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A first assessment of New Zealand beetles restricted to large forest areas

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Introduction

Habitat loss and fragmentation are recognized as the greatest threats to the maintenance of biodiversity and the long-term persistence of threatened populations (Tilman *et al.* 1994, Barbault & Sastrapradja 1995, Dobson *et al.* 1997, Meffee & Carroll 1997, Barbosa & Marquet 2002). One issue that arises directly from the fragmentation of natural habitat, is that the vast majority of surviving remnants are small in area and few retain large expanses of pristine 'core' habitat. For instance, in New Zealand there are nearly 20,000 forest remnants which are less than 10 ha in area, but only 367 remnants of 1,000 ha or larger (data from NZ Landcover Database 1997). Thus, species with large area requirements will have proportionately less viable habitat available in the landscape (and these large patches will be more dispersed throughout the country) than species which are able to fill all their resource requirements within much smaller areas of remnant forest.

It is widely accepted that larger fragments make better nature reserves because they contain a larger amount of forest interior habitat for deep-forest specialist species (Woodroffe & Ginsberg 1998). Furthermore, large fragments are able to support species with large area requirements and maintain larger populations with lower extinction probabilities (Schwartz 1999). Here, we present the first assessment of beetle (Coleoptera) species that are restricted to large (> 1,000 ha) forest fragments in New Zealand.

Methods

The data presented here were collected as part of the Hope River Forest Fragmentation Project, located on the boundary between the largely deforested Canterbury Plains and the extensively forested Southern Alps (Ewers *et al.* 2002, Ewers 2004). Invertebrates were sampled using flight interception traps that were buried into the forest floor up to the rim of the collecting funnel and thus acted as both low-flying intercept and ground pitfall traps. Traps were placed at the edges of 15 forest fragments spanning nine orders of magnitude in size (0.01 to 1,060,408 ha), and in two control sites that were located in deep continuous forest and deep continuous pasture matrix. Traps were located at up to 11 distances from the forest edge into the forest interior (0, 2, 4, 8, 16, 32, 64, 128, 256, 512 and 1024 m), and at the same series of distances out from forest edges into the adjacent matrix. In fragments with a minimum diameter of less than 2 km, larger edge distances were sequentially dropped from edge gradients. In total, 233 traps were operated continuously from 30 November 2000 to 10 February 2001 for a total of 16,940 trap-days sampling effort, of which 10,211 were selected for sorting.

All beetle (Coleoptera) specimens were dried, pinned and sorted to family and recognisable taxonomic units (RTUs, hereafter referred to as species) based on external morphological characteristics. Where possible, species names were assigned following the nomenclature of Leschen *et al.* (2003).

For analysis, samples were divided into two categories according to habitat type and fragment area. The first category contained samples from forest habitats within large fragments only. Fragments greater than 1,000 ha in area were considered 'large' for the purposes of this study, and this included three fragments of 1,060 ha, 3,486 ha and 1,060,408 ha (the latter of which included all samples from the deep forest control site). The second category contained the remaining forest samples (from fragments that ranged in size from 0.01 to 373 ha) and all pasture matrix samples, including the deep matrix control. Of the 233 traps, 44 were located within the forest of the three large fragments.

We collated a list of all species that were collected only within forest fragments larger than 1,000 ha in area. We termed these species 'large-area specialists' and checked their conservation status against the list of New Zealand's nationally threatened invertebrates (McGuinness 2001).

Results and Discussion

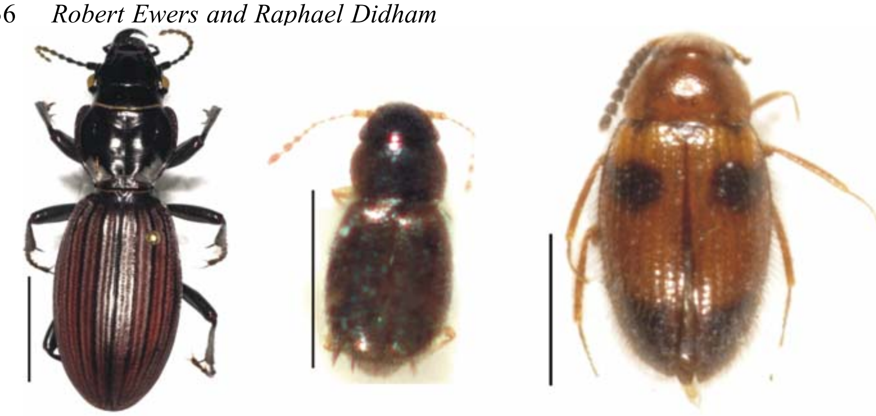
A total of 893 species were identified from the 35,461 specimens collected in the Hope River samples (Ewers 2004). Of these, a surprisingly large number of species (104, or 12 % of the total species pool) were found only in large fragments that were greater than 1,000 ha in area. Forty-three of the 104 species were restricted entirely to the deep forest control site (greater than 2 km from the nearest forest edge). Species restricted to the deep forest likely represent an extremely sensitive response to the presence of forest edges. Population densities of some invertebrate species are known to change in abundance across forest edges over distances of up to 200 - 400 m (Carvalho & Vasconcelos 1999, Didham *et al.* 1998, Laurance *et al.* 2002), and Ewers (2004) documents extraordinarily large-scale edge responses of over 1 km for some New Zealand beetle species at the Hope River site.

Table 1. List of beetle species collected at the Hope River Forest Fragmentation Project that were (a) categorised as large-area specialists with five or more specimens, and (b) recognized as nationally threatened (all category 'I': little known information, but based on existing knowledge are considered to be under threat) (McGuiness 2001). Species are arranged in taxonomic order. Abbreviations: n.g. = new genus, n.sp. = new species

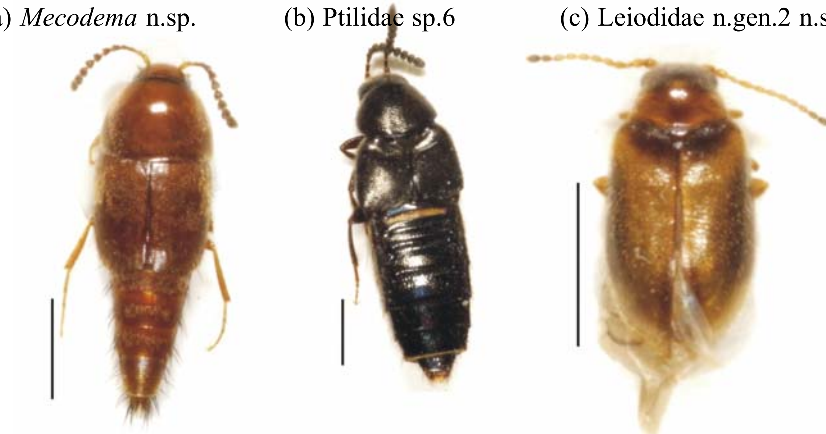
Family	Species	# of Specimens
(a) Species restricted to large forest areas in this study, but not currently listed as nationally threatened		
Carabidae	*Mecodema* n.sp.	7
Ptiliidae	Ptiliidae sp.6	52
Leiodidae	n.g.2 n.sp.1	7
Staphylinidae	*Sepedophilus* sp.5	5
Staphylinidae	*Aleochara subaenea*	7
Scirtidae	Scirtidae sp.4	27
Elateridae	*Acritelater* sp.	7
Zopheridae	*Heterargus* sp.2	6
Prostomidae	*Dryocora howitti*	5
Anthicidae	*Zealanthicus sulcatus*	7
Curculionidae	*Dermothrius brevipennis*	11
Curculionidae	*Rachidiscodes* sp.	5
(b) Species collected in this study that are currently listed as nationally threatened		
Carabidae	*Mecodema allani*	4
Tenebrionidae	*Zeadelium gratiosum*	6
Curculionidae	*Tychanopais tuberosus*	2

The majority of large-area specialists were rare, with 70 singletons (species with just one specimen recorded in all samples) and just 12 species having five or more individuals (Table 1, Figure 1). The percentage of large-area specialists that were singletons was much larger than for the complete species pool (68 % vs 26 % singletons, respectively), indicating that large-area specialists typically have low abundance. In total, the 104 large-area specialists represented less than 1 % of the 35,461 beetle specimens collected.

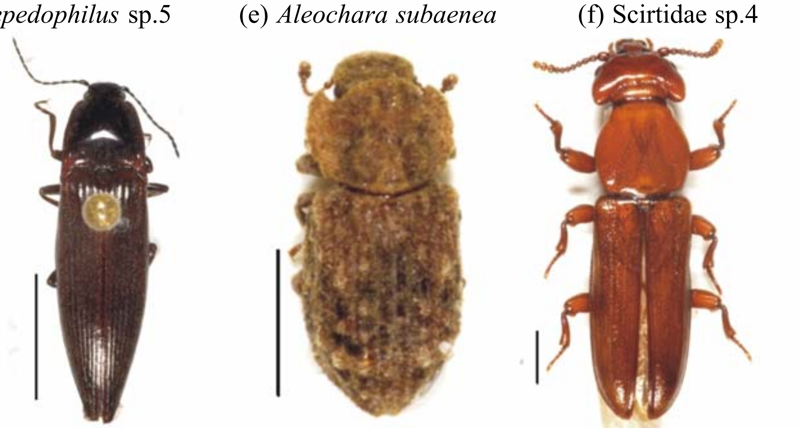
It is obviously difficult to conclude that all of the putative large-area specialists captured are, in fact, regionally or nationally rare. Flight intercept traps are activity based traps and are unlikely to catch large numbers of sedentary species (Martikainen and Kouki 2003). Furthermore, some species of beetles and fungus gnats (Diptera:



(a) *Mecodema* n.sp. (b) Ptilidae sp.6 (c) Leiodidae n.gen.2 n.sp.1



(d) *Sepedophilus* sp.5 (e) *Aleochara subaenea* (f) Scirtidae sp.4



(g) *Acritelater* sp. (h) *Heterargus* sp. (i) *Dryocora howitti*

(j) *Zealanthicus sulcatus* (k) *Dermothrius brevipennis* (l) *Rachidiscodes* sp.

Figure 1. The 12 most abundant large-area specialist beetle species collected in the Hope River Forest Fragmentation Project. Specimens are arranged in taxonomic order (see Table 1). Scale bars represent 1mm, except in (a) where the scale bar represents 10mm and in (g) where it represents 5mm.

Mycetophilidae) that are rare on the ground may be far more abundant in the forest canopy (*unpublished data*). Both of these factors may result in the underestimation of the abundance of the large-area specialists we have identified here. Furthermore, some species which are rare and restricted to large forest fragments at our study site, may be much more common in other parts of the country or in other habitat types (e.g., *Dryocora howitti*, Table 1).

Nonetheless, some species, such as the anthicid, *Zealanthicus sulcatus* Werner & Chandler 1995, are probably nationally rare. Only seven specimens of *Z. sulcatus* had been collected prior to the collection of seven further specimens in this study (Werner and Chandler 1995, Stephen Thorpe, *personal communication*), making it as rare (and nationally significant) as species such as *Brounia thoracica* (Chelonariidae) (Leschen & Early 2004). The specimens collected here represent a substantial extension to the known geographic range of *Z. sulcatus*, with the previous specimens only collected near sea level and only north of the Pelorus bridge in Marlborough. In contrast, two unidentified species, Ptiliidae sp.6 and Scirtidae sp.4, were collected in large enough numbers to be considered common by the criteria used in Ewers (2004). Clearly, these species should not be considered locally rare or threatened, but their distribution across forest fragments of different sizes is cause for concern because of the limited number of large forest areas remaining in this part of the country.

Most disturbing of all, was the fact that none of the large-area specialist species we identified are currently classed as threatened (McGuinness 2001), despite their

(a) *Mecodema allani* (b) *Zeadelium gratiosum* (c) *Tychanopais tuberosus*

Figure 2. Beetle species collected in the Hope River Forest Fragmentation Project that are listed in the national threatened invertebrates list. Specimens are arranged in taxonomic order (see Table 1). Scale bars represent 10mm.

apparently restricted habitat requirements. In contrast, only three of the 108 currently threatened beetles in New Zealand (McGuiness 2001) were present among our 893 recorded beetle species (Table 1, Figure 2), and none of these were restricted in their habitat requirements (occurring either near forest edges, in small fragments, or even in open pasture habitats). This lack of concordance between the national threatened invertebrates list and our list of large-area specialists likely occurs for three reasons. First, and most importantly, there is a distinct dearth of knowledge for many New Zealand invertebrates. It is certain that there are many more threatened invertebrate species than those which have been officially recognised in the threatened species list to date, some of which may well be contained within our large-area specialist category. For example, *Z. sulcatus* mentioned above, and two species of an undescribed genus of Leiodidae were classed as large-area specialists. One of these Leiodidae species, with seven specimens, was entirely restricted to the deep forest control site, indicating that it avoids forest edges over very large spatial scales.

Second, there is a clear bias in the nationally threatened invertebrate list toward large invertebrate species over small, inconspicuous species. Whether this genuinely reflects the fact that large-bodied organisms are intrinsically more threatened with extinction than small species (Didham *et al.* 1998) is unknown. Some families, such as Scirtidae, typically contain small-bodied, drab species which are taxonomically difficult to identify, and as a consequence they are largely unknown in New Zealand. These families have no representatives on the threatened list despite being quite speciose. In contrast, there is a high proportion of Carabidae beetles on the threatened invertebrates list. Carabids are well known and, as a group, contain a number of large-bodied genera that are, perhaps, overrepresented on the national list of threatened invertebrates. Surprisingly, *Mecodema* n.sp. is not currently listed as threatened (despite being well known amongst carabidologists; Peter Johns, *personal communication*), although the closely related *M. allani* has been placed in class 'I' and a further 29 *Mecodema* species are listed as nationally threatened (McGuinness 2001). We collected four specimens of *M. allani*, all from the large 1,060,408 ha fragment. However, we observed little overlap between the distributions of the two species. Three of the *M. allani* specimens were collected within 64 m of the forest edge and one of these was collected in the matrix surrounding the forest. Just one specimen was collected from the deep forest control. In contrast, *Mecodema* n.sp. was found only in the deep forest control, indicating there may be some type of competitive exclusion process ongoing between these two, similar species.

Finally, while a dependence on a rare habitat type is used as one criterion for the classification of species of high conservation priority (McGuinness 2001), the fragment-size distribution of relatively common habitat types, such as *Nothofagus* forest, is not. Consequently, species that we have identified as being restricted to large areas of beech forest are currently not receiving adequate conservation attention, even though they appear to be restricted by their habitat requirements to just a few surviving large habitat patches in a highly fragmented landscape.

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