A soil invertebrate indicator for New Zealand pastoral soils

Nicole Schon[A], Maria Minor[B], Alec Mackay[C], Gregor Yeates[D] and Mike Hedley[E]

[A] Ecology Department, Massey University, Palmerston North, New Zealand, Email nicoleschon@gmail.com
[B] Ecology Department, Massey University, Palmerston North, New Zealand, Email m.a.minor@massey.ac.nz
[C] AgResearch, Palmerston North, New Zealand, Email alec.mackay@agresearch.co.nz
[D] P O Box 1758, Palmerston North, New Zealand, Email gregor.yeates@gmail.com
[E] Soil and Earth Science Department, Massey University, Palmerston North, New Zealand, Email m.hedley@massey.ac.nz

Abstract

Soil invertebrates play an important role in a wide range of soil processes. A soil invertebrate indicator for pastoral soils in New Zealand is being developed. The indicator aims to add to current understanding of the role soil biota play in the provision of soil services and to give land managers an insight of how their current system is affecting soil biology and the soil processes they contribute to.

A large number of New Zealand sheep and dairy pastures across the major soil orders under different managements were sampled. The elements of the invertebrate indicator include the identification and quantification of selected soil invertebrates, as well as a measure of the food resources and habitable pore space available to the invertebrate community.

Key Words
Soil biological quality, soil functions, soil processes, soil invertebrates

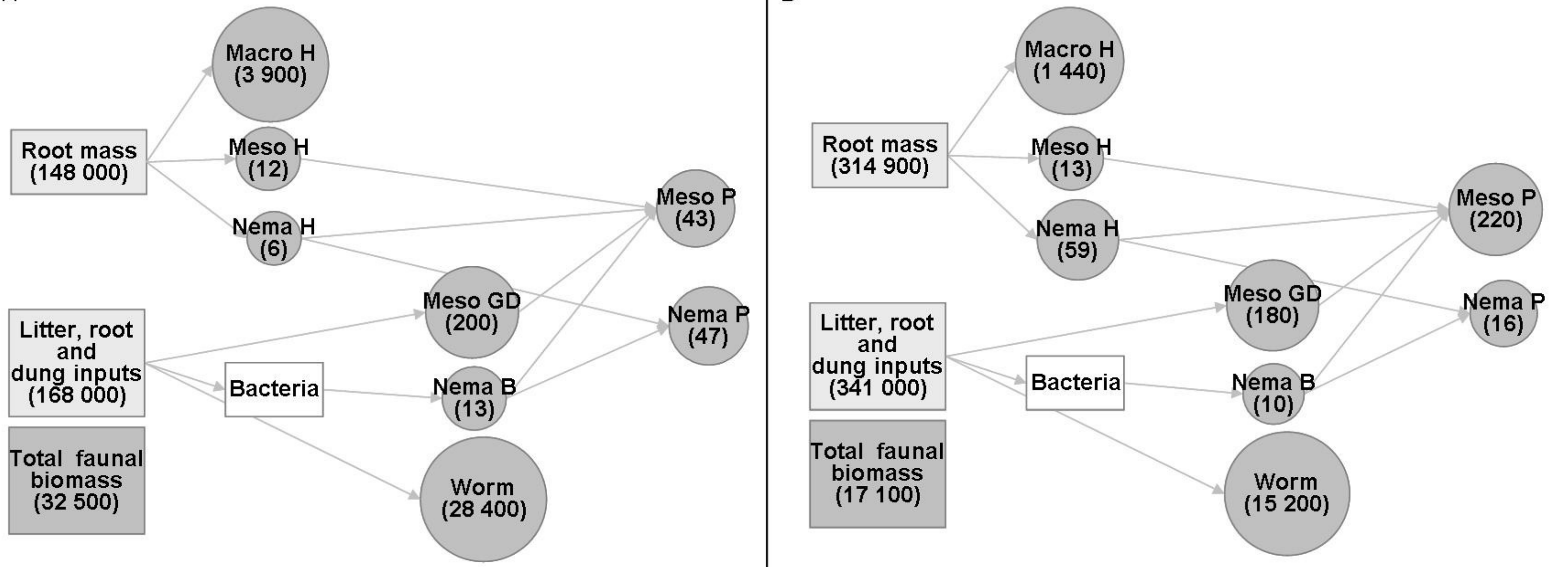
Introduction

Soil invertebrate communities are important within the soil system and contribute to a wide variety of soil processes. While they operate at small scales they have large scale benefits for ecosystem services (Lavelle *et al.* 2006; Wall *et al.* 2004), some of which are seen in Visual Soil Assessment (Shepherd 2000). Highly modified pastoral systems, which are a feature of agriculture in New Zealand, affect the soil and its biology. Soils with diverse food webs may require fewer inputs to achieve higher productivity than those with food webs missing a vital component.

The aim of this study was to explore the relationships between pastoral management practices on a range of New Zealand soils and the diversity and quantity of soil invertebrates. The end goal was a soil invertebrate indicator related to observed differences in soil properties and processes. The indicator aims to add to the current measures of soil services (e.g. nutrient supply), and to give land managers greater knowledge of how their system is affecting soil biota and the processes they contribute to, including litter incorporation, nutrient cycling, soil aggregate building and soil pore construction. This may guide land managers to ensure their management practices sustain the required biological community.

Methods

In developing the soil invertebrate indicator a large number of pastures under a wide range of managements were sampled. These included a long-term comparison of conventional and organic sheep-grazed systems on a Brown soil (Ballantrae Research Station); four paired commercial organic and conventional farms on different soil types; a long-term sheep-grazed fertiliser trial with either 10 or 50 kg/ha of phosphorus applied as single superphosphate on an Allophanic soil (Whatawhata Research Station), and the influence of a combination of increasing dairy cow numbers, fertiliser application and feed supplements on an Allophanic and Gley soil in the Waikato (2.3, 3 and 3.8 cows/ha at Newstead) and on an Allophanic soil in Taranaki (3, 4 and 5 cows/ha at Whareroa). In addition, three fertiliser trials examining the interaction between phosphorus, nitrogen and irrigation on Allophanic, Brown and Pallic soils where grazing animals had been excluded were sampled.



Food-web	A	B
Stock type	Sheep	Dairy
Stocking rate (SU/ha)	14.5	25
Liveweight (kg/ha)	800	1 500
Soil type	Allophanic	Allophanic
P inputs (kg P/ha)	50	47
Pasture production (kg DM/ha)	12 300	14 000

Figure 1. Examples of soil food webs based on standing biomass of selected soil faunal groups and associated site properties for a A) sheep-grazed pasture and B) dairy-grazed pasture. Macrofauna (Macro), mesofauna (Meso) and nematode (Nema) herbivores (H) feed on plant material. Earthworms (Worm), mesofauna general detritivores (GD) and nematode bacterial-feeders (B) feed on detrital inputs and associated microflora. The macrofauna, mesofauna and nematodes are in turn consumed by predators (P). Circle sizes represent the logarithm of the faunal biomass, actual biomass (dry weight mg/m^2) given in parenthesis. Trophic groups, including fungal-feeders, with biomass <1.5 mg dry weight/m^2 were excluded.

At all sites soil invertebrates (macrofauna, mesofauna and nematodes) were identified and quantified along with information on soil chemical and physical properties. Other information collected included soil moisture, pasture production, fertiliser application, and stocking rate. The invertebrate data was used to produce a food web of standing invertebrate biomass under each soil and management (Figure 1). This was used in combination with estimated dry matter to the soil from grass, roots and dung; habitable pore space (measured using fluorescent resin and imaging software) and treading pressure, to better understand factors influencing the soil biological communities. This information forms the basis for the soil invertebrate indicator. High and low abundances of selected invertebrate groups were calculated as the upper and lower 10^{th} percentiles.

Results and discussion

Under pastoral management soil invertebrates are influenced by pasture production, which affects food availability; and by livestock type and density through physical disturbance and treading pressure, which act to compact the soil, decreasing habitable pore space. These two factors (food availability and habitable pore space) are moderated by other factors such as climate and soil type, both of which must be considered in quantifying the effects of pastoral agriculture on the density of the soil invertebrates across the diversity of soils found in New Zealand. The implications of having no, low and high abundances of selected important invertebrates for key soil processes are listed in Table 1.

A productive pasture is dependent on a supply of nutrients and water arriving at the root surface and the continuous exchange of carbon dioxide and oxygen to ensure optimum root function. The incorporation, mixing and decomposition of litter and assistance in maintaining pore function for rapid drainage after rainfall to ensure good aeration are also essential. Soil organisms which are conducive to these conditions need to be encouraged (van Eekeren *et al.* 2007).

Table 1. Draft soil invertebrate indicator and its parameters. Additional information might include soil type, stock type, stocking rate, fertiliser application rate, pasture growth, supplements fed to stock, and amount of dry matter to the soil. Invertebrates may be important for more than one soil service. If invertebrates are absent or low in abundance their populations need to be stimulated to improve the soil's performance*. Low and high abundances of invertebrates (ind./m^2) are given for average sheep and dairy grazed pastures.

Soil processes (contributing to a service/disservice)	Important invertebrates	Low	High	Sheep (Fig 1A)	Dairy (Fig 1B)
Water and air movement					
- creation of soil pores	Endogeic earthworm[1]	250	500	516	278
	Anecic earthworm[1]	0	150	0	18
- sensitive to treading pressures	Oribatid mite[1]	65	21 100	17 100	8 100
Nutrient cycling					
- litter incorporation	Anecic earthworm[1]	0	150	0	18
	Epigeic earthworm[1]	10	125	132	8
- nutrient rich faecal pellets	Oribatid mite[1]	65	21 100	17 100	8 100
- controlling other populations	Nematode[1]	550 000	1 180 000	881 200	985 300
- dominant food web pathway	Nematode Channel Ratio	0.72	0.93	0.94	0.87
- plant growth	Nematode Plant Parasite Indicator	0.60	1.55	0.88	1.44
	Herbivorous macrofauna[1]	5	325	106	71
Green house gas regulation					
- carbon storage	Anecic earthworm[1]	0	150	0	18
	Epigeic earthworm[1]	10	125	132	8
- nitrous oxide production	Endogeic earthworm[1]	250	500	516	278
	Anecic earthworm[1]	0	150	0	18

[1] abundances

* High value of the Plant Parasite Indicator may indicate suppressed net plant growth.

Interpretation of the condition of the soil invertebrate community utilises the information in Figure 1 and Table 1. The two examples illustrated in Figure 1 are located on the same soil order and have similar inputs of phosphorus fertiliser and litter to the soil, but differ markedly in stock type and associated live weight, as well as in the soil biological communities. In the sheep-grazed pasture the maintenance and creation of soil pores (particularly deep pores) is constrained by the absence of anecic earthworms. The high abundance of epigeic earthworms ensures good litter incorporation from the surface, but the absence of anecic earthworms may have implications for organic matter incorporation deeper into the soil. The food web is bacterial dominated, with the level of plant-feeding nematodes not likely to be suppressing plant growth. Of concern in the dairy cow grazed pasture, is the low abundance of endogeic earthworms for pore formation, and along with the low abundance of Oribatida suggests that the stock live weight loading is exerting significant pressure on soil structure in the root zone. In this example, the total live weight of dairy cows is more than twice that of sheep (Figure 1). The high Plant Parasite Indicator may also be of concern, but not the abundance of herbivorous macrofauna.

Conclusion

The soil invertebrate indicator has the potential to give land managers greater knowledge about the function of soil invertebrates in their soils. Land managers can add the invertebrate indicator to more visible measures of soil quality, and use it to optimise their practices. Pasture management that includes consideration of the invertebrate community has the potential maintain or promote soil structure and increase nutrient availability.

References

Lavelle P, Decaens T, Aubert M, Barot S, Blouin M, Bueau F, Margerie P, Mora P, Rossi JP (2006) Soil invertebrates and ecosystem services. *European Journal of Soil Biology* **42,** S3-S15.

Shepherd G (2000) Visual Soil Assessment: Field guide, cropping and pastoral grazing on flat to rolling country. (horizons.mw & Landcare Research: Palmerston North) 84 p.

Van Eekeren N, Murray PJ, Smeding FW (2007) Soil biota in grassland, its ecosystem services and the impact of management. In 'Grassland Science in Europe 12, Ghent, Belgium'. (Ed A de Vliegher, L Carlier), pp. 247-257. (European Grassland Federation).

Wall DH, Bardgett RD, Covich AR, Snelgrove PVR (2002) The need for understanding how biodiversity and ecosystem processing affect ecosystem services in soils and sediments. In 'Workshop of the SCOPE-Committee on soil and sediment biodiversity and ecosystem processing'. (Ed DH Wall) pp. 1-12 (SCOPE, Colorado).