Characterising vibrational landscapes around mineral extraction sites: accelerating knowledge regarding noise and soil-associated biota

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Project Highlights:

- **Novel integration of the new discipline of biotremology with seismology and community ecology:** combining knowledge of how animals sense, use and respond to substrate-borne (ground) vibrations, with seismological measurements of extraction operations.
- **Investigation of individual-level and community-level biological responses:** focussing on soil-dwelling macrofauna and plants in varied experimental contexts.
- **Formulation of a cohesive assessment of the biological impact of ground-borne vibrations around extraction sites:** combining knowledge of potential vibrational noise impacts with sustainable extraction practises and management to inform future strategies.

Overview:

The global transition towards low-carbon technologies is driving demand for critical minerals and metals required for renewable energy systems, battery storage, and advanced manufacturing. While mineral extraction is essential for achieving net-zero targets, there remains limited understanding of ecological impacts on varied temporal and spatial scales.

Soil-dwelling invertebrates, including earthworms, ants, beetles and other macrofauna, play fundamental roles in ecosystem functioning through nutrient cycling, soil formation, and organic matter decomposition. Many of these organisms rely on substrate-borne vibrations in the soil to locate resources, communicate, sense and navigate their environment.

Noise has been shown to have negative behavioural and physiological impacts on animals, but so far has predominantly been investigated in terms of air-borne or water-borne sound. Given the importance of the vibrational mode to many taxa, ground-borne noise (vibrational noise) presents an additional potential stressor which is so far unquantified. Vibrational noise may be generated by mineral extraction activities at all phases of operation, for example via drilling, blasting and excavation. The influence of this mining-related noise on below-ground ecosystems represents a significant knowledge gap, and may alter behaviour, physiology and community dynamics in ways that remain poorly understood.

This PhD project will investigate the potential impacts of vibrational noise on soil invertebrates and plants by integrating field measurements, biological experimentation, and ecological assessment. The research will involve quantifying ground vibrations around active extraction sites, searching for any available existing vibration datasets, and developing controlled exposure experiments to determine responses to vibrational regimes. By linking measurements of vibration with biological and ecological outcomes, the project will generate novel insights into an overlooked environmental pressure associated with resource extraction. Ultimately the data from this project will seek to support the future of resource extraction operations within an ecologically-minded framework.

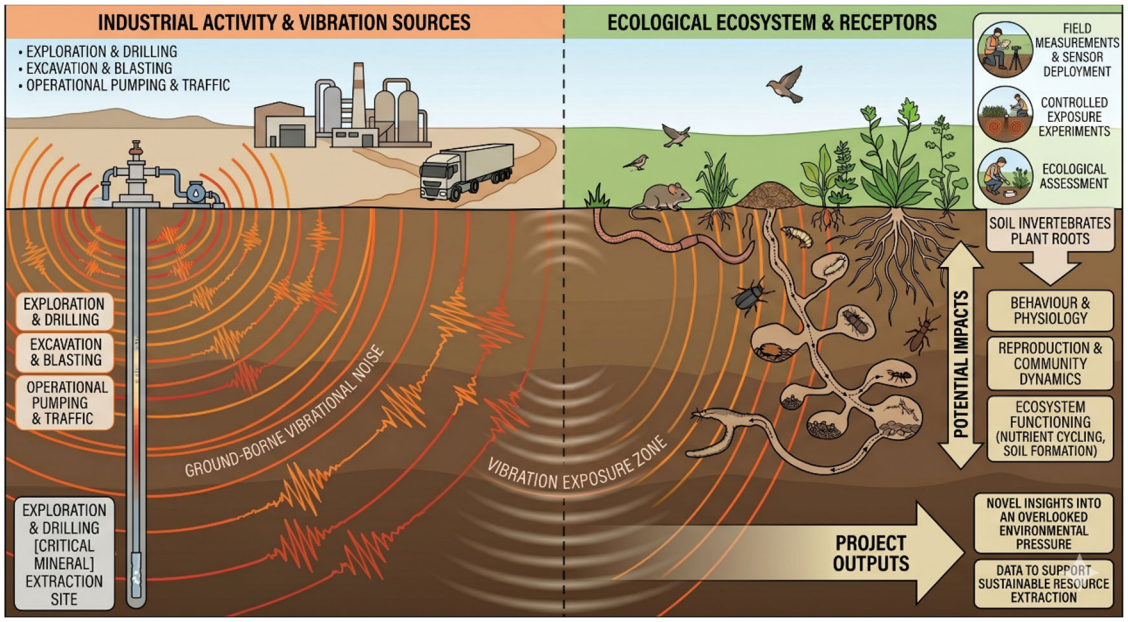

Figure 1: Diagram illustrating the interaction between industrial activity and ecological ecosystems through ground-borne vibrations.

Alt. text: Diagram illustrating the interaction between industrial activity and ecological ecosystems through ground-borne vibrational noise sources. The left section illustrates industrial activities like drilling, blasting, and traffic generating vibration noise in orange waves, while the right section depicts soil invertebrates, plant roots, and animals affected within a vibration exposure zone, highlighting potential impacts on behaviour, reproduction, and ecosystem function with labelled project research methods.

Methodology:

This project will address the following four questions:

1) How can mining-generated ground vibrations be characterised and modelled across different extraction technologies and environmental settings?

2) What vibrational thresholds, if any, trigger measurable behavioural or physiological responses in soil-dwelling invertebrates?

3) To what extent do the vibrations of mining activities affect the development and growth of relevant plants such as grasses under medium to long-term scales?

4) How can knowledge of potential vibrational impacts be incorporated into sustainable mineral extraction practises and management strategies?

Using a combined laboratory and field approach, the student will:

(i) Quantify the spatial and temporal characteristics of ground-borne vibrations around mineral extraction activities, across a range of soil types, landscapes and extraction technologies.

(ii) Examine the responses of soil-dwelling organisms (e.g., earthworms, ants) to vibrational noise under controlled laboratory conditions, paired with field exposures and surveys.

(iii) Cultivate selected common grass varieties under vibrational noise conditions in the laboratory, investigating plant structure, growth and function in relation to treatment.

(iv) Assess whether any individual-level responses scale up to community and ecosystem-level changes and ecosystem functioning.

(v) Combine vibrational measurements, laboratory and field-based biological data with distributional data, to assess and model impact ranges around extraction sites to inform impact assessments.

Possible Timeline

Year 1:

- Comprehensive literature review regarding vibrational noise and soil-dwelling biota, biotremology and seismology.
- Training in vibrational noise measurement and analysis.
- Testing and calibration of vibrational noise playback technologies and techniques for soil-borne noise exposures.
- Search and (potential) acquisition of existing vibrational data around relevant extraction operations.
- Set-up and identification of most feasible field sites where vibrational noise can be characterised around existing operations; vibrational noise surveys around various operations.
- Year 2:
- Running biological response exposure experiments at vibrational amplitudes relevant to particular distances from extraction sources: focussing on soil-fauna and grasses in laboratory conditions.
- Expansion of experiments to mesocosm community-level experiments in outdoor laboratory conditions.
- Year 3:
- Continuation of community-level experiments in conditions as realistic to actual mining operations as is feasible depending on field site access and partner collaborations.
- Integration of biological results, vibrational noise data into a holistic assessment of actual anthropogenic operations with a view to informing future sustainable practises.
- Presentation of results at conferences and manuscript writing.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

Partners and collaboration (including CASE):

Dr Louise Roberts (University of Liverpool) brings expertise in sensory ecology, biotremology and soil ecosystems including the exposure of invertebrates to vibrational noise. Professor Kate Parr (University of Liverpool) will contribute expertise in community and ecosystem ecology, and responses to disturbances, with a focus upon ecosystem functioning and biodiversity particularly regarding social insects, ants and termites. Professor Ben Edwards (University of Liverpool) has extensive experience of seismology in both industrial and academic contexts, with research focussed around seismic hazard and risk and seismic site characterisation. Professor David Burslem has extensive (Aberdeen) knowledge of plant science, soil ecology and fertility, biodiversity assessments and conservation. Dr Tom Bishop will bring a wealth of experience to the team regarding physiological and behavioural traits of small cold-blooded organisms, ecological and morphological trait-analysis.

The supervisory team are in discussions with relevant industry project partners; further information will be provided soon.

Further reading:

Hill, P. S. M., & Wessel, A. (2016). Biotremology. *Current Biology*, *26*(5), R187–R191.

Roberts, L., & Howard, D. R. (2022). Substrate-Borne Vibrational Noise in the Anthropocene: From Land to Sea. In P. Hill, V. Mazzoni, N. Stritih-Peljhan, Virant-Doberlet, & W. A (Eds.), *Biotremology: Physiology, Ecology, and Evolution* (1st ed., pp. 123–155). Springer Cham.

Phillips, J.N., Termondt, S.E., & Francis, C.D. (2021) Long-term noise pollution affects seedling recruitment and community composition, with negative effects persisting after removal. *Proceedings of the Royal Society B*, 288, 20202906.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply. Informal enquiries regarding this project may be addressed to Dr Louise Roberts Lou.Roberts@liverpool.ac.uk https://www.liverpool.ac.uk/people/louise-roberts