SHORT COMMUNICATION

Ground invertebrate fauna associated with native shrubs and exotic pasture in a modified rural landscape, Otago, New Zealand

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Abstract: This study examined whether the diversity and relative abundance of ground-dwelling invertebrates changed in relation to type of vegetation cover. Invertebrate taxon diversity and relative abundance were assessed with pitfall traps placed under the native shrubs *Olearia bullata* and *Coprosma propinqua*, and in surrounding patches of exotic pasture. A total of 1935 invertebrates and at least 152 invertebrate taxa were recorded from 49 pitfall traps. The number of native taxa was *c*.63% of all taxa recorded, whereas exotic invertebrates represented only *c*.9%. The other *c*.28% were of undetermined origin. Taxon richness and relative abundance under the two shrub species were statistically similar, although all mean values (except for Coleoptera) were higher for traps set beneath *C. propinqua*. In contrast, taxon richness and relative abundance were significantly higher in the exotic pasture than under either of the shrub species. The same pattern was evident for exotic invertebrates and the relative abundance of native invertebrates, and for some of the most speciose orders. The data indicate that nearly half of native taxa occurred only under native shrubs. In contrast, 7 out of 12 exotic species were found in all three vegetation types, and all but one of them were recorded at least in exotic pasture. We conclude that the value of locally-modified and patchy vegetation cannot be underestimated for its potential in providing native biodiversity reservoirs for New Zealand's native invertebrate fauna.

Keywords: biodiversity; exotic pasture; ground fauna; invertebrates; native shrubs; New Zealand; pitfall traps.

Introduction

The international importance of New Zealand's fauna has been widely acknowledged (Myers *et al*., 2000). A significant feature of the country's invertebrate fauna is that at least 90% of the recognized species are endemic (Klimaszewski, 1997; Patrick, 1994), one of the highest levels of endemism for a single large discrete area (Dugdale, 1988). Despite this status, New Zealand's terrestrial invertebrates remain poorly understood, and knowledge of the taxonomy, ecology and distribution of many groups is inadequate (Ramsay *et al*., 1988; Watt, 1979). Given the modified condition of much of the country's vegetation, understanding relationships of New Zealand's invertebrates to native and exotic plant communities is paramount to understanding and predicting basic distributions of indigenous biodiversity and the extent of exotic species invasion.

Derraik *et al*. (2003) demonstrated that the diversity of plant-dwelling invertebrates varies among native shrub species. Associated with that study, an investigation of ground-dwelling invertebrate fauna in relation to vegetation cover was carried out. In this paper, we compare the ground invertebrate fauna sampled beneath the canopy of two native shrub species and adjacent exotic pasture.

Study area

Invertebrates were collected from a modified native shrubland at 450 m altitude (45º 30' S, 170º 03' E) in the Brookdale Conservation Covenant on the lower eastern slopes of the Rock and Pillar Range, South Island, New Zealand. Located 50 km inland, the mountain range rises to an altitude of 1450 m a.s.l. (Talbot *et al.*, 1992) and experiences annual rainfall of approximately 600 mm at the study site (Knight Frank N.Z. Ltd., 1995).

Native vegetation in the region of the Rock and Pillar Range has been altered dramatically since human occupation *c.*800 years ago, with lower-elevation shrublands now largely confined to gullies that have offered some protection from fire and heavy grazing. Although these shrublands probably do not represent the original pre-human vegetation (McGlone, 2001), they remain dominated by native woody species that have survived various historical disturbance processes and management regimes. The shrubland area where our study was undertaken is protected under the Reserves Act 1977 because of its value as a regional representative of native flora (Knight Frank N.Z. Ltd., 1995). The covenant is protected in perpetuity in the land title, and while limited grazing is allowed, the use of fire as a management tool is not.

This particular covenant was the focus of a wider plant-invertebrate biodiversity research programme (see Derraik *et al.* 2001, 2002a, 2002b, 2003). A 5 ha area on the south-facing (shady) aspect of the main gully bisecting the covenant was selected for study, as its vegetation cover was deemed most suitable for the research programme overall. Moreover, the shady slope was predicted to have higher soil moisture and more favourable conditions for invertebrates than the drier, northerly (sunny) faces. The shrubland was relatively more intact at the base of the gully. It became increasingly fragmented further upslope. The shrubs were mostly morphologically divaricating. This form creates a dense, often impenetrable vegetation cover above the ground.

Methods

Fifty pitfall traps were set at random in the shrubland, with 20 under individual *Coprosma propinqua* (Rubiaceae) shrubs, 20 under *Olearia bullata* (Asteraceae) shrubs and 10 in adjacent exotic pasture dominated by *Agrostis capillaris* (browntop) and *Anthoxanthum odoratum* (sweet vernal). Traps set in pasture were located approximately 10 m away from the nearest shrub of any species. Each pitfall trap consisted of PVC pipe (80 mm diameter) cut into 100 mm lengths with a plastic cup (diameter 75 mm) inside. Each cup was two-thirds filled with ethylene glycol, and traps were covered by a plastic lid supported by bent wire 10–20 mm off the ground.

Sampling was conducted over a 2-week period during March/April 1999. Contents of 49 traps were retrieved (the contents of one trap from under *O. bullata* was accidentally lost). All invertebrates were sorted initially into morphospecies by JGBD, using a low-power binocular microscope. The majority of the vials containing the morphospecies were then sent to specialist taxonomists for identification or verification. Acari specimens could not be examined by specialists so were retained as separate morphospecies. Onychiuridae specimens (Collembola) were not individually counted due to their extremely high abundance, and although excluded from counts of relative abundance they were recorded in presence/absence data.

To compare invertebrate taxon richness and relative abundance between pitfall traps set in different sampling environments (under two shrub species and in exotic pasture), we used a generalized linear model assuming a poisson distribution. The model gives a reasonable estimate as it allows for overdispersion of data. However, the robustness of the analysis was compromised by uneven sample numbers in the different vegetation types; the likelihood of recording rare taxa increases with greater sampling effort. As a result, the data were subsampled to compare the distribution of rare taxa amongst the three habitats.

Non-metric multidimensional scaling (MDS) ordinations (based on Bray-Curtis dissimilarity measures) were carried out to compare the assemblages of taxa between the three sampling environments (*C. propinqua*, *O. bullata* and exotic pasture). The MDS ordinations were carried out for all taxa at the species, family and order level, and also for the 25 most abundant taxa and the full species assemblage of individual orders. All ordinations were run from 30 random restarts. One-way analyses of similarities (ANOSIM) were used to test whether the above assemblages from the three sampling environments were statistically different from each other. The R statistic given by ANOSIM provides a useful comparative measure of the degree of separation of sites, and if $R = 1$, all replicates within sites are significantly more similar to each other in comparison to any replicates from other sites (Clarke and Warwick, 2001). The value of the R statistic "is at least as important as its statistical significance (arguably more so)" (Clarke and Warwick 2001). Statistical significance for all analyses was set at the 95% level.

Results

A total of 1935 specimens was recorded from 49 pitfall traps. At least 152 invertebrate taxa were recorded, 95 of which were confirmed to be native and 13 exotic. The origin of the remainder could not be confirmed. Exotic taxa were few, but nonetheless made up 36.5% of all specimens, in comparison wtih 39.1% for native taxa. The remaining 24.4% represented the undetermined taxa.

Traps beneath *C. propinqua*, *O. bullata*, and exotic pasture yielded mean relative abundances of 38.8 (SE = 4.0), 30.0 (SE = 2.7) and 63.3 (SE = 16.6) invertebrates per trap, respectively (Table 1). The mean number of specimens was therefore approximately twice as high in exotic pasture as under either shrub species (Table 1). Mean taxon richness was similar for the three sampled habitats, being 14.6 (SE = 0.7), 14.1 (SE = 1.1) and 17.9 (SE = 2.4), respectively for *C. propinqua*, *O. bullata* and exotic pasture. Although mean taxon richness and native taxon richness were similar under the two shrub species, mean relative abundance was considerably (but not significantly) higher under *C. propinqua* (Table 1). A comparison of the data for traps beneath each species of shrub also yielded similar values for the individual invertebrate orders examined; no comparisons were statistically significant (Table 1).

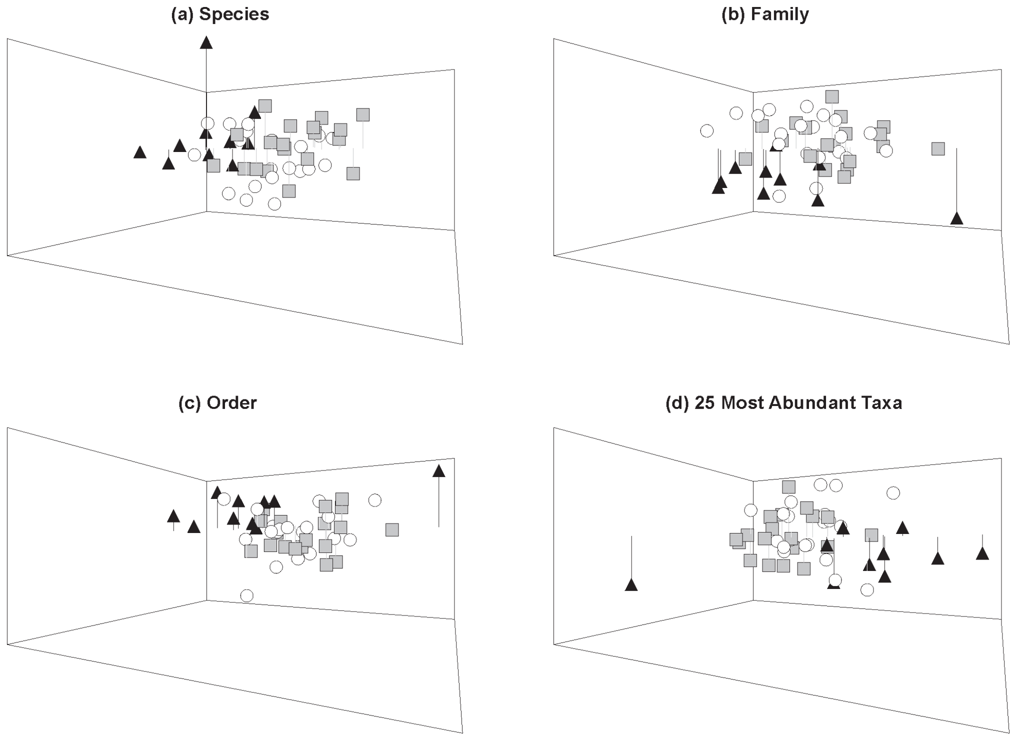
However, when the shrub fauna was compared with the pasture fauna, mean taxon richness and relative abundance were found to be higher in the pasture than beneath either shrub species (Table 1). Mean relative abundance of native and exotic taxa, and mean taxon richness of exotics were significantly higher in the pasture (Table 1). Mean taxon richness of Acari, Diptera, Hemiptera and Hymenoptera were also significantly higher in the pasture than under either shrub species, as was the mean relative abundance of Diptera, Hemiptera and Hymenoptera (Table 1). Eight times more adult Diptera (mostly exotic species) were collected from pitfall traps in the exotic pasture than under the shrubs (Table 1). The four remaining invertebrate orders, except Lepidoptera, had higher mean taxon richness and relative abundance in the pasture, although differences were not statistically significant (Table 1).

The multidimensional scaling (MDS) ordinations and analyses of similarities (ANOSIM) for all invertebrate taxa indicated that assemblages beneath *C. propinqua* and *O. bullata* were not separable at the taxonomic levels inspected (all $R \leq 0.09$; Fig. 1a–c). However, despite considerable overlap, invertebrate communities under *C. propinqua* and *O. bullata* were significantly different from those in comparison to exotic pasture at the species, order and family levels (Fig. 1a–c).

Table 1. Results from generalized linear models for the invertebrate groups sampled by pitfall traps in the Brookdale covenant, Rock and Pillar Range, Otago. The values shown for *Coprosma propinqua*, *Olearia bullata* and exotic pasture are means with standard errors in parentheses. All analyses comparing *C. propinqua* and *O. bullata* were non-significant. For the comparison between exotic pasture and scrub, statistical significance is indicated for each group, where *, **, *** and n.s. are *P*-values significant at the 95, 99 and 99.9% levels, and non-significant results, respectively.

Dependent variable	Invertebrate group	*Coprosma propinqua*	*Olearia bullata*	Exotic pasture
Taxon richness	Community *	14.6 (0.7)	14.1 (1.1)	17.9 (2.4)
	Exotic spp. ***	2.8 (0.3)	2.1 (0.2)	3.7 (0.4)
	Native spp. **	7.2 (0.6)	7.0 (0.5)	8.2 (1.3)
	Acari *	1.3 (0.2)	1.1 (0.2)	2.4 (0.7)
	Araneae (n.s.)	2.2 (0.3)	2.2 (0.3)	2.8 (0.8)
	Coleoptera (n.s.)	1.8 (0.4)	1.6 (0.3)	2.6 (0.7)
	Diptera *	1.4 (0.3)	1.7 (0.3)	3.4 (0.8)
	Hemiptera *	0.9 (0.2)	1.0 (0.2)	2.0 (0.8)
	Hymenoptera **	1.7 (0.3)	1.5 (0.4)	3.6 (0.9)
	Lepidoptera (n.s.)	0.8 (0.2)	0.8 (0.2)	0.8 (0.4)
Relative abundance	Community ***	38.8 (4.0)	30.3 (2.7)	63.3 (16.6)
	Exotic spp.*	13.2 (3.0)	8.4 (1.2)	18.5 (4.7)
	Native spp. **	15.1 (2.4)	10.8 (1.0)	23.3 (6.8)
	Acari (n.s.)	3.3 (1.0)	2.7 (0.7)	6.1 (2.0)
	Araneae (n.s.)	3.9 (0.7)	4.7 (0.8)	5.3 (1.2)
	Coleoptera (n.s.)	2.3 (0.7)	1.9 (0.3)	2.7 (0.8)
	Diptera ***	2.9 (0.8)	2.5 (0.5)	22.8 (8.4)
	Hemiptera **	1.0 (0.2)	1.1 (0.3)	3.0 (0.9)
	Hymenoptera **	6.1 (1.7)	2.5 (0.6)	11.5 (4.7)
	Lepidoptera (n.s.)	1.0 (0.3)	1.0 (0.3)	0.5 (0.2)

Figure 1. Multidimensional scaling ordinations of the species assemblage recorded from pitfall traps under *Coprosma propinqua* (open circles), *Olearia bullata* (gray squares) and in exotic pasture (black triangles). Ordinations a, b and c represent assemblages at the species, family and order level, respectively. Ordination d includes only the 25 most abundant species.



The taxon assemblage beneath *O. bullata* was most dissimilar to that in exotic pasture (Fig. 1a–c). Dissimilarity was largest at the species level ($R = 0.53$; $P < 0.001$), but also marked at both family and order levels, $R = 0.44$ ($P < 0.001$) and $R = 0.41$ ($P < 0.001$), respectively. Pairwise comparisons between the data sets for *C. propinqua* and the exotic pasture, also showed dissimilarity was highest at the species level ($R = 0.36$; $P = 0.002$). However, assemblages became progressively more similar (and barely separable) at higher taxonomic levels, with $R = 0.30$ ($P = 0.002$) and $R = 0.23$ ($P = 0.013$) for family and order levels, respectively. Replicate analyses including only the 25 most abundant taxa (listed in Table 3) indicated little change from the overall community pattern obtained when all taxa were included (Fig. 1d), with *R* statistics and *P*-values nearly identical to those obtained at the species level.

Subsampling analyses to test comparable trapping efforts between habitat types (10 traps from each habitat) indicated that when all traps were included a two-fold increase in sampling effort led to a 25% increase in taxon richness, with only two new exotics being recorded compared with 31 new native taxa. The proportion of native to exotic taxa (and their respective relative abundances) changed little when the traps were subsampled. Nonetheless, the subsampled data indicate that many native taxa (*c.* 70%) were restricted to one of each habitat type, with 48% occurring only under native shrubs (Table 2). In contrast, 7 out of 12

Table 2. Taxon richness of native invertebrates recorded in subsamples of 10 pitfall traps within each of three vegetation types at the Brookdale covenant, Rock and Pillar Range, Otago.

Species origin	Grass + shrub(s)	*C. propinqua* only	*O. bullata* only	Pasture only
Native	22	21	14	16
Exotic	7	1	0	4
Total	29	22	14	20

Table 3. Rank order of the twenty-five invertebrate taxa collected most frequently in pitfall traps underneath *Coprosma propinqua* and *Olearia bullata* shrubs, and in pasture. Ranks in bold correspond to species ranked in the top 25 for all three of the trap environments. Dashes indicate no taxonomic information available, or when a taxon was not present in pitfall traps at a particular habitat.

Overall rank	Order	Family	Species	Origin	*Coprosma propinqua*	*Olearia bullata*	Exotic pasture	% total abundance
1	Juliformia	Julidae	*Ophyiulus pilosus*	exotic	**1**	**1**	**4**	15.7
2	Diptera	Ephydridae	*Hydrellia tritici*	exotic	**9**	**7**	**1**	7.8
3	Acari	–	Morphospecies 5	–	**4**	**5**	**3**	6.7
4	Collembola	Tomoceridae	–	–	**3**	**2**	**14**	5.9
5	Coleoptera	Scelionidae	*Baeus* sp.	native	**2**	**7**	**11**	5.7
6	Stylommatophora	–	unidentified species	exotic	**5**	**3**	**17**	5.1
7	Hymenoptera	Formicidae	*Huberia striata*	native	**8**	**11**	**2**	4.8
8	Amphipoda	Gammaridae	*Puhuruhuru aotearoa*	native	**7**	**6**	**21**	3.0
9	Araneae	Lycosidae	unidentified species	native	**13**	**4**	**25**	2.7
10	Isopoda	Porcellionidae	*Porcellio scaber*	exotic	6	18	42	2.7
11	Diptera	Sarcophagidae	*Oxysarcodexia varia*	exotic	20	53	5	2.4
12	Araneae	Linyphiidae	*Diplocephalus cristatus*	exotic	**11**	**9**	**16**	2.1
13	Diptera	Sciaridae	*Corynoptera harrisi* group	native	**31**	**10**	**6**	2.1
14		–	unidentified species	–	15	31	7	2.0
15	Araneae	Lycosidae	*Lycosa hilaris*	native	–	18	8	1.6
16		Linyphiidae	unidentified species	–	10	11	30	1.6
17	Hemiptera	–	Homoptera sp. B	–	27	39	10	1.1
18	Hymenoptera	Diapriidae	unidentified species	–	–	–	9	1.1
19	Araneae	Hahniidae	*Rinawa otagoensis*	native	11	18	–	0.9
20	Coleoptera	Staphylinidae	Aleocharine spp.	native?	**20**	**18**	**20**	0.9
21	Hymenoptera	Diapriidae	*Trichopria* sp. B	native	–	18	14	0.9
22	Acari	–	Morphospecies 2	–	14	27	42	0.8
23	Diptera	Calliphoridae	?*Pollenia* sp.	native	48	–	12	0.8
24	Enchytraeida	Enchytraeidae	Species B	native?	–	–	13	0.8
25	Orthoptera	Anostostomatidae	*Hemiandrus* sp.	native	20	–	18	0.8
			Cumulative percentage		79.6	73.6	86.6	80.1

exotic species (*c.*58%) were found in all three vegetation types, and all but one were recorded in exotic pasture (Table 2).

Ranking of invertebrates based on abundance data showed that the 25 most abundant taxa comprised 80.1% of all specimens, and included 12 native, 6 exotic and 7 taxa of undetermined origin (Table 3). Only one of these taxa, the native spider *Rinawa otagoensis* (Hahniidae), was not recorded from pasture, whereas two other taxa, an undescribed Diapriidae species (Hymenoptera) and an oligochaete species (Enchytraeidae), were absent beneath both shrub species. Of the shared taxa, nine were caught in higher numbers in pasture (3 native, 3 exotic, 3 undetermined), 4 under *O. bullata* (1 native, 1 exotic, 2 undetermined) and 2 under *C. propinqua* (2 native; Table 3). Twelve of the taxa were ranked amongst the most abundant in all three environments, but only two taxa had similar distributions in pasture and shrubland, an aleocharine species (Coleoptera, Staphylinidae) and Acari morphospecies number 5 (Table 3).

Discussion

Despite sampling in a highly-modified terrestrial habitat, we found that the invertebrate community was made up predominantly of native taxa. Most taxa were taken in low numbers in the 2-week sampling session. Exotic species were relatively few, but they were proportionally much more abundant. Overall, a small number of taxa dominated the community, and these common taxa tended to be widely distributed across all three habitats.

The subsampling data (that allowed a comparison of absolute values) showed that nearly half of the native taxa recorded were collected only from under native shrubs. The MDS ordinations and ANOSIM indicated that many taxa in the community were unique to traps placed under shrubs compared with those in exotic pasture. These differences were detectable at species, family and order levels, and were most evident for the fauna beneath *O. bullata* in comparison to exotic pasture. As a result, there is an indication that the removal of the native shrub cover (especially of *O. bullata*) may lead to the local extinction of some native ground invertebrate species.

Many native taxa were also recorded in the adjacent exotic pasture, and it is possible that we obtained a 'spill over' effect for certain native species that occur primarily in the shrubland. In an example of this from the Wellington area, Crisp *et al*. (1998) identified a small modified patch of native forest as an important reserve for local native insects, even though some of the species were also located in an adjacent area of exotic grass (see also Harris and Burns, 2000). Regarding the native taxa recorded solely in the exotic pasture, the change from a relatively dense shrub cover to open pasture may have benefited some of the surrounding native grassland invertebrate species. For example, Rufaut (2002) showed that a high number of native invertebrate species collected from montane tall tussock grasslands (400 m above the studied shrubland) were also present in areas of exotic pasture immediately adjacent to the tussock lands.

The apparently (but not statistically) higher diversity and relative abundance of ground-dwelling invertebrates recorded under *C. propinqua* compared with *O. bullata* contrasts with previous results for this shrub-dwelling invertebrate community. Derraik *et al.* (2003) found that the diversity and abundance of invertebrates collected from shrub foliage by beating was higher on *O. bullata* than *C. propinqua.* Reasons for these contrasting results are not clear, but it is likely that different factors influence the plant- versus ground-dwelling invertebrate communities. For example, warmer soil temperatures and greater soil depth recorded beneath *C. propinqua* (Derraik, 2001) may increase the activity of ground-dwelling invertebrates, and result in higher catches in pitfall traps. Alternatively, higher ground invertebrate numbers under *C. propinqua* may be related to the presence of large quantities of its fleshy fruit that fall and often accumulate under the plants.

Exotic pasture can be very unsuitable habitat for native species, but there is a growing body of evidence in New Zealand that suggests local areas of pasture are well used by native invertebrates when adjacent to, intermixed with or linked to native vegetation. Consequently, the value of modified and patchy native vegetation cannot be underestimated for their potential in providing native biodiversity reservoirs in agricultural and pastoral environments. We believe that maintaining areas of native vegetation, even when relatively small in size and highly modified, can be valuable for the conservation of New Zealand's native invertebrate fauna.

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