Effects of pest control on forest invertebrates in Tongariro National Park—preliminary results

Murray Potter, Ian Stringer, Mike Wakelin, Paul Barrett and Duncan Hedderley

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ABSTRACT

This paper presents the first results from a 5-year study investigating the benefits to terrestrial invertebrates of reducing the abundance of mammalian predators in forested sites in Tongariro National Park, New Zealand. Results are presented from the period before mammal control began (January 2000 to September 2001). The overall similarity of sites is assessed in terms of terrestrial invertebrate diversity and abundance, using pitfall traps in paired blocks at three sites. A power analysis is also included, to determine the magnitude of change in catch of major invertebrate taxa that we are likely to be able to detect following rodent control. In total, 271 550 invertebrates, belonging to 332 recognisable taxonomic units (RTUs), were caught in nine paired pitfall traps in six blocks. Catch rates were low from January 2000 to January 2001; they then increased at all three sites to reach maxima in February and April 2001, before declining to the previous low levels. The majority of invertebrates caught comprised Coleoptera (31.8%), Collembola (19.7%), Diptera (14.5%), and mites (9.8%). There was a high correlation between each pair of blocks for the total number of individuals caught ($r > 0.9$), but a low correlation for the numbers of RTUs caught (0.3–0.4). Shannon's diversity indices for pairs of blocks varied widely. Reducing the number of paired pitfall traps from nine to six or five per block substantially reduced the total number of invertebrates caught. However, the power analysis indicated that this would result in little reduction in the chance of detecting a significant change in the number of invertebrates caught following mammal control in the proposed treatment blocks.

Keywords: invertebrates, mammal control, pitfall trap, biodiversity, Shannon's index

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1. Introduction

Invertebrates are the principle components of biodiversity in forests and are essential to forest ecosystems. Invertebrate numbers can be highly variable both spatially and seasonally, and they can respond quickly to natural and human-induced changes. Their vulnerability to pest control operations has been controversial, but research by Sherley et al. (1999) simulating an aerial 1080 operation in a small area of Tongariro National Park forest near Ohakune, New Zealand, showed that such operations have only localised and temporary effects on a few invertebrate species or groups. There is now a need to assess the benefits to forest invertebrates of large-scale control of their mammalian predators.

Rodents are the principal mammalian predators of invertebrates in New Zealand forests (e.g. Ramsay 1978; Brockie 1992). Our aim is to determine the effects of intensive rodent poisoning on forest invertebrates. This is a long-term research project, which will compare invertebrate diversity and abundance in three paired plots (with and without rodent control) before and during prolonged rodent control.

An important part of this study is to use methods that are practicable for conservation managers. We know of no easy methods that managers could employ to reliably sample non-flying invertebrates in the canopy; therefore, invertebrate sampling methods must be restricted to the ground. In our experience, few invertebrates are caught in leaf-fall traps, and frass collection is ruined by rain. Although Malaise traps sample flying insects, our planned mammal-free areas are likely to be too small to sample only those insects that fly within them (without also sampling insects from the surrounding non-poisoned areas). Furthermore, the numbers of specimens collected with Malaise traps are usually so high that analysing them is extremely time consuming. Therefore, in this paper the focus is on results obtained from pitfall traps.

The primary long-term goals of this research are to:

- Identify changes in the numbers and species of forest-floor invertebrates following intensive mammal control.
- Identify which invertebrate groups benefit from mammal control.
- Identify suitable invertebrate indicator species or groups for monitoring the effects of mammal control in mainland islands.
- Assess seasonal variation in the abundance of such invertebrate indicator species or groups.

In addition, we hope to obtain the following information:

- An estimate of how intensive rodent poisoning influences rodent numbers in surrounding areas.
- A comparison of the composition and phenology of the invertebrate communities in Tongariro National Park with those in Orongorongo Valley (Moeed & Meads 1985, 1986, 1987) and Taranaki (Meads 1994).

- Information on the mammal-invertebrate predator-prey relationship. We plan to investigate whether rodent predators regulate invertebrate numbers, and possibly what indirect effects they have on the invertebrate communities.

This paper, which is the first of a series, presents preliminary pitfall-trap results from January 2000 to September 2001. We focus on assessing the overall similarity in terrestrial invertebrate diversity and abundance between paired blocks at three forest sites. We also present a power analysis to determine the change in numbers (increase or decrease) for a taxon that can be detected using different numbers of pitfall traps; this enables us to predict the magnitude of change in abundance of major taxa that we are likely to be able to detect following rodent control in one block at each forest site.

2. Methods

2.1 OVERVIEW

Three sites were established in podocarp-broadleaf forest near the western boundary of Tongariro National Park (Fig. 1); all sites were relatively flat. Sites 1 and 2 were near Horopito (site 1: 175°23′E, 39°22′S; site 2: 175°24′E, 39°23′S), and site 3 was near Erua (175°24′E, 39°15′S). Each site comprised two paired blocks (each 400 m × 400 m), which were separated by over 500 m to ensure that the blocks were far enough apart to be independent in terms of their rodent and invertebrate populations. It is planned that one of each pair of blocks will have rodent control imposed, and invertebrates will be sampled for 2.5 years both before and during rodent control to determine the effects of intensive rodent poisoning on forest invertebrates. No poison was applied during the period covered by this report.

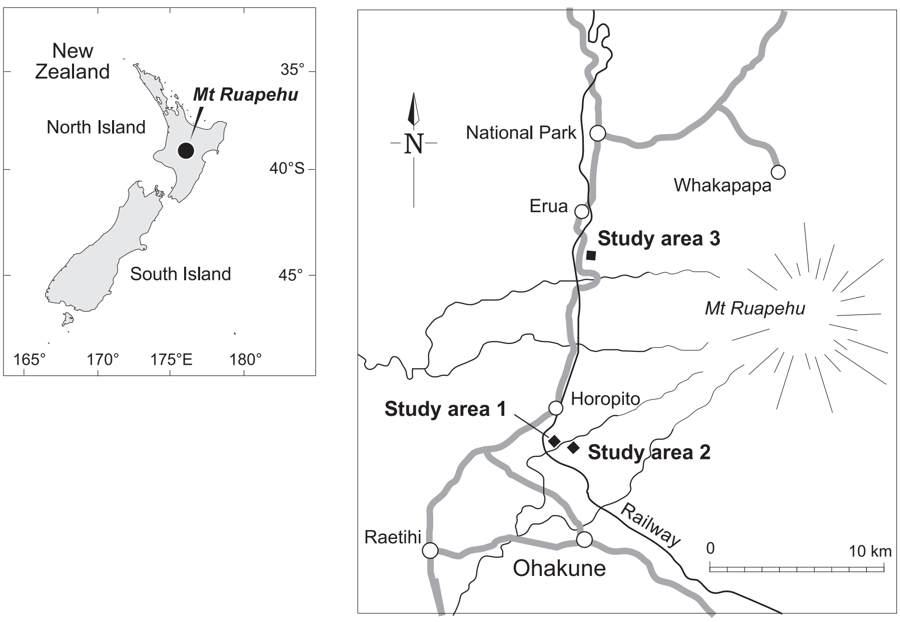


Figure 1. Location map for the three study sites in Tongariro National Park, New Zealand.

2.2 INVERTEBRATE MONITORING

Nine paired pitfall traps were positioned in the centre of each block, 50 m apart on a 3 × 3 grid. These were cleared and reset every 8 weeks. A Malaise trap was also placed in the centre of each block, but the results from each of these are not presented here; the Malaise traps were cleared at the same time as the pitfall traps.

The pitfall traps comprised cylindrical plastic containers (11 cm diameter, 10 cm deep) dug-in level with the surrounding ground and filled with 300 mL of 70% ethylene glycol. Pairs of traps were placed 5–10 m apart. Samples were sieved through squares of 'Chux Multicloth' and stored in 70% ethanol prior to sorting. Samples were processed to recognisable taxonomic unit (RTU) according to the method of Beattie & Oliver (1994).

Statistical Analyses

All analyses were conducted using SAS 8.2 (SAS Institute Inc., Cary, NC). Standardised Shannon's diversity index was used as a measure of diversity (Savage et al. 2000). Similarities between paired blocks in the numbers of invertebrate taxa caught were assessed using Pearson's correlation. Total numbers were $\log_e$ transformed to normalise the data for both Shannon's index and Pearson's correlation analyses. Power analyses were used to assess the minimum changes in catch of invertebrates that could be detected at the 5% level: multifactorial ANOVA was used to determine the variation between blocks; this variation was then used to perform the power analyses. Subsets of the nine pairs of pitfall traps were selected, as illustrated in Fig. 2, to assess the effect of reduced trapping effort on the number and diversity of taxa caught, and on our ability to detect changes.

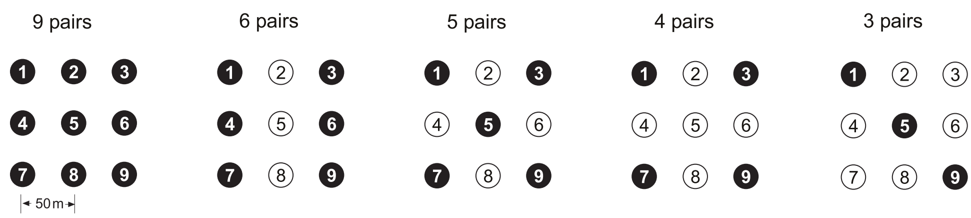


Figure 2. The layout of the nine pairs of pitfall traps in each block, and the pattern used to select six, five, four and three pairs of pitfall traps (shown in black), as used in power analyses for examining the consequences of reducing trapping effort. The patterns for selecting fewer than nine of the paired positions were selected to cover as much of the total area as possible.

3. Preliminary results

3.1 NUMBERS OF INVERTEBRATES CAUGHT

In total, 271 550 invertebrates were caught between January 2000 and September 2001 (Table 1), comprising 332 RTUs. Fourteen percent of individuals were identified to species, 20% to genus, 32% to family, and the remainder was identified to order or higher (Table 2). Four major taxa contributed 84.2% of all specimens caught. These comprised Coleoptera (95 RTUs; 31.8% of the total number of individuals), Collembola (4 families; 19.7%), Diptera (65 RTUs; 14.5%), and mites (≥ 3 families of Acari; 9.8%). Twelve and a half percent of individuals, belonging to 17 composite groups (the 'Other' category in Table 1), were either too small to identify or were larvae or higher taxa that were not identified further (e.g. Oligochaeta and Platyhelminthes).

TABLE 1. TOTAL NUMBERS OF MAJOR TAXA CAUGHT BETWEEN JANUARY 2000 AND SEPTEMBER 2001 IN PITFALL TRAPS IN PAIRED BLOCKS AT THREE SITES IN TONGARIRO NATIONAL PARK.

TAXON	SITE 1		SITE 2		SITE 3		TOTAL
	1	2	1	2	1	2	
Coleoptera	15 173	18 523	15 403	14 743	13 763	8847	**86 452**
Collembola	10 333	8689	13 000	10 292	5655	5558	**53 527**
Diptera	5371	6933	5864	6844	8985	5513	**39 510**
Acari	4749	4357	5427	5393	3650	2980	**26 556**
Hemiptera	1481	1174	1628	1119	653	525	**6580**
Opiliones	1385	1221	913	1106	687	717	**6029**
Hymenoptera	669	642	655	829	520	529	**3844**
Diplopoda	459	602	778	530	367	517	**3253**
Isopoda	329	429	1123	209	686	375	**3151**
Araneae	520	520	578	598	428	297	**2941**
Amphipoda	450	409	853	527	219	149	**2607**
Pseudoscorpionida	123	139	241	161	122	92	**878**
Lepidoptera	182	124	125	184	151	107	**873**
Orthoptera	71	62	81	136	246	146	**742**
Chilopoda	48	56	40	38	36	17	**235**
Siphanaptera	32	12	8	23	53	18	**146**
Psocoptera	17	18	10	12	12	11	**80**
Gastropoda	4	9	3	4	8	18	**46**
Symphyla	12	3	4	7	5	1	**32**
Blattodea	6	2	0	7	1	1	**17**
Dermaptera	0	0	1	1	3	7	**12**
Diplura	4	1	5	0	0	1	**11**
Neuroptera	1	1	1	2	3	0	**8**
Onychophora	0	0	3	1	2	1	**7**
Ephemeroptera	0	0	1	3	0	0	**4**
Phasmatodea	0	1	0	1	0	2	**4**
Odonata	0	0	0	0	1	0	**1**
Others (larvae, etc.)	6050	6104	5449	8171	5262	2968	**34 004**
Total	**47 469**	**50 031**	**52 194**	**50 941**	**41 518**	**29 397**	**271 550**

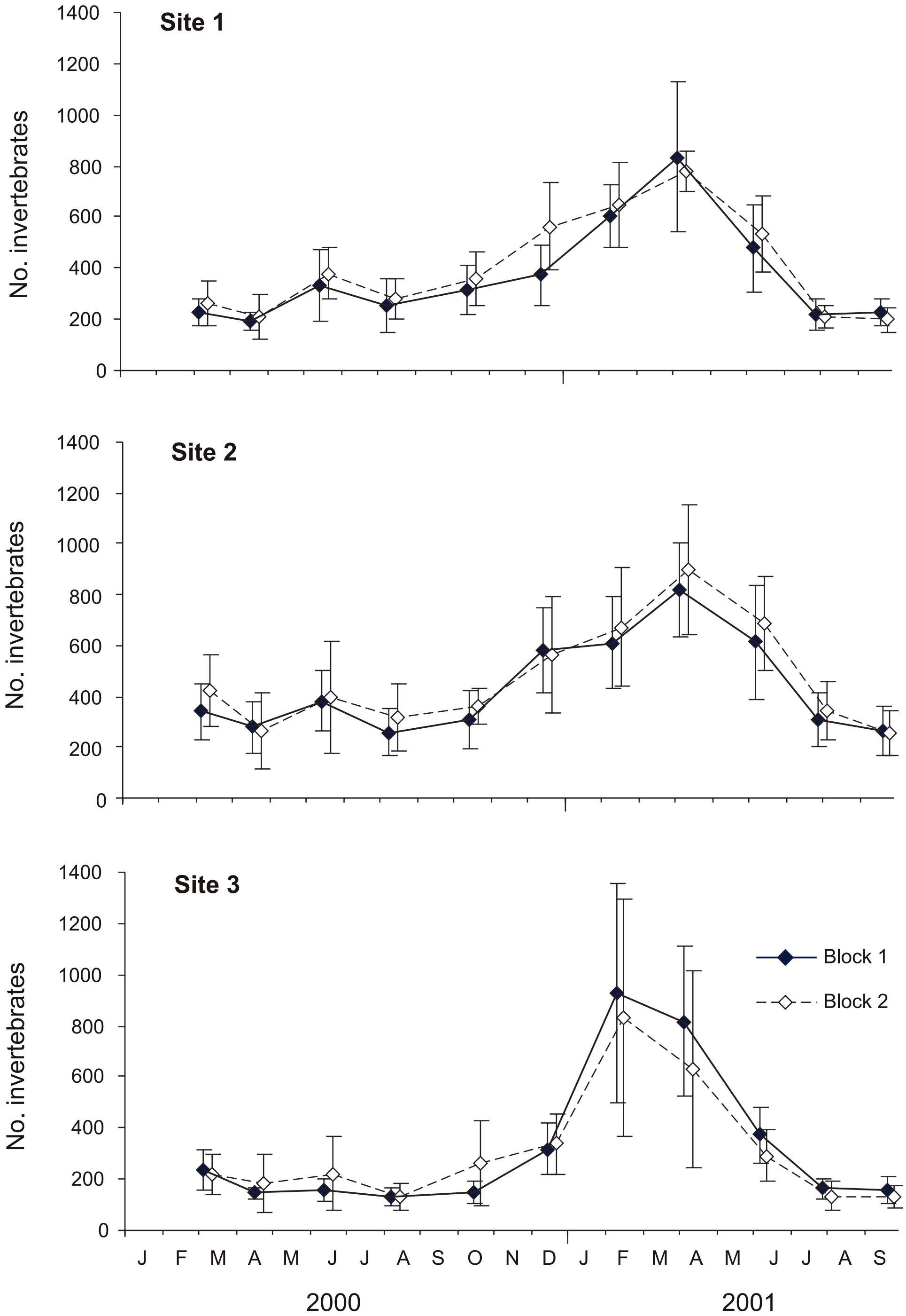
The total number of invertebrates caught in pitfall traps was low during year 1 (2000), and then increased at all three sites to reach maxima in February and April 2001 (Fig. 3). In general, the total number of captures followed similar patterns at all three sites, although there was an indication that the peak occurred 8 weeks earlier at site 3. There was no significant difference between each pair of blocks at each site in the numbers of invertebrates caught (Fig. 3).

TABLE 2. NUMBERS OF RECOGNISABLE TAXONOMIC UNITS IDENTIFIED FROM PITFALL TRAPPING AT ALL THREE SITES IN TONGARIRO NATIONAL PARK BETWEEN JANUARY 2000 AND SEPTEMBER 2001.

The table shows the lowest taxonomic group the specimens were identified to. Seventeen composite groups are not included (see text).

TAXON	ORDER OR HIGHER	FAMILY	GENUS	SPECIES	TOTAL
Acari	2	3	0	0	**5**
Amphipoda	0	0	0	2	**2**
Araneae	18	8	3	0	**29**
Blattodea	1	0	0	0	**1**
Chilopoda	0	2	0	0	**2**
Coleoptera (Carabidae)	0	–	4	4	**8**
Coleoptera (Curculionidae)	14	–	3	3	**20**
Coleoptera (Other)	21	15	18	13	**67**
Collembola	0	4	0	0	**4**
Dermaptera	1	0	0	0	**1**
Diplopoda	2	0	4	0	**6**
Diptera	13	37	10	5	**65**
Ephemeroptera	0	0	1	0	**1**
Gastropoda	0	0	0	1	**1**
Hemiptera	11	4	4	0	**19**
Hymenoptera	8	19	0	4	**31**
Hymenoptera (Formicidae)	2	–	1	2	**5**
Isopoda	2	0	2	0	**4**
Isoptera	1	0	0	0	**1**
Lepidoptera	3	12	2	2	**19**
Neuroptera	1	0	0	1	**2**
Odonata	1	0	0	0	**1**
Onychophora	1	0	0	0	**1**
Opiliones	5	0	5	6	**16**
Orthoptera	2	2	8	1	**13**
Phasmatodea	2	0	0	0	**2**
Plecoptera	1	0	0	0	**1**
Pseudoscorpionida	1	0	0	0	**1**
Siphonaptera	0	0	1	1	**2**
Symphyla	0	0	1	0	**1**
Trichoptera	1	0	0	0	**1**
Total	**114**	**106**	**67**	**45**	**332**

Figure 3. Numbers of invertebrates (mean ± 95% CI) caught in pitfall traps in paired blocks at three sites in Tongariro National Park. Each block had nine paired pitfall traps; the data are numbers of invertebrates totalled for each pair of pitfall traps.



3.2 CORRELATIONS BETWEEN PAIRED BLOCKS IN RELATION TO SAMPLING EFFORT

3.2.1 Total number of invertebrates caught

Pearson's correlations between each pair of blocks within each site for the total number of invertebrates caught were very high (r = 0.9–1.0) when nine, six, five and four pairs of pitfall traps were examined (Fig. 4A). Weaker correlations resulted when three pairs of pitfall traps per block were used, but the coefficient was still greater than 0.7 (Fig. 4A). The confidence intervals for these correlations were similar and large when nine, six, five or four pairs of pitfall traps were used, but increased further when three pairs of pitfall traps were used (Table 3).

3.2.2 Number of taxa caught

Pearson's correlations between each pair of blocks for the number of RTUs caught were low ($r = 0.3–0.4$) when the catches from all nine pairs of pitfall traps were considered (Fig. 4B). The correlations were highly variable when fewer pairs of pitfall traps were used, and in many cases they increased. The confidence intervals for these correlations were similar when nine, six or five pairs of pitfall traps were considered, but decreased when four or three pairs of traps were used (Table 3).

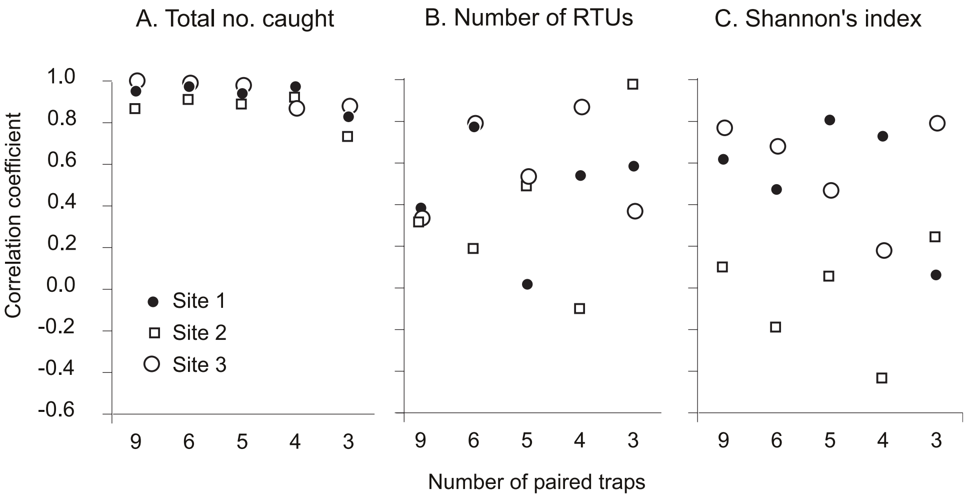


Figure 4. Pearson's correlation coefficients between pairs of blocks for A. Total number of invertebrates caught ($\log_e$ transformed data); B. Number of recognisable taxonomic units (RTUs) caught; and C. Shannon's indices ($\log_e$ transformed data). Data are presented in relation to the number of paired pitfall traps selected for analysis (nine, six, five, four or three pairs per block).

TABLE 3. ANALYSIS OF VARIANCE SHOWING 95% CONFIDENCE INTERVALS (CI) FOR INVERTEBRATES CAUGHT IN PITFALL TRAPS ON PAIRED BLOCKS AT THREE SITES IN TONGARIRO NATIONAL PARK.

Data include the total number of invertebrates ($\log_e$ transformed data) and number of recognisable taxonomic units (RTUs) caught, and Shannon's diversity index ($\log_e$ transformed data). Data are presented according to the number of paired pitfall traps used (Traps: nine, six, five, four or three pairs). Site, block, and seasonal differences have been accounted for.

	TRAPS	95% CI
Total invertebrates	9	-36% to +52%
	6	-36% to +55%
	5	-32% to +46%
	4	-36% to +56%
	3	-44% to +77%
Number of RTUs	9	± 3.17
	6	± 3.05
	5	± 3.24
	4	± 2.95
	3	± 2.49
Shannon's index	9	± 11%
	6	-12% to +13%
	5	-11% to +12%
	4	-15% to +16%
	3	-14% to +17%

3.2.3 Shannon's index

Pearson's correlations between paired blocks for Shannon's indices were moderate at sites 1 and 3 (r = 0.4–0.8) but were poor at site 2 ($r \leq 0.1$) when nine or six pairs of pitfall traps were used (Fig. 4C). Using five or less pairs of pitfall traps resulted in widely differing correlations.

When nine, six or five pairs of pitfall traps were considered, the confidence intervals for the Shannon's indices were similar (≤ ± 12%); these increased slightly when four or three pairs of pitfall traps were used (Table 3).

3.2.4 Correlations between paired blocks for the number of higher taxa

Pearson's correlations between paired blocks for the number of major taxa caught varied enormously (Fig. 5). These were always ≥ 0.80 for some taxa (Diptera, Acari, Hemiptera, Isopoda, Amphipoda and Pseudoscorpionida), regardless of the number of traps (Fig. 5). For other taxa, coefficients that were initially high (> 0.9) fell when fewer traps were examined (Coleoptera, Opiliones and Araneae). Other taxa showed huge variation as the number of pairs of pitfall traps was altered, and in some cases using fewer traps resulted in higher Pearson's correlations (e.g. Collembola). There was a tendency for higher Pearson's correlations ($r > 0.6$) to be associated with taxa containing more individuals (> 870); for these taxa, the correlation coefficients tended to change less when fewer pairs of pitfall traps were used than for taxa where fewer individuals were caught (Fig. 5).

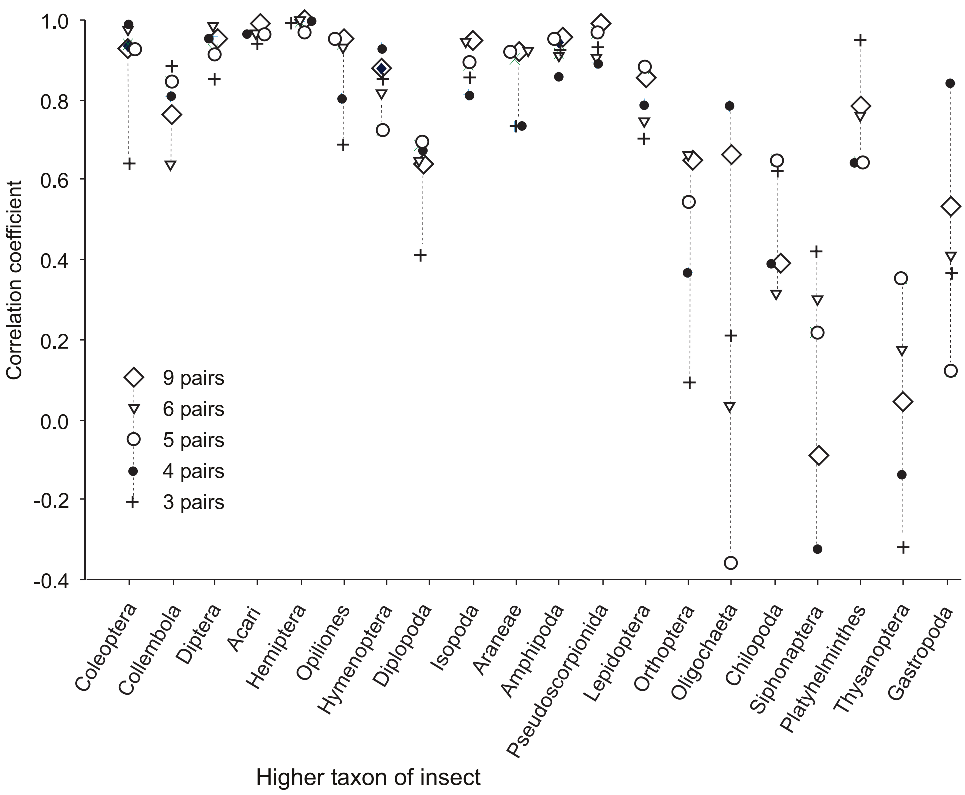


Figure 5. Correlation coefficients between paired blocks for numbers of higher taxa caught using various numbers of paired pitfall traps, pooled for data from January 2000 to September 2001. Selection of pitfall traps is illustrated in Fig. 2. Higher taxa are arranged in decreasing order of the total number of individuals caught.

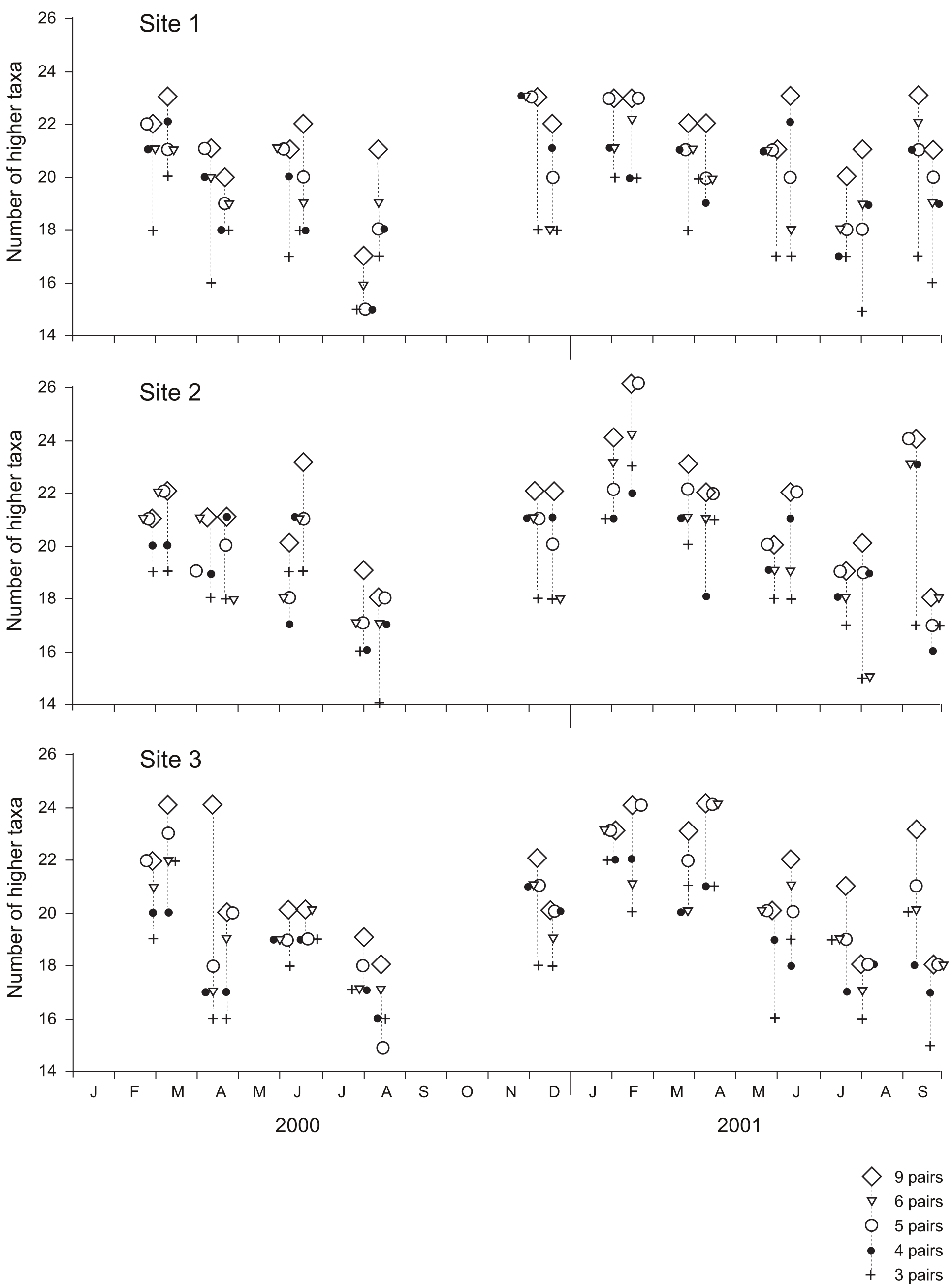
3.2.5 Seasonal variation in the number of higher taxa caught

Seasonal variation in the number of higher taxa caught was pronounced at sites 2 and 3 but much less evident at site 1 (Fig. 6). There was often less difference between paired blocks at all sites in summer (December to February) than at other times.

3.2.6 The number of higher taxa caught and sampling effort

On most sampling occasions in each block at each site, the total number of higher taxa (as listed in Table 1) detected was maximal when all nine paired pitfall traps were used (Fig. 6). When averaged, 1–1.25 fewer higher taxa were detected when six pairs of pitfall traps were used, and 1.5–1.75 fewer higher taxa were detected when five pairs of pitfall traps were used.

Figure 6. Relationship between the total number of higher taxa caught per block at each site on each sampling occasion, using different numbers of paired pitfall traps. The data points for blocks 1 and 2 are jittered left and right respectively. Data for October 2000 have yet to be analysed.



3.2.7 Power analysis

A power analysis of seven higher taxa, which were selected to encompass a range between the most numerous taxon (Coleoptera) and a less numerous taxon (Gastropoda), indicates that using nine, six or five pairs of pitfall traps per block has little effect on the probability of detecting a significant change in catch per block (Table 4). However, using all nine pairs of pitfall traps gave the maximum probability of detecting a significant change in numbers for Collembola, Araneae, Arachnida (mites and harvestmen combined), Gastropoda and Orthoptera.

TABLE 4. POWER ANALYSIS RESULTS INDICATING THE MINIMUM DECREASE AND INCREASE IN CATCH RATES THAT WOULD BE REQUIRED FOR AN 80% OR 50% CHANCE OF DETECTING A CHANGE AT THE 5% SIGNIFICANCE LEVEL (ONE-TAILED).

Results are presented for various taxonomic groups caught in different numbers of paired traps (Traps: nine, six or five pairs of pitfall traps per block) on paired blocks at three sites in Tongariro National Park.

TRAPS	TAXON	80% CHANCE		50% CHANCE	
		DECREASE	INCREASE	DECREASE	INCREASE
9	Coleoptera	53%	115%	41%	71%
	Collembola	36%	55%	26%	36%
	Diptera	59%	142%	46%	86%
	Araneae	37%	60%	28%	39%
	Arachnida	46%	85%	35%	54%
	Gastropoda	53%	114%	41%	70%
	Orthoptera	68%	208%	55%	120%
6	Coleoptera	52%	109%	40%	67%
	Collembola	44%	80%	34%	51%
	Diptera	63%	172%	50%	101%
	Araneae	45%	83%	35%	53%
	Arachnida	51%	104%	39%	65%
	Gastropoda	66%	195%	53%	113%
	Orthoptera	76%	322%	63%	174%
5	Coleoptera	53%	113%	41%	70%
	Collembola	38%	62%	29%	40%
	Diptera	48%	94%	37%	59%
	Araneae	45%	82%	34%	52%
	Arachnida	52%	108%	40%	67%
	Gastropoda	58%	136%	45%	82%
	Orthoptera	70%	228%	56%	130%

4. Discussion

Most of the primary aims of this study have yet to be addressed, because we have not yet sorted and analysed the samples taken during the period when mammals were controlled (June 2002 to February 2005). However, the high correlations between the numbers of invertebrates found in the paired blocks show that the pairs of blocks are similar in invertebrate community composition, which means that any effect due to mammal control is unlikely to be confounded by other factors. In general, the correlations between the paired blocks for Shannon's biodiversity indices were poor, indicating that this index is likely to be of little use in detecting a change in community diversity following mammal control. This is disappointing, because Shannon's index is influenced most by species of intermediate abundance (e.g. Hutcheson et al. 1999), and may well include species that are likely to change in abundance when mammal control is imposed. The power analysis on the number of individuals belonging to the major higher taxa that were caught indicates that there is a good chance of detecting a difference in invertebrate communities between poisoned and non-poisoned blocks.

Overall, it appears that it would be most efficient to use six or five pairs of pitfall traps per block to detect a change after poisoning. At present, there would seem to be little advantage in using the results from all nine pairs of pitfall traps; however, we do not yet know which taxa will respond to rodent poisoning. We therefore propose to continue sorting samples from all traps from all three sites to maximise experimental power, in case the response occurs in less numerous taxa. To save time and resources, we will adopt an alternative strategy: we will sort samples from all traps from two contrasting sample periods of each year (summer and winter) instead of for all six sample periods, and analyse these for differences in invertebrate composition between poisoned and non-poisoned blocks. The unsorted samples will be stored in case they are required for confirmation at a later date.

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