorting and combustion of oil shale. *Energy, Waste and the Environment: A Geochemical Perspective* 236, 263-284. https://doi.org/10.1144/GSL.SP.2004.236.01.16

Simms, Ó., Jonsson, T. & Emmerson, M.C. (2010). Temporal variability in predator-prey relationships of a forest floor food web. *Advances in Ecological Research* 42, 171-264. https://doi.org/10.1016/B978-0-12-381363-3.00004-6

Skelcher, G. (2014). *Arnside & Silverdale Area of Outstanding Natural Beauty. Special Qualities Report*. https://www.arnsidesilverdaleaonb.org.uk/uploads/2016/03/mp_specialqualitiesreport.pdf Accessed 4th November 2022.

Thomas, R.N. (1930). Flora of paper-mill lime waste dumps near Glasgow. *Journal of Ecology* 18, 333-351. https://doi.org/10.2307/2256012

Tropek, R., Cerna, I., Straka, J., Cizek, O. & Konvicka, M. (2013). Is coal combustion the last chance for vanishing insects of inland drift sand dunes in Europe? *Biological Conservation* 162, 60-64. https://doi.org/10.1016/j.biocon.2013.03.027

Walmsley, A., Vachová, P. & Vach, M. (2017). Topography of spoil heaps and its role in plant succession and soil fauna presence. *Scientia Agriculture Bohemica* 48, 30-38. https://doi.org/10.1515/sab-2017-0005

Warton Mourholme Local History Society Book Group (2009). *Warton Parish 1850-1900: Borwick, Carnforth, Priest Hutton, Silverdale, Warton, Yealands*. Mourholme Local History Society, Warton, Lancashire.

Woch, M. W., Radwańska, M. & Stefanowicz, A. M. (2013). Flora of spoil heaps after hard coal mining in Trzebinia (southern Poland): effect of substratum properties. *Acta Botanica Croatia* 72, 237-256. https://doi.org/10.2478/v10184-012-0020-x

Woods, R. (2012). Brownfield sites and moth diversity in the Tees Estuary. *Entomologists' Record and Journal of Variation* 124, 89-100.