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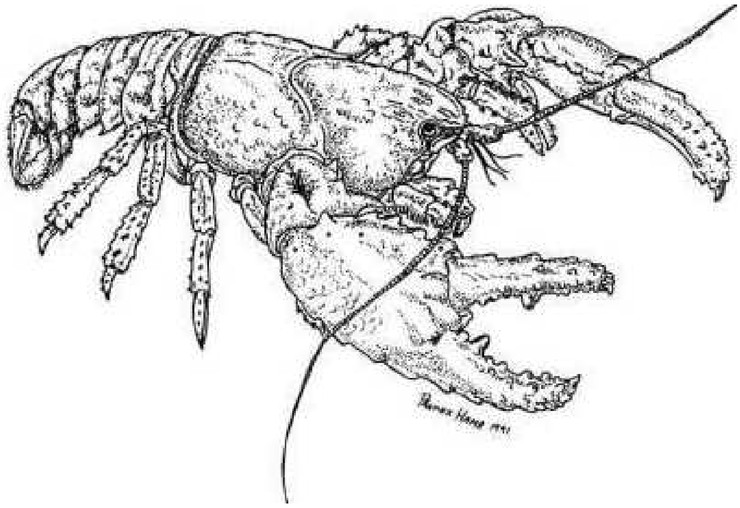

Factors Affecting Soil Biology

by **Sue Gebicki**

Collembola on slime mould

The environment is changing at an unprecedented rate and one of the best survival techniques for soil biota is adaptability, and to be adaptable it must be diverse. The most recent figures from a study of 2 million records for nearly 40,000 terrestrial species have found that across 65% of the land, biodiversity has decreased by over 10%.

The effects of disturbance to soil ecosystems may be positive or negative, depending on the amount. Generally, high disturbances are the main cause of species loss as only the species tolerant of stress can survive. In frequently disturbed soils well-adapted bacteria tend to predominate.

Causes of species loss include conversion of ecosystems, deep ploughing, irrigation, chemicals, vegetation removal, roads and building construction, over-grazing, the use of genetically modified organisms and unnatural fire regimes. These cause erosion, salination, pollution, compaction, and acidification of the soil.

Conversion of natural ecosystems to agriculture and changes in land use are the most common causes of extinction as they are imposed on large scales and do not allow species time to adapt. Research in disturbed forested ecosystems has shown that alteration of the soil can affect vegetational succession, in some cases resulting in sites that cannot be regenerated to particular vegetation communities. The conversion of forests and native grasslands to croplands and plantations reduces the soil's capacity to act as a carbon sink by as much as 20-40%.

Soil compaction is caused by heavy machinery, repeated tillage, running stock on wet soil and, in Australia, by introduced hard-hoofed animals. Compaction results in loss of soil aeration and water infiltration which favours anaerobic bacteria that are more likely to be pathogenic, leading to a decrease in plant growth and a loss of earth worms and microinvertebrates.

Additions to the soil include fertilisers, lime, chemicals, sludges and animal excreta. Fungicides reduce beneficial fungi and herbicides remove plants which reduces soil biotoa. Herbicides can be toxic to some organisms, particularly nitrifying bacteria, and their continued use significantly affects micro-organisms. Research has found long-term impacts on vegetation communities up to 16 years after a single herbicide application. The use of inorganic fertilisers has a range of effects: increased vegetation growth supports higher biota populations, but high applications of nitrogen fertiliser causes the microbial population to fall, probably by acidifying the soil. Nitrogen-rich fertilizers also favour bacterial growth over fungi. High inputs of fertilisers can reduce the symbiotic effectiveness of soil organisms. Pesticides alter the balance of soil biota by selectively removing some species.

Cultivation causes rapid decomposition and nutrient mineralisation through improved soil-stubble contact and increased respiration rate. This leads to less organic matter, and fewer earthworms. It is particularly deleterious for fungi as it severs the hyphae.

The consequences of fire are determined by fire intensity, duration and frequency, soil moisture and vegetation type. High intensity fires remove or destroy litter and organic matter in the top few centimetres of soil, with a loss of nitrogen, carbon, phosphorus and other nutrients but an increase in nutrients such as calcium, phosphorus and potassium. Low intensity fires can increase the nitrogen availability in soil. Fire changes the water repellence of soil, making it more susceptible to erosion and ability to absorb heat. The re-establishment of soil biota after fire varies from a few days to several years. For example, Ratkowski and Gates (2008) have found changes reflected in a fungal community more than 75 years after fire in a wet sclerophyll forest.

The removal or degradation of vegetation and deep tillage make the litter and topsoil more susceptible to erosion. This can set up a vicious cycle in which the eroded soils are less able to support vegetation and so are even more likely to erode. Australia is particularly prone to erosion due to its ancient and fragile soils. More than 90% of collembola are located in the top 5 cm of soil, so numbers decline rapidly if erosion occurs.

Salination that occurs near the soil surface can cause desiccation of some organisms. More salt-tolerant organisms may benefit by the increased availability of organic matter, although this will only be temporary if vegetation fails to grow. Salination can ultimately lead to desertification. Large swathes of soil in Australia have been lost to salinity through excessive extraction of groundwater. Vegetation removal and inappropriate irrigation causes the water table to rise, which brings dissolved salts into the top soil as the water evaporates.

When soils are covered by an impermeable layer, e.g. by urbanisation, the soil biota exhausts the existing moisture and organic matter and most eventually die. Roads have been shown to impact macroinvertebrate abundance and microbial activity for up to100 m from roadsides, and faunal diversity for 15 m. The pathogen *Phytophthora cinnamomi* is known to spread along roads, onto verges and into the watershed up to 600 metres from the road. The greatest incidence is near 4WD tracks – certainly worrying information for 'recreational' driving in World Heritage Areas.

Changes in soil pH can affect the metabolism of organisms by affecting the activity of enzymes and nutrient availability, and affecting the symbiotic relationships between vegetation and organisms. Most soil fauna have little capacity to cope with large changes in pH, and most macrofauna decrease in acidic soils.

Acidification is caused by pasture improvement and removal of crops, nitrogen fertilizers, nitrate leaching, build-up of organic matter and plantation forestry. While the build-up of organic matter is potentially acidifying, it can also buffer against acidificatio, depending on the nature of the organic matter and the soil history. Forestry involves the removal of biomass which contains large amounts of cations, resulting in the lowering of soil pH. This is further exacerbated when acidifying plantation trees are established. The extent of acidity is increasing in the surface layers of cropping soils in all major grain growing areas of Australia.

Genetically modified plants have been found to principally affect the chemical processors, or decomposers, by altering the quantity and quality of growth substances, the structure of bacterial communities, bacterial genetic transfer and the efficiency of microbial-mediated processes. They favour the development of genetic resistance in target pest organisms, alter the mycorrhizal colonisation of roots and effect earthworm physiology.

Soil biota and climate change

How will organisms in soil respond to climate change? The direct effects of climate change on the relative abundance and function of soil communities have been studied extensively. However, less focus has been placed on the indirect effects and the interactions between them, which may be as large, or larger than, the direct effects.

Analysis of the impacts of elevated CO2 on soil microorganisms concluded that levels of microbial biomass and fungal abundance increase, but conflicting results occur for bacterial diversity and abundance. Results demonstrate that increased CO2 causes changes in the structure of the soil.

Results from warming showed positive and consistent results for increases of microbial, fungal and bacterial abundance, which almost certainly causes changes in the structure of the soil. However in long-term field studies these increases were found to be short-lived.

Drought was found to increase fungal abundance consistently relative to that of bacteria, but decrease the biomass and abundance of most microbial and soil fauna. It particularly impacts fauna that depend on a water film, such as protozoa and nematodes, and reduces the diversity of mites and collembola.

Fewer studies have been conducted on the effects of increased flooding and rainfall, although these are certain to alter the soil environment by increasing erosion, removing nutrients and litter, creating periods of anaerobic conditions and affecting the soil properties.

Analysis of the effects of climate change on soil fauna revealed that responses of different groups are highly variable. Nematodes increase in abundance with warming; collembola and enchytraeids increase with increased precipitation. Several studies found elevated CO2 levels caused a decrease in diversity of faunal groups and growth of earthworms and collembola.

Plants are migrating with temperature, but not much is known about the ability of microorganisms to shift their range. Climate change can provoke loss of species due to nutrient enrichment of native ecosystems which favour fast-growing species. Observations in Germany on a broad scale over the last 20 years have found the average yields of agricultural production increased by 10%. Mineral fertilization had been reduced and there were no large scale changes in agricultural practices, so the increase was possibly caused by climate change.

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