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Impacts of climate change related flooding on earthworm populations

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Earthworms play important roles in maintaining soil structure and function, soil aeration, drainage, the moisture holding capacity of soils and the cycling of nutrients. The presence of earthworms in soil can lead to greater plant growth. Evidence suggests that earthworm abundance has been declining over the last several decades, which potentially negatively impacts soil function. Anthropogenic climate change means extreme weather events are becoming more frequent and intense; flooding is particularly relevant for earthworm populations, with increasing flood frequency and duration. Soils become rapidly anoxic when flooded, which threatens earthworm survival. We are investigating whether flooding is likely to change earthworm populations, through changes in abundance, diversity and distribution.

We carried out surveys to sample earthworms, collecting data on abundance and species distributions at field sites with twinned flooding and non-flooding areas and differing soil moistures and flooding histories. In laboratory experiments we have been working with common UK species, such as the lob worm *Lumbricus terrestris*, the green worm *Allolobophora chlorotica*, the grey worm *Aporrectodea caliginosa*, the blue-grey worm *Octolasion cyaneum*, and the European nightcrawler compost worm *Dendrobaena veneta*.

To determine moisture preferences of earthworm species we carried out choice chamber experiments, providing standard soils with a gradient of soil moisture contents. All species had similar, but soil specific, moisture preferences, choosing moist, but not waterlogged conditions.

Survival experiments were carried out, exposing earthworms to conditions of restricted oxygen, simulating flood conditions. Species commonly found in wetter or drier soils were found to survive for a similarly short duration of approximately 22 hours in oxygen-depleted water (0.25 mg l^{-1} dissolved oxygen). This is in contrast to our previous research in which *A. chlorotica*, a species that is able to aestivate, survived in oxygen-depleted water, whereas *L. terrestris* did not.

Furthermore, *A. chlorotica* has more oxygen-carrying haemoglobin (0.22 vs 0.125 µmol Hb g^{-1}), and its haemoglobin is more efficient at binding and retaining oxygen than the much larger *L. terrestris* (4.18 vs 11.47 mmHg P_{50}), which suggests that *A. chlorotica* may be better adapted to survive in oxygen-depleted conditions resulting from flooding.

We are also monitoring the hatching success of earthworm cocoons exposed to 90 hours of oxygen depletion in simulated flood conditions. Cocoons were subjected to oxygenated conditions of 2 mg l^{-1} or a treatment restricted to 0.25 mg l^{-1} of dissolved oxygen for the duration. The majority of cocoons of *A. chlorotica* and *D. veneta* remain viable when subjected to reduced oxygen but suffer lower hatching success than those with unrestricted oxygen. A difference was found between species, *D. veneta* retained higher viability than *A. chlorotica*, time to hatching was found to be delayed in both species when exposed to low oxygen conditions.

The above evidence is consistent with an increasing frequency of flooding causing changes in earthworm population structure and potentially reducing earthworm abundance, with cocoons being a key component for the survival of earthworm populations after flood events. Our results highlight one possible consequence of climate change on earthworm populations and consequent impacts on soil functionality.