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INTERACTIONS BETWEEN NATIVE AND INTRODUCED EARTHWORMS

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There are three ways in which one group of animals may interact with another. They may (i) compete for food, (ii) compete for living space, or (iii) prey upon one another.

This paper discusses the taxonomic status and ecological preferences of the native and introduced earthworms and the extent to which they interact in these three ways.

Included in the native earthworms are about 170 species, all belonging to the family Megascolecidae. The introduced earthworms comprise 14 species of the family Lumbricidae and five species of the family Megascolecidae.

NATIVE EARTHWORMS

Two distinct subfamilies of Megascolecidae are found in New Zealand. In one subfamily (Acanthodrilinae) there are 17 New Zealand genera, of which 14 are confined to New Zealand, while in the other subfamily (Megascolecinae) there are 10 genera, none of which is peculiar to New Zealand. It is considered that both groups have been here for a long time. The Acanthodrilinae probably arrived in Mesozoic times and the Megascolecinae in early Tertiary times.

Many of the native species are highly specialised, morphologically, physiologically, and in their behaviour, to fit them for a very limited range of ecological conditions. They are primarily inhabitants of forest soils, and appear to have only recently spread into open country habitats.

In forest soils, three groups of native worms are recognisable on ecological grounds. Some inhabit leaf mould on the ground surface, some topsoil, and some subsoil. Leaf mould species move about among the plant debris and make no permanent burrows. They are mostly small in size, very active, and darkly pigmented. They feed on the leaf mould in which they live. Topsoil species make permanent burrows in the topsoil, leaving them only to forage for food in the leaf mould above. Apart from feeding on leaf mould, they apparently also continue burrowing to some extent throughout their lives, feeding on organic matter in the topsoil and extending their burrows laterally within the topsoil. They are larger than leaf mould species, and are not so active nor so darkly pigmented. Subsoil species make very extensive burrows, mainly in the subsoil, but occasionally coming up into the topsoil or even opening at the soil surface. They seem to feed mainly on the organic matter contained in subsoil and they make very extensive burrows, feeding on the soil as they move along. They are usually of large size, sluggish in their movements and unpigmented or very lightly pigmented.

INTRODUCED EARTHWORMS

There is no record of any deliberate introduction of Lumbricidae into New Zealand. All the species are of European origin and almost certainly came from Great Britain with the early settlers, probably within the

last 120 years. Smith (1894) was the first to refer to their introduction. He attributed their introduction to the importation and widespread planting of English trees and shrubs and to the dumping of soil that was frequently used as ballast in ships from England. Lumbricidae are found in New Zealand in soils under pasture and in cultivated land. Four species, *Allolobophora caliginosa, A. terrestris, Lumbricus rubellus* and *Octolasium cyaneum* are very widespread, and there can hardly be a pasture or garden soil in New Zealand where one or more of these species would not be found.

Lumbricidae are the dominant earthworms of Great Britain and Europe. The four species that are most common in New Zealand are widely distributed in England and are most commonly found in cultivated land, parks, gardens and pastures (Cernosvitov and Evans 1947). They are topsoil species, and in pasture soils are most common very close to the surface, among the roots of pasture grasses. They feed mainly on dead grass roots (Waters 1955). They reproduce rapidly and, in fertile New Zealand pastures, populations of three to five million per acre have been found.

The introduced Megascolecidae have little significance as an element in the New Zealand fauna, as they appear to be represented only by small populations or isolated individuals that have been found in cultivated gardens and nursery glasshouses.

Darlington (1959) states that "dominant animals are conspicuously successful ones. Dominant groups are usually numerous in species, often diverse in adaptations, and often widely and continuously distributed in diverse habitats." Megascolecidae in New Zealand apparently fitted this statement closely before European settlement, and still do where soils and vegetation have had little human interference. Lumbricidae in Europe also fit the statement closely. It should therefore be of interest to see the result when a dominant group of native soil animals is faced with widespread introduction of a potentially dominant group of alien soil animals.

The feeding habits of the two groups exclude the possibility of predation one on the other as a significant factor in any interaction that may take place between them. There remain only competition for food or competition for living space as possible points of interaction.

In 1954, an area of scrub was cleared and sown in pasture on Taita hill soils (moderately weathered yellow-brown earths) at the Taita Experimental Station. Changes that took place in the soil fauna were studied (Miller, Stout and Lee 1955). Before the scrub was cut and burned the earthworms present were *Eodrilus pallidus*, a leaf mould species, *Maoridrilus ruber*, a topsoil species, and *Octochaetus multiporus*, a subsoil species. The felled scrub was burned in May, 1954. In July 1954, sampling showed that there was still much of the original leaf mould on the surface among small pasture plants. The earthworm fauna had not changed greatly, although *Eodrilus pallidus* was found to have moved down into the topsoil. By March, 1955, *Eodrilus pallidus* and *Maoridrilus ruber* had entirely disappeared, but *Octochaetus multiporus* remained in the subsoil, apparently unaffected. By this time there was little or no leaf mould on the soil surface, and this was fairly obviously the cause of extinction of the leaf mould and topsoil earthworms. There was then a period when there were no topsoil earthworms at all, and this was followed by the arrival of lumbricids. *Allolohophora calignosa* and *Lumbricus rubellus* are now found in the topsoil and *Octochaetus multiporus* continues to live in the subsoil.

A similar series of changes was noted in soils formed from Taupo pumice in the Waikite-Ngakuru area, south of Rotorua (Lee 1959). Under the original vegetation (manuka, bracken, some tussock) a small population of *Rhododrilus similis*, a native topsoil species, was found. Nearby, the land was being developed, or had been developed, for dairy farming. Earthworms were collected from pastures at various stages of development. It was found that *Rhododrilus similis* disappeared very rapidly when the native vegetation was removed. In pastures up to about three years old there were no earthworms. After four or five years, lumbricids could be found in the pasture soils, and in progressively older pastures the population of lumbricids increased until populations of one to two millions per acre,

dominated by *Allolobophora caliginosa* or *A. terrestris*, were found.

These examples can be taken as typical of what has happened wherever native vegetation has been cleared and replaced by pasture. There has been no competition between native and introduced species, either for food or for living space. All but subsoil species among the native earthworms have died out before the introduced lumbricids became established, and the few subsoil earthworms that have remained do not compete with the lumbricids, as the latter are confined to the topsoil.

Where native vegetation has not been interfered with introduced earthworms are usually absent, and if present they are usually rare. An exception to this generalisation is found at Raoul Island, where the dominant earthworm of forest litter and topsoil is *Eisenia foetida*, an introduced lumbricid. *E. foetida* is usually found in New Zealand, and in Europe, in compost and manure heaps, and is rare in agricultural soils. Its presence in forest soils at Raoul Island probably results from the high rate of decomposition of forest litter in a warm climate, producing conditions that would not be found in forests in the cooler climate of New Zealand. In addition to the higher rate of litter breakdown, the spread of *E. foetida* has apparently been facilitated by the absence of native topsoil earthworms on Raoul Island. The native earthworm fauna of Raoul consists of only two species of very small leaf mould earthworms. So in this case too, there has apparently been no competition either for food or for living space between introduced and native species.

The introduction of European earthworms has been accompanied by far reaching changes in the soil environment, brought about by man. The result has been that the native earthworm fauna has been destroyed, but its destruction stems directly from the man-induced environmental changes, and is not a result of interaction between introduced and native species. The same can be said of many groups of soil invertebrates, and may well be true of other animal groups.

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THE INTERACTION OF NATIVE AND INTRODUCED BIRDS IN NEW ZEALAND

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The purpose of this paper is to outline the factors which are believed to influence the status of native and introduced birds — including their interaction — and as a background it will be necessary to re-examine the history of settlement. Some effects of settlement are obvious: the clearing of forest and the acclimatisation of birds from overseas were major events transforming certain aspects of the environment. Other events, especially the arrival of mammalian predators and probably of avian diseases, did not