SPRING INTO ACTION: LIFE IN EARTH'S RAREST SOILS UNDER THREAT

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Invasive springtail (Collembola) in sub-Antarctic soil
PHOTO CREDIT: Laura Phillips

Springtails (Collembola) in the Antarctic indicate that unique soil biodiversity in the region faces biotic homogenization due to increased human activity

Efforts to understand and protect Earth's biodiversity have largely overlooked life present in the soil. However, soil biodiversity is critical to ecosystem health, playing an integral role in nutrient cycling, carbon storage, water filtration, and food production¹.

The Antarctic, once a pristine wilderness, is undergoing rapid environmental change and increased human pressures. Yet the true diversity, uniqueness, and vulnerability of its soil communities are only beginning to be revealed. As tourism and science expeditions bring ever more passengers and cargo to Antarctica, human-induced transport of species ('biological invasion') – both into and throughout the region – presents a growing threat to soil biodiversity, as highlighted recently in our [study](#).

In the Antarctic region, which broadly covers approximately 30% of the planet's surface, soil organisms represent the vast majority of terrestrial life. Antarctic soil organisms,

which include nematodes, mites, springtails, fungi, and tardigrades, have eked out a largely isolated existence over millions of years in fragmented patches of ice-free land on the continent, or on the sub-Antarctic islands. On the Antarctic continent, ice-free soil represents <1% of the total land area and can be found on mountain tops, scree slopes, valleys, and the coast. The sub-Antarctic islands encircle the continent, located in the frigid waters of the Southern Ocean and each is separated by up to thousands of kilometres of open ocean. Antarctic soil species are therefore highly isolated and possess unique adaptations to their harsh environment. They are at risk of being outcompeted, or ultimately even replaced, by invasive species as the climate warms².

In our study, we used DNA barcoding to investigate the spread of an invasive springtail species, known to adversely affect native soil species, across the sub-Antarctic islands. Identification of numerous divergent barcode se-

THE ANTARCTIC TERRESTRIAL BIOME NEAR MCMURDO STATION
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quences revealed that the invasive has been introduced to Antarctica several times.

By comparing barcodes from Antarctic specimens in **BOLD** to those found elsewhere in the world, we could identify genetic lineages shared across countries which aligned with known shipping routes to the Southern Ocean, highlighting the utility of molecular tools in tracking invasion. For example, a shared barcode haplotype between Norway and the sub-Antarctic island of South Georgia accords directly with Norway's long history of whaling on this island. That a well-known invasive species has been introduced on multiple occasions to such a remote region emphasises the importance of ongoing biosecurity monitoring, even for invasive species that have already established, since multiple invasions can introduce more genetic resilience and enable the invasive species to spread.

Our study also explored the consequences of intra-regional human transport on native soil species. Antarctic soil organisms are typically highly endemic, even to local patches within the region. This raises the concern that increased human traffic throughout Antarctica could transport and ultimately homogenise soil populations, altering the region's unique biogeography. Using genome-wide SNPs, we showed that a widespread native springtail species is indeed so distinct between sub-Antarctic islands that it is likely in the process of speciating. Clearly, future exchange of individuals among islands could possibly dis-

HELENA BAIRD AND COLLEAGUES BUSY WITH SUB-ANTARCTIC FIELDWORK ON MARION ISLAND WHILE KING PENGUINS WATCH IN THE BACKGROUND
PHOTO CREDIT: CHARLENE JANION-SCHEEPERS

rupt this biodiversity process, diluting the specific adaptations each population has evolved over millennia. Potential evolutionary consequences include a decrease in the fitness of island-specific populations, lineage extinction, or the loss of biodiversity by 'reverse speciation'³.

Regardless of the outcome, the threat of disrupting biodiversity processes among these unique and fragile islands emphasises the importance of biosecurity for ships travelling throughout the Southern Ocean, particularly when passengers embark and disembark at multiple locations.

One of the main hurdles to accurately predicting future changes to soil communities is a lack of basic biodiversity knowledge. In the Antarctic, molecular work such as metabarcoding continues to reveal far more soil diversity – most of which is locally endemic – than previously recognised^{4,5}. This situation echoes worldwide, with biodiversity and biogeography patterns constantly revised as we probe the soil biome deeper. Fortunately, schemes such as the Global Soil Biodiversity Initiative are bringing fragile soil ecosystems under the spotlight, where we will be better served to protect them.

SOIL SAMPLING WITH THE USE OF A SOIL CORE — AN UNDISTURBED CYLINDRICAL SAMPLE

PHOTO CREDIT: CHARLENE JANION-SCHEEPERS

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CHARLENE JANION-SCHEEPERS (LEFT) AND HELENA BAIRD (RIGHT) SORT SOIL SPECIES AT SEA USING BERLESE FUNNELS

PHOTO CREDIT: STEVEN CHOWN

RESEARCH VESSEL AS IT APPROACHES POSSESSION ISLAND, CROZET ARCHIPELAGO, ONE OF THE SUB-ANTARCTIC ISLANDS IN THE REGION

PHOTO CREDIT: HELENA BAIRD

TAKING A BREAK TO ENJOY THE VIEW IN THE SUB-ANTARCTIC

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