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Response of Coleoptera Communities to Mammalian Pest Eradication at Maungataurari, New Zealand

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RESPONSE OF COLEOPTERA COMMUNITIES TO MAMMALIAN PEST ERADICATION AT MAUNGATAUTARI, NEW ZEALAND

Tracy H. Durnell

EcoQuest Education Foundation Directed Research Project 2005
HONORS THESIS

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Signature

Date May 9, 2006
"I went out collecting with Albert Way of Trinity, who in after years became a well-known archaeologist; also with H. Thompson, afterwards a leading agriculturalist, chairman of a great railway, and a Member of Parliament. It seems therefore that a taste for collecting beetles is some indication of future success in life." -Charles Darwin
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Abstract

Coleoptera communities are considered effective bioindicators of ecological health and entire invertebrate communities. Mammalian pest-proof fences have been constructed to create two mainland islands at Maungatautari (WO), New Zealand. The objective of this study was to assess the response of Coleoptera communities to pest eradication inside the two pest-free enclosures. Pitfall traps were placed along transect lines at lowland sites inside and outside the enclosures on both the north and south sides of Maungatautari. Invertebrates were collected twice at two week intervals and classified to family. A total of 703 Coleoptera individuals from 21 families were collected. There was no significant difference in Coleoptera family richness or abundance between pest and pest-free areas, and little difference in relative abundance of Coleoptera families. Likewise, there was no significant difference in microhabitat characteristics inside and outside the pest-free enclosures. Coleoptera family richness and relative abundance were significantly different between north and south lowland habitats. Pests had only been eradicated in the enclosures for one year at the time of this study, which is probably insufficient time for Coleoptera communities to respond.

Key Words: ecological restoration, pest eradication, Coleoptera, community structure, bioindicators, microhabitat, Maungatautari.
1. Introduction

1.1. Overview

New Zealand’s geographic isolation and the absence of terrestrial mammals have resulted in a unique invertebrate assemblage; approximately 90% of all species are endemic (Derraik et al., 2003; Derraik et al., 2001). Humans have significantly impacted New Zealand’s native invertebrates by introducing mammalian pests and altering habitats. Introduced mammalian pests like rats (Rattus spp.), possums (Trichosurus vulpecula), and stoats (mustelids) have had the greatest impact on invertebrates because endemic species are not adapted to the presence of mammalian predators and competitors. Ground beetles (order Coleoptera) are particularly susceptible to predation (Lövei & Cartellieri, 2000; Baber & Breijaart, 2005). In New Zealand, 11 invertebrate species are known to be extinct and 280 are threatened with extinction, though the actual number of extinct and threatened species is probably much higher (Baber & Breijaart, 2005).

Ecological restoration, which can be defined as “the active intervention and management to restore or partially restore biotic communities, both their plants and animals, and the associated physical environment as fully functioning and sustainable systems with a predominance of indigenous species,” can prevent the extinction of more native invertebrates (Norton, n.d.). In New Zealand, restoring native ecosystems requires the removal of mammalian pests, which predate and compete with natives and can alter vegetative structure (McQueen, 2004). Pests can be eradicated on offshore islands as large as 11000 ha (Griggs, 2005) in a single operation; however, on mainland New Zealand, where pests are ubiquitous, the constant threat of pest re-invasion means that pest control must continue indefinitely. A recently developed alternative is to create a “mainland island” by constructing a pest-proof fence and eradicating all pests within the enclosure. Because the technology is new, the effect of complete pest eradication on native invertebrates and other species is largely unknown.

The effects of pest control on indigenous invertebrates can be measured by monitoring. Certain species and communities can be used as bioindicators to reflect the health of the ecosystem as a whole or of other taxa and communities in the area (Niemi & McDonald, 2004). Taxonomic levels higher than genus and species can effectively be used as bioindicative groups because changes in communities observed at a species level are generally also visible at higher taxonomic levels (Pik et al., 1999).

Invertebrates are useful bioindicators for entire ecosystems because they: represent several trophic levels; are abundant, nearly ubiquitous, and rich in species; hold key roles in
ecosystem functions (Niemi & McDonald, 2004; Norton, 1996; Price, 1975; Huffaker & Rabb, 1984; Kimberling & Karr, n.d.; Baber & Brejaart, 2005); and are more sensitive and respond faster to environmental changes than vertebrates (Norton, 1996; Kimberling & Karr, n.d.). Because invertebrates are the main food source for insectivorous vertebrates, invertebrate abundance can indicate the status and potential abundance of those vertebrates (Huffaker & Rabb, 1984; Ward & Lariviére, 2004).

Beetles (order Coleoptera) are commonly used as bioindicators to represent insect community richness as a whole (Watts & Gibbs, 2002). In New Zealand, beetles comprise about half of the known insect fauna (as opposed to 20% worldwide [Barratt et al., 2003]). Coleoptera make good bioindicators because they are abundant, species rich, functionally diverse, multitrophic, taxonomically well-known, and sensitive to environmental changes (Burke & Goulet, 1998; Watts & Gibbs, 2002).

Past recorded effects of pest control on invertebrates have varied. The abundance of large invertebrate species on Tiritiri Matangi Island increased after mice were eradicated (Baber & Brejaart, 2005). Previous monitoring at Maungatautari found that Coleoptera abundance inside pest-controlled areas was significantly less than outside the pest-controlled areas; the composition and relative abundance of Coleoptera families was different between pest-controlled and non-pest-controlled areas (Baber & Brejaart, 2005). Beetle community composition at Karori Wildlife Sanctuary changed following eradication of pests (except mice), although beetle richness and abundance did not change (Baber & Brejaart, 2005).

At Maungatautari (Appendix A), near Hamilton, an ecological restoration project is being conducted by the Maungatautari Ecological Island Trust (MEIT), a group of local landowners, iwi, government representatives, and scientists (MEIT, 2005). A 47km pest-proof fence is currently being constructed (Innes et al, 2003). Pests were exterminated in mid-2004 in a 35ha enclosure in the north and a 65ha enclosure in the south (Durfee, 2004). The project’s goal is “to remove forever, introduced mammalian pests and predators from Maungatautari, and restore to the forest a healthy diversity of indigenous plants and animals not seen in our lifetime” (McQueen, 2004).

1.2. Study Objectives

The objective of this study is to assess the response of Coleoptera communities to pest control measures at Maungatautari. To this end, I will compare Coleoptera community structure at sites inside current pest-proof enclosures, where pests have been eradicated for one year, with sites outside the enclosures, where pests remain. Because differences in microhabitat may
affect or even cause results that vary between pest and pest-free areas, I will also examine the relationship between microhabitat characteristics and invertebrate community structures.

Because past response of invertebrates to pest control has varied, it is difficult to predict what their response at Maungatautari will be. Because pests have only been eradicated for one year, the invertebrate community may not yet have responded to changes. I expect that most differences between pest and pest-free invertebrate communities will be primarily due to microhabitat differences, as beetles are extremely dependent on microhabitat characteristics (Burke & Goulet, 1998; Watts & Gibbs, 2002) and habitat characteristics contributed to differences noted at Maungatautari in previous studies (Baber & Brejaart, 2005). If there are differences between pest and pest-free transects, I expect differences in community structures but little difference in beetle abundance.
2. Study Site

The Maungatautari Mountain Scenic Reserve comprises c. 3400 ha of native bush (Innes et al., 2004). Vegetation covers Maungatautari, an extinct andesitic volcanic cone, between 280m and its peak, 797m above sea level (Innes et al., 2004; Durfee, 2004). Forest types range from lowland rimu (*Dacrydium cupressinum*)/tawa (*Beilschmiedia tawa*) forests to tawari (*Ixerbra brexiodes*) - kamahi (*Weinmannia racemosa*) and tawheowheo (*Quintinia serrata*)-dominated montane forests (Innes et al., 2003). Approximately 240 vascular plants have been identified on Maungatautari (Durfee, 2004). Average annual rainfall on Maungatautari is approx. 1400-1600mm (Durfee, 2004) and the average daily temperature is about 14 degrees C (McQueen, 2004). Maungatautari was aerially treated with 1080 in June 1997 and August 2002, which reduced possum numbers (Innes et al., 2004), and goats and pigs are periodically controlled (Baber, pers. comm.).
3. Methods

3.1. Experimental Design

Eight 100m transects were placed using a stratified random technique, their origins 20m from established tracks at random compass bearings (Baber & Brejaart, 2005). We established four lowland transects outside the two current enclosures, two in northern Maungatautari and two in southern Maungatautari, and four lowland transects inside the enclosures, two in the north and two in the south (Appendices B & C).

3.2. Invertebrate Collection

Pitfall traps, passive traps insects fall into and cannot get out of, were used to gather invertebrate specimens. Each transect contained six pitfall traps set at 20m intervals (0m, 20m, 40m, 60m, 80m, 100m) to ensure spatial independence. There were a total of 48 pitfall traps. The traps were set between October 14, 2005 and November 11, 2005 and collected twice at c. two week intervals.

Pitfall traps were cylindrical 500ml plastic containers 11cm in diameter and 7cm deep and were dug into the ground so their rims were flush with the ground. Traps were filled with 100ml of water, 5g sodium benzoate (a preservative), and a drop of household dishwasher detergent to act as a surfactant. Plastic lids 18cm square were positioned 2-3cm over the traps with weedguard pegs to minimize rainfall entering the traps.

3.3. Habitat Characteristics

Habitat characteristics were recorded at each pitfall trap to determine the effect of microhabitat characteristics on invertebrate community structure. One m² quadrats were centered over the pitfall trap and the following characteristics were recorded: canopy cover (open, semi-closed, or closed), percent covered by vegetation 30-100cm tall, presence or absence of coarse woody debris (>20cm diameter), presence or absence of tree trunks (>20cm diameter), and percent dead organic matter on the ground.

3.4. Specimen Processing and Identification

Samples were stored temporarily in sodium benzoate solution, then sifted through a 1mm sieve and placed in 70% ethanol. They were identified to family level by Dr. Peter Maddison.
3.5. Data Analysis

To compare mean Coleoptera richness and abundance inside and outside pest-free enclosures and between northern and southern enclosures, we used Analysis of Variance (ANOVA). To determine the relationship between microhabitat characteristics and mean Coleoptera family richness and abundance, we used multiple regression analysis.

![Graph showing relative abundance of Coleoptera families](image-url)
4. Results

4.1. Overview

Between October 26, 2005 and November 11, 2005, we collected 703 Coleoptera individuals from 21 families. The most common Coleoptera families from all samples collected were, in order of relative abundance, Leiodidae (round fungus beetles), Carabidae (ground beetles), Scarabaeidae (scarab beetles), Curculionidae (weevils), and Staphylinidae (rove beetles) (Figure 1). More than half (12 of 23) of the families recorded three or fewer individuals.

![Relative abundance of most common Coleoptera families from all samples on Maungatautari](image)

Figure 1 Relative abundance of most common Coleoptera families from all samples on Maungatautari

4.2. Coleoptera Community Structure in Relation to Pest Control

There was no significant difference in Coleoptera abundance (ANOVA, F=1.617, p=0.21, Figure 2) or family richness (ANOVA, F=0.709, p=0.404, Figure 3) between pest and pest-free areas. Relative abundance of Coleoptera families was similar between pest and pest-free areas (Figure 4 & Appendix D). The most relatively abundant family in pest areas was Carabidae, whereas in pest-free areas the most relatively abundant family was Leiodidae (Figure 4).
Figure 2 Mean Coleoptera abundance per replicate per pitfall week in pest and pest-free areas on Maungatautari

Figure 3 Mean Coleoptera family richness per replicate per pitfall week in pest and pest-free areas on Maungatautari
4.3. Coleoptera Community Structure in Lowland North and South Habitats

There was no significant difference in Coleoptera abundance between north and south Maungatautari habitats (ANOVA, p=0.490, F=0.484). However, Coleoptera family richness was significantly higher at northern than southern replicates (ANOVA, p=0.026, F=5.301, Figure 5).

Additionally, there were differences between north and south relative abundance of the most common Coleoptera families. Specifically, Leiodidae relative abundance was more than four times greater in southern Maungatautari than in northern Maungatautari, and Scarabaeidae relative abundance was nearly six times greater in the north than the south (Figure 6).
4.4. Microhabitat

There was no significant difference in microhabitat characteristics between pre- and post-fire areas in the study area. However, the number of species in the southern habitat was significantly higher than in the northern habitat (Figure 5). The percentages of species were also higher in the southern habitat, with 45% and 25% of the species present in the southern and northern habitats, respectively (Figure 6). Average cover in the northern habitat was 60%, while in the southern habitat, it was 85%.

![Figure 5 Mean Coleoptera family richness per replicate per pitfall week in north and south habitats at Maungatautari](image1)

![Figure 6 Relative abundance of the most common Coleoptera families in northern and southern Maungatautari](image2)

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4.4. Microhabitat

There was no significant difference in microhabitat characteristics between pest and pest-free areas.

Percent dead organic matter was significantly higher in southern Maungatautari than northern Maungatautari (Figure 7). Trees were absent from all northern sites, while trees were present in c. 20 percent of southern sites (Figure 8). Average canopy cover was more closed at southern sites than northern sites (Figure 9).

Figure 7 Mean percent dead organic matter on ground in microhabitats at sites in northern and southern Maungatautari
5. Discussion

5.1 C. cinctipes Community Structure in Relation to Pest Eradication

...there was no significant difference in C. cinctipes abundance or family richness between pest and pest-free areas (Figure 2.3, Figure 3). There were slight differences in abundance, however, between pest and pest-free areas at northern sites (Figure 4). Durban et al. (2008) reported a decline in C. cinctipes abundance per replicate, as well as in abundance, between pest and pest-free areas at northern sites in Durban. This decline was most pronounced at northern sites, where they found significant differences between pest and pest-free areas (Durban et al., 2008). If this is...
5. Discussion

5.1. Coleoptera Community Structure in Relation to Pest Eradication

As expected, there was no significant difference in Coleoptera abundance or family richness between pest and pest-free areas (Figure 2 & Figure 3). There were slight differences in relative abundance of Coleoptera families between pest and pest-free areas (Figure 4). Durfee (unpub. data) found no significant difference in Coleoptera abundance per replicate, as well as little difference in Coleoptera relative abundance, between pest and pest-free areas at Maungatautari.

Predation is a key pressure on Coleoptera (Lövei & Cartellieri, 2000), so it would be expected that eradication of pests would allow increased Coleoptera population or, if some beetles were more susceptible to predation than others, changes in Coleoptera community structure. No such changes have been observed, suggesting that either predation was not significant at Maungatautari, insufficient time has elapsed for significant population growth, or those beetles most susceptible to pests were already made extinct (Longden, pers. comm.); if this is the case, the original beetle assemblage will not be restored, although beetle relative abundance may change. Continued monitoring will help distinguish between these three possibilities.

Invertebrates are particularly sensitive to environmental and microhabitat changes (Burke & Goulet, 1998; Watts & Gibbs, 2002). Mammalian pests like goats and pigs can affect microhabitats (Longden, pers. comm.); however, no disturbance was noted at any replicate. There was no significant difference between microhabitat characteristics inside and outside pest-free enclosures, suggesting the impact of mammalian pests on microhabitat is insignificant or that insufficient time has elapsed for any difference in microhabitat characteristics to be significant.

Seasonality affects Coleoptera abundance because many beetles have distinct seasonal activities, such as breeding (Cartellieri & Lövei, 2003); their activity is greatest during breeding season (Moeed & Meads, 1985). Predation pressure may also vary through the year; however, invertebrate consumption by native insectivorous forest birds varies little by season (Moeed & Fitzgerald, 1982, as cited in Moeed & Meads, 1987). If predation by mammals is different during different seasons, the effects of mammalian pest eradication may only be apparent after the peak season of predation or after one or several breeding seasons following the peak season of predation. Population size increases only after breeding seasons, which may occur only once or a few times each year; there was no significant difference in
abundance or richness between pest and pest-free areas, which suggests that not enough breeding seasons have passed to cause significant population growth. Changes in community structure will become more apparent after many breeding seasons because heightened success by adults will probably be reflected in increased reproductive success and thus increased relative (as well as overall) abundance.

5.2. Coleoptera Community Structure in North and South Habitats

Community structure varied between north and south more than between pest and pest-free areas (Figure 4 & Figure 6). Relative abundance of Leiodidae was four times higher in the south than the north, and Scarabaeidae relative abundance was five times lower in the south than the north (Figure 6).

There were significant differences in percent dead organic matter, presence of trees, and canopy cover between north and south transects (Figure 7, Figure 8, & Figure 9). The differences in these microhabitat characteristics could explain the differences in relative abundance of Coleoptera families between the north and the south. Canopy height and density, leaf litter, and the amount of decaying woody debris on the ground are key factors in beetle diversity and abundance (Watts & Gibbs, 2002). Leaf litter influences Coleoptera diversity because it retains moisture and provides shelter for invertebrates, including prey species (Watts & Gibbs, 2002).

Relative abundance of Leiodidae was greater in the south than the north (Figure 6). Average percent dead organic material per each replicate was significantly greater in the south than the north (Figure 7). The correlation of Leiodidae relative abundance with dead organic matter was expected because Leiodidae commonly live in habitats with decaying wood and vegetation (Borror & White, 1970). However, it was unexpected that Scarabaeidae relative abundance was lower in the south than the north (Figure 6) because all members of Scarabaeidae found were genus Saprosites, which live in leaf litter and are mostly soft saprophages, feeding on decaying wood (Stebnicka, 2001) and thus were expected to be most abundant in areas with high amounts of dead organic matter. This suggests that leaf litter is not the main determinant of Scarabaeidae population size.
6. Conclusions and recommendations

There was no significant difference in Coleoptera abundance and Coleoptera family richness between pest and pest-free areas, most likely because insufficient time has passed since pest eradication for changes in Coleoptera communities to be significant.

It is important to continue repeating this study in the future to see how much time will elapse before Coleoptera community structure changes significantly in response to pest eradication, or whether community structure does change at all. Night-active invertebrates like Carabidae are under most pressure from mammalian pests (Lövei & Cartellieri, 2000), so it will be interesting to observe whether Coleoptera abundance or relative abundance increases as time elapsed since mammal eradication increases. Because invertebrate activity is seasonal, the study should be conducted in more than one season to determine the difference in community composition by season and to ascertain whether there are differences between pest and pest-free areas during different seasons. Because differences in community composition were found between north and south Maungatautari, future repetitions of this study should compare north and south aspects of Maungatautari as well as overall pest versus pest-free areas as north and south Coleoptera communities may respond differently over time.

To improve this study, I recommend measuring the SVL of Coleoptera individuals to determine the health and age structure of Coleoptera communities within and without pest enclosures because previous studies have found changes in Coleoptera size classes after pest eradication (Green, 2002, and Watts, unpub. data, as cited in Baber & Brejaart, 2005). Only three individuals were found for over half of the families (12 of 23), suggesting that the number of replicates and the sampling period were insufficient to account for most ground-dwelling Coleoptera on Maungatautari (Baber & Brejaart, 2005). Observations of microhabitat characteristics, particularly canopy cover, were relatively subjective and may not have reflected the actual conditions. Adding categories to record overall forest structure and vegetative composition (by species or by type e.g. tree-dominated, shrub-dominated) could provide more information regarding macrohabitat characteristics that might influence Coleoptera richness or abundance.

To learn more about invertebrate community structure, it would be useful to record orders other than Coleoptera found. Recording weta and amphipod abundance could provide a wider perspective of forest health because weta and amphipods can serve as bioindicators (Baber, pers. comm).
Acknowledgements

I would like to thank the Maungatautari Ecological Island Trust for allowing us to research at the Maungatautari Mountain Scenic Reserve. Dr. Peter Maddison’s assistance in identifying our samples was invaluable. Thanks to Dr. Matthew Baber for his continued patience and guidance during the writing of this report. Many thanks to my invertebrate team—Aaron, Jen, and Lori—for their good company and preservation of my sanity during many hours sifting and sorting samples and entering and re-entering data. Jean-Michel Jarre’s wonderful music helped me write. Lastly, I would like to dedicate a special thanks to Microsoft for the Paste Special function in Excel, which both caused and prevented many problems in my data sheets.
References


Appendix A

Maungatautari Locality Map
Appendix B

Maungatautari Transect Map

Key to Transect Names

MNL1 & 2       Maungatautari North Lowland Habitat
MNLE1 & 2       Maungatautari North Lowland Habitat Enclosure
MSL1 & 2        Maungatautari South Lowland Habitat
MSLE1 & 2       Maungatautari South Lowland Habitat Enclosure
Appendix C

Directions to Transects

Transect MSL1 (Maungatautari South 3-400m above sea level [asl])

From the car park, walk through the wooden fence and continue on Tari Road, the dirt road to the left of the Xcluder fence. Walk 2-3 minutes up the road and is marked on a fencepost on the right side of the road by a yellow inverted triangle labelled with a silver tag. The transect's origin is 20 meters from the mark at a bearing of 225°M and the transect follows that bearing.

Transect MSL2 (Maungatautari South 3-400m asl)

Past the first transect, walk 2-3 minutes and the beginning of the new track will intersect the road. The transect begins on the left hand side, 50m past the entrance to the track, and is marked by an inverted yellow triangle labelled with a silver tag. The origin to the transect is 10m into the woods from the mark, at a bearing of 315°M. The transect follows the same bearing.

Transect MSLE1 (Maungatautari South, 3-400m asl, inside enclosure)

From car park, walk through wooden fence, and enter enclosure. Follow Xcluder fence to the left and walk along the path, uphill, for about 5 minutes. A yellow inverted triangle with a silver label will be on a tree to the right. The transect begins 20m into the bush at a 45°M bearing from the marker, and the transect follows that bearing.

Transect MSLE2 (Maungatautari South, 3-400m asl, inside enclosure)

From the first enclosure transect, continue walking along the fence for about 5 minutes, passing the marker for MSL1 that is on the outside of the fence. An inverted yellow triangle will be on a tree to the right. The transect origin is 20 meters into the bush at a 90°M bearing from the mark, and the transect follows that bearing.

Transect MNL1 (Maungatautari North, 3-400m asl)

From the carpark, go through the gate and follow the gravel road. Follow the orange triangle markings from at the base of the Northern entrance up the road and through the pasture. Once you come to the gate, which is to the right of the enclosure entrance, walk along the gravel
road labeled the ‘Over-the-Mountain’ track, which runs along the outside of the Xcluder fence. After approximately 4 minutes of steady walking, inverted yellow triangles should be seen. We apologize for no proper bearings.

We apologize for no directions to transects MNL2, MNLE1 and MNLE2.
Relative Abundance of All Coleoptera Families Recorded in Pest and Pest-Free Areas of Maungatautari

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Pest</th>
<th>Pest Free</th>
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<td>36.4</td>
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