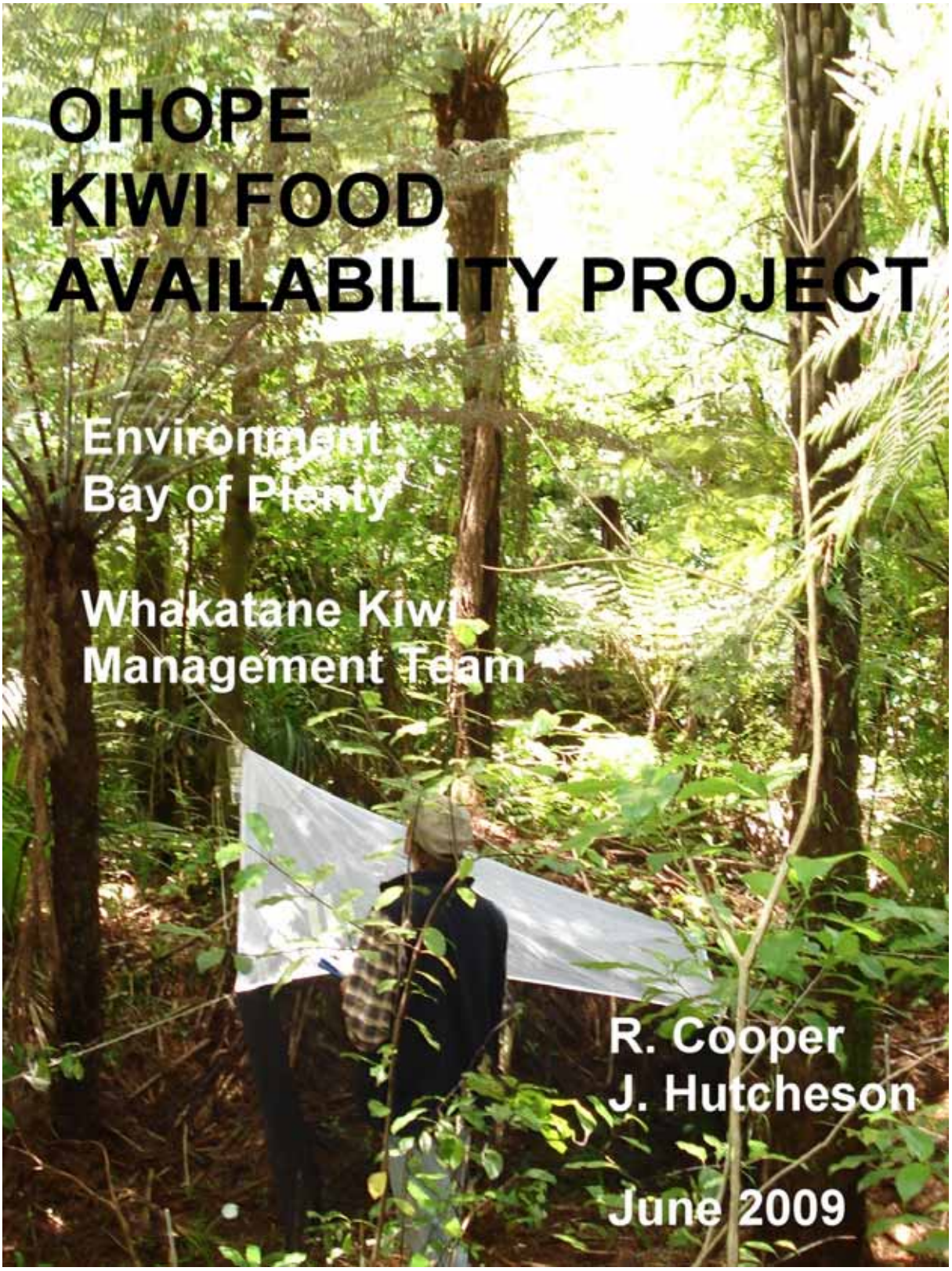

OHOPE
KIWI FOOD
AVAILABILITY PROJECT
Environment
Bay of Plenty
Whakatane Kiwi
Management Team
R. Cooper
J. Hutcheson
June 2009

Ohope kiwi food availability project

Ohope Scenic Reserve, Bay of Plenty, New Zealand

Pilot Study Report

For

EBOP Land Resources Management Team
Whakatane Kiwi Management Team

Bob Cooper
Tai Perspectives
Tauranga

John Hutcheson
Biological Systems Ltd
Ngongataha

June 2007

CONTENTS

List of figures

List of tables

List of Photos

Photo 11.Leaf beetle (Chrysomelidae) *Eucolaspis pallidipennis.* A herbivore
Photo 12.Broad nosed weevil (Anthribidae)
Photo 13. Land snail, *Suteria ide*
Photo 14. Cicada nymphs, abundant in the reserve
Photo 15. American cockroach, *Periplaneta americana*
Photo 16. Auckland tree weta, *Hemideina sp.* – key kiwi food item
Photo 17. Malaise trap, site 1
Photo 18. Malaise trap, site 2
Photo 19. Malaise trap, site 3
Photo 20. Malaise trap, site 4
Photo 21. Banded tunnel-web spider, *Hexathele hochstetteri*
Photo 22. Millipede – common in rotten logs
Photo 23. Dry ridge forest, Site 1
Photo 24. Dry ridge forest, Site 2
Photo 25. Moist valley bottom forest, Site 3
Photo 26. Moist valley bottom forest, Site 4

Photo sources

Photos 1-4, 10, 17-20, 23-26 R.Cooper
Photos 11, 12 G Weavers
Photo 7 TOL Web
Photo 6,8,13-16, 21,22 Soil animals webpage, Massey University
Photo 9 Landcare Research

ACKNOWLEDGEMENTS

The authors of this Project wish to thank the staff of Environment Bay of Plenty who supported this Project in its development. Particular mention must be made of David Paine, Pest Programme Coordinator for his untiring efforts and support during the Project.

The Project could not have worked without the support of Dr. Mere Roberts, Te Whare Runanga o Awanuiarangi Whakatane who provided guidance, laboratory support and found two exemplary students to conduct the fieldwork. The cheerful and careful efforts of Graeme Weavers, Jean McCauley and later Keriana Te Rire in collecting and sorting samples enabled the project to function. Their enthusiasm saw the creation of a video about the Project for use in the Batchelor of Environmental Studies programme.

We are very grateful to Beverley Hughes of Te Runanga o Ngati Awa and the members of the Joint Kiwi Management Team in allowing the project to take place in the Ohope Scenic Reserve.

Tansy Bliss and Michele Howard of the Department of Conservation, Whakatane, involved in the BNZ Kiwi Trust programme, gave much advice about the habits of Kiwi in the Reserve**.** We thank Tansy in particular for helping direct us to appropriate field sites.

Executive summary

The main barrier to increasing New Zealand's iconic kiwi population is predation by introduced pests.

Environment Bay of Plenty's intensive pest control programme in the Ohope Scenic Reserve seeks to improve Kiwi growth rates and breeding success.

Mustelids and rats, the main predators, have been reduced to low levels in the Reserve, but growth rates of juveniles appear to be lower than those for Motuhora Island.

A Pilot Study in 2006 – 2008 provided baseline data needed for preliminary analysis of the impact of pest predators on insect and invertebrate species taken by kiwi for food.

The Invertebrate protocol, developed during the study, was to be assessed as an outcome monitoring tool for the Ohope Reserve pest control programme, part of a longer term project.

Methods used were based on scientifically sound protocols developed in New Zealand.

Insects and other invertebrates of the Ohope coastal bush provide a critical analytical context for evaluation of pest predator control as a means of improving kiwi breeding success.

The Pilot Study provided sufficient confidence to recommend the method for pest control outcome monitoring in 2010.

A better basis for determining kiwi carrying capacity in the Ohope reserve is achievable using protocols developed as part of this study and the BNZ Kiwi Trust programme.

Invertebrate protocols developed from this project can be applied in any major vegetation type in New Zealand as a tool for assessing the impact of natural or man-induced interventions on biodiversity.

Key findings

Beetles were targeted as they provide a major food source for all small vertebrates, thereby influencing kiwi health and productivity both directly and indirectly.

A combination of Malaise and Pitfall traps effectively sampled ground dwelling and airborne populations of beetles and other invertebrates eaten by kiwi at each site. The relation ship between the two methods and its value are yet to be evaluated.

Beetle communities in the ‘dry’ and ‘moist’ coastal bush environments used by kiwi have a small average size as they lack some of the larger beetle groups used by kiwi for food. This also applies to other invertebrates, for example, weta and larger spiders.

The dominance of a wide range of endemic species in both Malaise and Pitfall trap samples is very encouraging, particularly given the burning and grazing of the reserve area in the past and the current proximity of the valley trap-sites to the reserve edge.

A partial indication of seasonal peaks in beetles and other invertebrates, their significance for kiwi egg development and juvenile growth, can be developed from the available data.

A review of the range of species eaten by rats, mice, hedgehogs and stoats identified these pests as serious competitors for food items eaten by kiwi in the reserve.

The reserve is a valuable reservoir, sustainer and generator of Eastern Bay of Plenty endemic coastal forest invertebrate fauna.

Monitoring protocols developed in this study provide a critical tool for understanding the ecological processes behind natural environmental regulation, information crucial to guide sustainable management.

The value of qualitative assessment of abundance and species richness (trophic diversity) as a statistical tool for measuring biodiversity values has been demonstrated.

A biodiversity context for management has been developed, beginning at the scale of the coastal forest habitat, then stepping down to the scale of the site habitat, as recorded by the Recce-plots and then to the beetle communities.

Invertebrate monitoring protocols developed from this study will be invaluable for measuring biodiversity in key vegetation types, pest predator impacts, levels of whole farm biodiversity for export assurance, the effect on the environment of development and management interventions.

Chapter 1: Introduction

Environment Bay of Plenty are investigating whether there may be improvement in Kiwi growth rates and breeding success of the Kiwi population in the Ohope Scenic Reserve as a result of intense pest animal control.

This report outlines the findings of a Pilot Study to validate the approaches adopted for this Project, carried out in the period December 2006 – March 2007.

1.1 Goals

The Ohope Scenic Reserve Kiwi Food Availability Project has the following goals;

- To provide data about the invertebrate population in the Reserve.
- To monitor invertebrate populations for changes that may result from intensive pest control.
- To relate changes in invertebrate availability to Kiwi growth rates and breeding success in this habitat.

1.2 Rationale

Intense pest control is expected to improve the availability of invertebrates that comprise Kiwi food and this is expected to enhance Kiwi nutrient status (and breeding success) and to increase the Kiwi carrying capacity of the Reserve.

The effect of pest control programmes on invertebrate community diversity and species abundance may be measured to assess improvement in food sources for kiwi and other native birds.

An understanding of the measurements gained can only be determined within a context of knowledge of the characteristics and dynamics of the invertebrate community and the ecosystem concerned.

The traditional inferential sampling approach has not been used to analyse community biodiversity. [1]

[1] The rationale for the statistical approach was presented in Drafts of this Report and can be viewed if required. Punlished background to the approach is contained in Hurlbert 1984, Hosking and Hutcheson 1986, Hurlbert and White 1993, 1988, Hosking 1993

The general vegetation of the area has been recorded by Beadle 1998. Vegetation demography and dynamic phase at each site is recorded using recce-plots. [2] This habitat context enables linkages to species present, and hence to better evaluation of changes occurring after intense pest control.

Insect communities can illustrate how ecosystems function because insects provide most of the functional pathways that biodiversity represents. Documenting the patterns in the insect communities, which comprise most of biodiversity, can assist with both kiwi management and understanding biodiversity ecology.

Terrestrial invertebrates appear to provide at least two thirds of the global species total. Although virtually all vertebrates are described, it is estimated that perhaps 80% of insects may be as yet undescribed. Insects thus comprise most of species biodiversity, but they are restricted to non-marine habitat. This single group of organisms therefore totally dominate the variety of functional pathways of terrestrial ecosystems. In contrast, plants comprise c. 5% and all vertebrates only c. 3% (Fig. 1). As a consequence, all meaningful evaluations of terrestrial biodiversity must either use, or be benchmarked against, the insect communities.

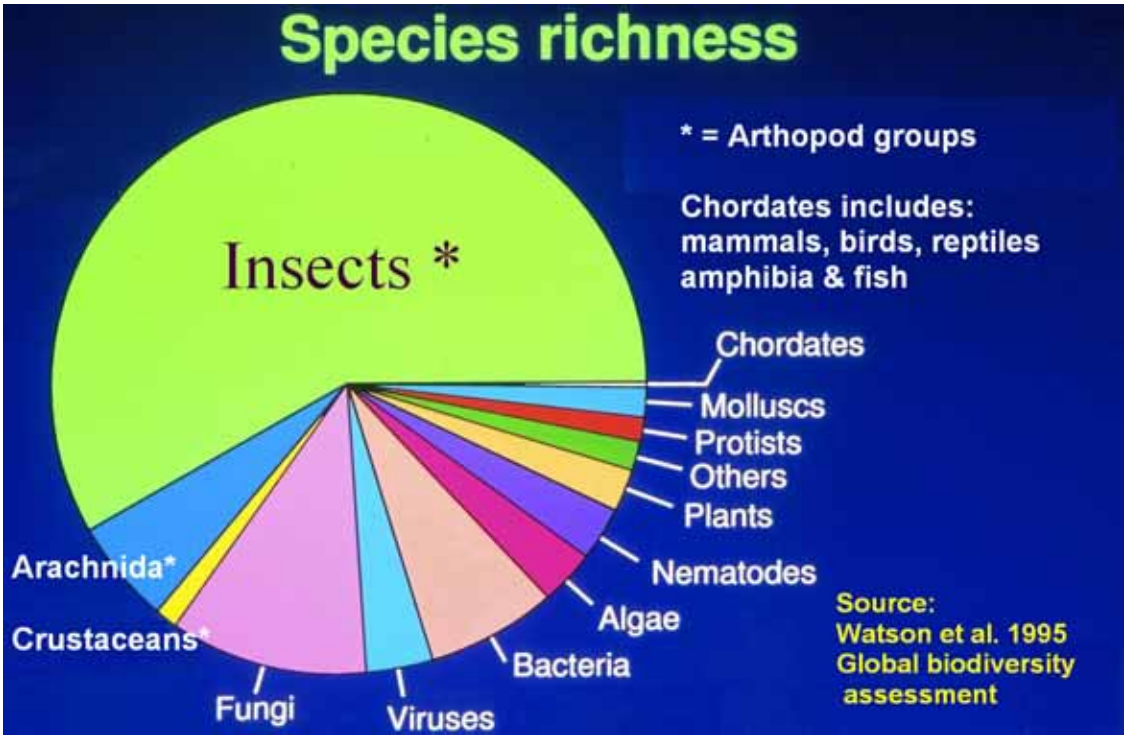


Figure 1. Distribution of total species diversity across taxonomic categories [3]

[2] See Allen 1992, Allen and McLennan 1983
[3] Watson et al 1995

Beetles comprise nearly half of the insect species in New Zealand, and so the Malaise protocols used in the Ohope reserve document the functional characteristics for the largest single order of biodiversity for the sites and season sampled.

Beetles totally permeate terrestrial ecosystems and processes, and range across all insect lifestyles. Therefore, when an appropriate approach is used, their study can provide the greatest depth of understanding about relationships between habitats and biodiversity.

The Malaise trapped beetle protocols used were developed for evaluating New Zealand's unique biodiversity situation [4]. They enable comparisons of biodiversity over time and space and can be used to evaluate the relative retention of indigenous biodiversity in highly modified habitats that are dominated by exotic vegetation [5]

The Ohope Malaise samples provide core community benchmarks that may be used in evaluations of current biodiversity status and changes following management interventions such as pest control.

The relationships between the beetle community and wider kiwi food resources will be indicated in a longer term project through linking the Malaise results with the other sampling conducted.

The approach proposed here is being advocated for biodiversity evaluation in New Zealand because insects and other invertebrates:

- Are the most abundant and diverse animals in ecosystems and have the greatest biomass.
- Can respond rapidly to environmental change, and are therefore better for evaluating human impacts or recovery from them than e.g. plants.
- Are effective as a monitoring tool because their relative diversity and abundance can be relatively pragmatically determined when an appropriate approach is used.
- Can be cost effective in demonstrating differences in biodiversity and ecosystem functioning of various habitat types.
- Can illustrate the functional status of systems through their trophic diversity and life histories.
- React to plant physiological responses to environmental conditions prior to these effects being apparent to ecologists.

[4] See Hutcheson et al 1999

[5] Hutcheson et al 1999, Ward 2003

Kiwi feed predominantly on invertebrates because of their very high nutrition value, providing specific energy needs during breeding and juvenile growth periods. [6]

A good indication of relative nutrition value is shown by the increasing concentration of nitrogen through ecological foodwebs. For wood the carbon:nitrogen ratio is in the region of 500:1, for wood decay fungi it is about 50:1, while for the insect feeding on the fungi that rots the wood, the ratio is closer to 5:1. [7]

Beetles provide a major food source for all small vertebrates, thereby influencing kiwi health and productivity both directly and indirectly.

The dominance of biodiversity by the beetles, together with the higher level of taxonomic and ecological understanding for this group, and the logistical benefits of their use, define the beetles as the most effective indicators of ecosystem biodiversity status and functioning in New Zealand. [8]

1.3 Pilot project outcomes

This Report covers Pilot Project outcomes and focuses on the initial intensive December 2006 Malaise trapping period and seasonal pitfall trap collections in the period December 2006 to March 2007.

The Pilot Project was designed to deliver baseline information through the characterization of both the vegetation and the associated insect communities in selected sites within the Ohope Scenic Reserve. These include two sites within the valley area known to be currently most productive for Kiwi and two sites on an adjacent ridge that juvenile birds are known to disperse over.

The insect community characterization process uses standardised protocols for Malaise trapped beetles that have been specifically developed in and for New Zealand habitats. [9]
Pitfall trapping will extend the characterization process by targeting the ground dwelling invertebrates that are directly available to Kiwi.

This information will provide a ‘community biodiversity status’ context for analysis directed at:

- Identifying food items available to kiwi;

---

6 Kleinpaste 1990, P.Jansen, D. Wills pers com. 2006
7 White 1993, Chapter 2
8 See Hutcheson et al 1999
9 See Hutcheson et al 1999

- Enabling comparison of relative biodiversity within the Reserve area after intensive pest control; and
- Enabling comparison of relative invertebrate diversity in other habitat types, land management regimes or geographic areas should this be required in the future.

The pilot study report includes:

- Standard vegetation RECCE-plot documentation of the sites sampled. [i]
- Standardized Malaise trapped beetle sampling results
- A preliminary inventory of :
    - The beetle species taken during the pilot project; and
    - Other invertebrate species considered to be Kiwi food items.
- The characteristics of the beetle communities in the moist (Valley) and dry (Ridge) habitats in the productive Kiwi area based on Malaise and pitfall trap samples.
- Records of current growth rates of Kiwi already within the Ohope SR, provided by existing DOC Kiwi project data. [10]
- A functional listing and interpretation from the dominant (most abundant) beetle species in these samples.
- Some preliminary comment on the relationship between the characteristics of the Malaise trapped beetle samples and those collected by other methods.

In order to improve interpretability of the invertebrate data, a further study (not the pilot study) would be needed to compile more in-depth information on what is known of:

- Kiwi food preferences and availability.
- The impact of competition for food, by rodents, mustelids and insectivores, on kiwi growth and breeding success.
- Kiwi growth rate at various sites and success parameters.
- The impact of past pest control in the Ohope, Mokorua and Te Kohi Point Reserves.

[10] See Appendix 4

Chapter 2: Pilot Study methods and protocols

A Pilot Study, designed to provide an outcome monitoring methodology for pest predator control in the Ohope Scenic Reserve, was run between December 2006 and March 2007.

.

The Reserve is a series of bush covered ridges and valleys drained by streams entering the Ohiwa Harbour. The main vegetation type is coastal forest, rewarewa, kanuka and pohutukawa being dominant. [11]

Two sets of Malaise and pitfall traps (in moist/lower slope and dry/higher slope) were established within the Ohope Reserve in areas known to be frequented by kiwi (*Apteryx australis mantelli).*

Sampling sites were located in the main kiwi 'egg production' valley and on the adjacent ridge, the juvenile dispersal zone. Two sampling sites, over a hundred meters apart, were chosen in each area.

Habitat characteristics on site, earlier forest floor invertebrate and kiwi food studies, [12] and the protocols for the Malaise trap approach developed by Hutcheson [13] guided the design of each sampling location.

Recce-plots were used to define the characteristic vegetation for each site.

Complementary methods were used to investigate other invertebrate groups that contribute to kiwi diet from litter, soil and rotten logs.

The methods used are based on many years research that has established appropriate and scientifically defensible protocols for obtaining samples characteristic for habitats in New Zealand. [14]

Vegetation and invertebrate community data provided an ecological context for analysis of the effect of predator control over time in the two types of coastal forest used by kiwi.

---

11 Beadle 1998

12 Chapman et al 2004, Moed & Meads 1985, 1987 a, b, c

13 See Hutcheson 1990, Hutcheson 1991(a), Hutcheson1996, Dugdale and Hutcheson 1997, Hutcheson 1999, Hutcheson and Kimberley 1999

14 See Hutcheson 1990, Hutcheson 1991(a), Hutcheson1996, Dugdale and Hutcheson 1997, Hutcheson 1999, Hutcheson and Kimberley 1999

2.1 Recce- plots

Standardized recce plots were used in the Ohope Reserve to document the characteristics of vegetation structure and composition for each site. [15] The method is efficient, as it is rapid, semi-quantitative, and provides an easily interpretable table of the vegetation composition, demographics and structure for the time and place.

A modification of this method has been used extensively for historical documentation of New Zealand vegetation systems. The recce-plot as used here includes observations from an undefined area of approximately 12m radius around the Malaise trap.

Use of this standard radius, rather than having plot size related to vegetation height as in the original recce plots enables comparisons despite vegetation change through disturbance or succession.

Site documentation records site attributes, vascular plant species and their cover classes within 6 fixed vertical tiers. These tiers are defined as: <30cm, 30cm-2m, 2-5m, 5-12m, 12+m (canopy) and emergent. The cover classes are defined as: 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-95%, 7 = 95-100%.

The use of these broad categories prevents the assumption, during analyses, of greater precision than is possible to achieve in the field. Notes are also made on the presence of unhealthy and dead stems, debris, fungi and leaf litter. These notes are pertinent to interpretation of invertebrate data and are additional to the original recce plot protocols which were focused entirely on living vegetation. [16]

2.2 Malaise trapped beetles

Beetles were sampled at four sites using a single Malaise trap per site over four consecutive weeks in December (See photos 17-20 and Figure 2).

Malaise traps passively intercept low-flying, crawling and emerging insects, many of which spend part of their lifecycle in the forest floor and may be eaten by kiwi and other native birds, as well as by the pest animals being targeted for control.

Unlike many other approaches, it is largely independent of both the habitat and the researcher. [17]

---

15 Allen and McLennan 1983 as modified by Leathwick 1987 and Hutcheson *et al.* 1999

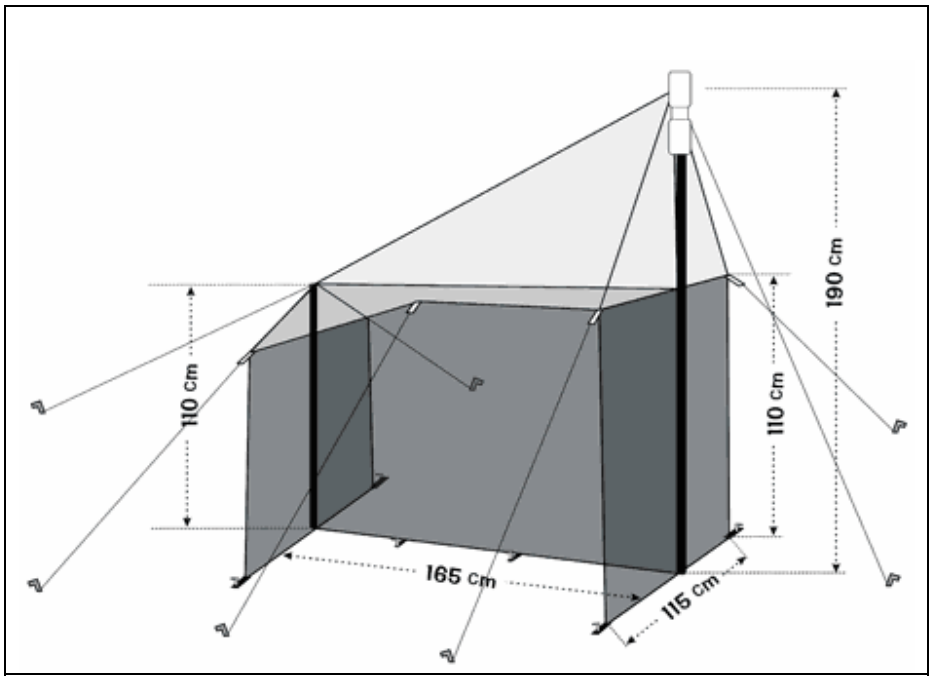
16 Hutcheson et al 1999

17 Extended discussion in Hutcheson et al 1999

Traps used were full-sized and were erected on patches of reasonably level ground, with the base of the central interception panel pegged closely to the forest floor.[18] The trap peak (and collecting attachment) was located toward the northern, lighter part of the sky, as the trap makes use of the dispersal-phase movement toward light of the insects. The attachment used was modified to hold approx 400mm of 70% ethanol.[19]

The traps were serviced weekly for 4 weeks. During protocol development, it was found that 4 separate weekly catches from within December provides samples that are most characteristic for their communities. [20] Earlier sampling includes low pre-activity catches, while later sampling is influenced by the greater mixing of the very mobile species that occurs at the end of the season. The large seasonal variation that occurs in New Zealand insect communities can easily eclipse community differences between habitats or treatments. [21] By focusing on the four week period as defined in the protocols, a much clearer discrimination of community characteristics is possible.

Figure 2: Malaise trap



Source: bugdorm.megaview.com

18 Townes 1972

19 Hutcheson 1992, Cresswell 1995

20 See Hutcheson 1990, Hutcheson 1991(a), Hutcheson1996, Dugdale and Hutcheson 1997, Hutcheson 1999, Hutcheson and Kimberley 1999

21 Hutcheson 1990

Photos 17-20: Malaise traps at sites 1 & 2 (Photos 17, 18) 3 & 4 (Photos 19, 20)
Note: Collection jar at peak of white trap roof

Most species in communities occur in lower abundances so large samples are required to provide characteristic community representation. [22] Samples from smaller (commercially available) Malaise traps have been found inadequate to provide the same clear discrimination of community samples to habitats. [23]

[22] May 1975, Tokeshi 1993, Zak 1992
[23] Dudale and Hutcheson 1997

2.3 Pitfall traps

Beetles and other invertebrates were sampled at four sites using four pitfall traps per site. Samples were collected at seven day intervals in December 2006, and monthly in the January – May 2007 period. These samples provide an indication of the diversity and relative abundance of ground living invertebrates that are potential kiwi food items.

Pitfall traps passively capture ground dwelling invertebrates. Traps were established on reasonably flat ground away from tree trunks or water channels, within 3m of each corner of the Malaise trap (See Photo 1).

The traps consisted of a plastic cup within a 200x76mm PVC tube, with a wooden cover pegged above the trap for protection. A 2cm gap between the cover and soil surface allowed ingress.

2.4 Litter, soil and log samples

Malaise and pitfall traps were complemented by targeted sampling in January and February 2007. Samples from litter, soil, rotten logs and galleries under bark on standing dead trees were investigated for significant kiwi food items and beetles not collected by core methods. [24] All samples were collected within 5 metres of the Malaise trap.

Dry surface litter and some underlying humus was removed from a 20 x 40cm quadrat square. A 20 x 40cm sample of loose soil and litter was taken from under Nikau frond spathes lying at the base of Nikau palms at Valley site 4.

A 10cm core, 20 x 10cm wide was taken under each litter sample site.

A 60cm length of a 6-10cm rotten log was collected from the forest floor at each site.

A 20 x 40cm area of bark was removed from standing dead trees and a sample of underlying loose material and bark collected.

Litter, Nikau and bark samples were put through 2 sieves, the coarse fraction examined by eye and the finer under a stereomicroscope.

Rotten log samples were broken up and coarse material sieved out. The remaining material was examined under a stereomicroscope.

[24] See Moed & Meads 1987 a & c

Photos 1-4: Graeme Weavers at Pitfall trap, Site 1 (Photo 1); Jean McCauley sorting pitfall samples (Photo 2); Graeme Weavers sorting Malaise trap samples. Beetles are being dried for mounting and identification (Photo 3); John Hutcheson identifying malaise trapped beetles (Photo 4).

Soil samples were frozen, thawed, broken up and put through 2 sieves. The remaining fine material was examined under a stereomicroscope.

2.5. Sample processing

Pitfall trap samples were rinsed through a 75 micron sieve to remove propylene glycol and placed in water in a petrie dish for examination. All samples and part samples were supplied with two labels.

The first was the standard insect collection label including location, collection method, collector and date. [25] The second label carries a code for the collection series (1OHP = 1st sampling of Ohope Reserve), the trap number and a brief habitat description derived from the Recce plot of canopy vegetation.

Beetles were removed to filter paper to dry for mounting and identification. Specimens of known beetles and other invertebrates that are kiwi food items were removed to specimen phials for identification and inclusion in a voucher collection. All specimens were given an RTU identification number, Samples for spirit storage and sample residue was stored in 70% ethyl alcohol.

Beetles were sorted from weekly Malaise trap catches under dissecting microscopes in the laboratory and transferred onto fine filter paper in petrie dishes to dry sufficiently to observe surface features clearly.

Easily identified specimens were documented and transferred back into alcohol, with one container for each weekly catch. Remaining specimens were mounted in the standard manner [26] compiled into a reference collection and identified using a wide range of published and unpublished diagnostic aids.

Beetles and invertebrates known to be eaten by kiwi from the litter, soil and rotten log samples were removed, given an RTU number and preserved in Ethyl alcohol as a voucher or in a sample bottle labelled for that site and method.

All sample residues were retained for future reference purposes.

2.6 Data analysis protocol

Data analysis is designed to provide information on the characteristic invertebrate community of the Reserve, particularly focused on Malaise trapped beetles, and to indicate their relative diversity and abundance. Other invertebrates that are potential kiwi food items may then be related to the core Malaise trapped beetle samples.

---

[25] Walker & Crosby 1988

[26] Walker & Crosby 1988

Analysis of Malaise trap samples provides:

- A benchmark inventory of invertebrate species, especially the Malaise trapped beetles, that occur in the Ohope Scenic Reserve;
- A snapshot of the invertebrate community characteristic for coastal forest of this type, and the functional relationship of communities to the habitats from which they were sourced;
- An indication of the diversity and relative abundance of invertebrates that are potential kiwi food items;
- A comparison of the invertebrate populations at 'dry' and 'moist' sites.

Pitfall trap samples for December 2006 – March 2007 provide:

- Further material for the inventory;
- An indication of the diversity and relative abundance of ground-living invertebrates that are potential kiwi food items.

Litter, soil and rotten log samples taken in January and February provide a further indication of the diversity and relative abundance of invertebrates that are potential kiwi food items. Many of these invertebrates did not occur in either the Malaise or pitfall trap samples.

2.7 Analysing Malaise trapped beetles

Species and their abundance by catch (trap-week) were recorded in an excel spreadsheet and subjected to a range of analyses including:

- Level of taxonomic definition, that is % identified to species, genus or family level;
- Percentage of endemic and adventive species;
- Sample affinities, the similarities and differences between samples from each site;
- Community profiles in terms of abundances, species richness, diversity, trophic structure and species ecology.

Success in identifying RTUs to the species, generic or family level and the number of endemic (native) and adventive (introduced) species is depicted graphically. Affinities of the 16 weekly Malaise catches (i.e., 4/trap), were objectively assessed using multivariate analyses. The divisive classification procedure TWINSPAN separates catches into groups that are most different from each other in terms of their species composition within defined abundance classes.[27]

[27] Hill 1979a

This enables intra-community difference between trap-sites to be objectively evaluated relative to the changes that occur within the communities over the 4 week sampling period. (The ongoing divisive procedure is assessed as being no longer meaningful with regard to habitat when the weekly catches become grouped by time rather than by trap-site). Results are given as a chart of the meaningful divisions and their eigenvalues (amount of the variation accounted for by a division).

The relative affinities of the weekly catches were also depicted graphically in three-dimensional space using Detrended Correspondence Analysis (DCA). [28]

Community profiles provide a picture of the relationship between a population of invertebrates (in this case beetles) and the habitat in which they live by representing differences as percentages or numbers of 'species' present in feeding (trophic) groups or guilds.

This is done using the qualitative statistical procedure TWINSPAN which uses abundance classes that are defined as: 1, 2-4, 5-9, 10-19 and 20+ specimens. The distributions of these classes are shown as mean weekly catch by site.

The functional structure of the communities was compared using four simplified trophic (feeding) groups. These included predators (including parasites etc.), herbivores (all live plant feeders), detritivores (including scavengers and fungi feeders), and aquatic species. The aquatic group is mostly in the family Scirtidae, whose larvae are semi-aquatic filter-feeding detritivores. The functional relationships between trap-site communities and their habitat is illustrated by using diversity, numbers of individuals and species in each of the four trophic classes, and the natural histories of species present where this is known.

2.8 Analysing Pitfall trap samples for beetles and other food species

Unique species were given RTU numbers, their diversity, abundance, trophic class, size, and location at either ridge or valley sites was plotted for adult beetles, for larval beetles and other invertebrates considered to be kiwi food items. This was documented for the weekly samples taken in December and the monthly samples from January – March 2007 (See Appendix 4).

The value of the combined Malaise/Pitfall method is to be tested using both sets of data.

Difficulty in identifying beetles and other invertebrates considered food for kiwi constrained the depth of analysis achieved in the Pilot Study.

[28] Hill 1979a

2.9 Analysing soil, litter and log samples for kiwi food species

Samples had a greater number of juvenile or immature forms and adult species that were not encountered in either Malaise or pitfall trap samples.

Chapter 3: Results

3.1. Trap site Habitat

The recce-plots (Appendix 1) document the composition, demographics and general health of the vegetation in the trap sites during the sampling period.
Standard six letter codes, comprising the first three letters of generic and specific names are used on the forms, on labels for pinned insect collection and for the samples preserved in alcohol.

Rewarewa (*Knightia excelsa*) is emergent over broadleaf forest canopy throughout the area (Photo 24), with a patchwork of pohutukawa (*Metrosideros excelsa*) and kanuka (*Kunzea ericoides*) over a canopy of mixed broadleaf species and silver fern (*Cyathea dealbata*), kohuhu (*Pittosporum tenuifolium*), mahoe (*Melicytus ramiflorus*) and heketara (*Olearia rani*). The presence of tall old kanuka and rewarewa strongly suggest the area was burnt over several decades ago and the area was reportedly grazed until about 35 years ago.[29].
Emergent rewarewa on ridge site 1 was undergoing exposure related dieback, leading to adjustment in the canopy of mahoe and heketara, and the subcanopy of kohuhu, red matipo (*Myrsine australis*), five finger (*Pseudopanax arboreus*) and shining karamu (*Coprosma lucida*).

Ridge site 2 had Pohutukawa and kanuka over sparse, very old mingimingi (*Leucopogon fasciculatus*), kohuhu (*Pittosporum tenuifolium)* and, five-finger (*Pseudopanax arboreus*). The relatively dense understorey of site 2 was showing some suppression, with the onset of a self-thinning phase (Photo 23).

The club moss *Lycopodium deuterodensum* was a common ground cover on the dry ridge, which included sites 1 and 2. Branches and logs were a common component of the dry litter which had a high percentage of pohutukawa and rewarewa leaves.

Valley site 3 (Photo 25) was close to the stream and the understorey habitat was open under tall kanuka (*Kunzea ericoides*) growing on the base of the valley slopes. Canopy composition included kanuka, mahoe (*Melicytus ramiflorus*), tree ferns (*Cyathea dealbata, Cyathea cunninghamii*), pigeonwood (*Hedycarya arborea*) and mangeao (*Litsea calicaris*).

[29] G. Weavers, W. Shaw pers com. 2006

Valley site 4 (Photo 26) was a warm north-facing microsite with mangeao (*Litsea calicaris*), titoki (*Alectryon excelsus*) and mature nikau palm (*Rhopalostylis sapida*). Broken kanuka tops on the ground indicated the site was undergoing a transitional phase from the kanuka canopy to that of broadleaf species, particularly mangeao (*Litsea calicaris*) and mahoe (*Melicytus ramiflorus*).

The ground ferns *Blechnum novae-zealandiae*, *Asplenium bulbiferum, Pteris macilenta* and *Blechnum chambersii* were relatively common at sites 3 and 4, topped by young tawa (*Beilschmiedia tawa)*, mangeao (*Litsea calicaris*), pigeonwood (*Hedycarya arborea*) and nikau (*Rhopalostylis sapida*). Leaf litter was damp, sparse, with many tree fern or nikau fronds and few logs or branches.

3.2 Characteristic beetle communities (Malaise)

A total of 1765 beetles were collected in the four Malaise traps over the four weeks. These comprised 218 Recognizable Taxonomic Units (RTUs) in 38 families. The full list of species names is given in Appendix 2.

Taxonomic definition

Over 60% of the RTUs have been identified to species level so far, while a further 26% have been taken to the level of genus. This gives a total of 85% of the RTUs with reasonable taxonomic definition. Approximately 7% of the RTUs (called species hereafter for convenience) were identifiable to each of the levels of subfamily and family.

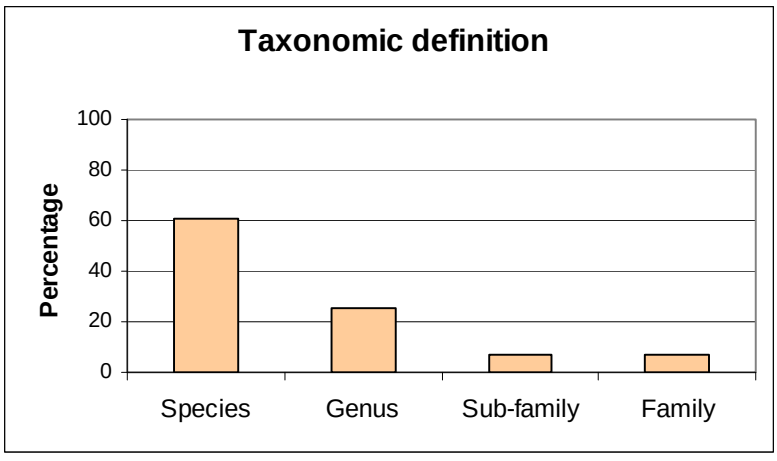


Figure 3. Current levels of taxonomy of the Malaise trapped beetles from Ohope Reserve, December 2006.

Number of endemic and adventive species (provenance)

The majority of species (nearly 75%) were determined to be endemic, while a further 12% are probably endemic, giving an estimated total of about 85% endemic New Zealand species (Fig. 4).

Despite having been burnt over in the past, and grazed perhaps 35 years the reserve is acting as a valuable reservoir, sustainer and generator of Eastern Bay of Plenty endemic coastal forest invertebrate fauna.

Only 5% of the species captured are known to be non-indigenous, however about 9% were of undetermined provenance and these will undoubtedly include some adventive species.

Some spill-over of adventive species from adjoining pasture was revealed by the valley trap-sites, which were closest to the reserve edge. Seven of the eleven known adventives, including the cocksfoot grass anthribid weevil, *Euciodes suturalis,* the clover weevil *Sitona lepidus* and the nodding thistle weevil *Rhinocyllus conicus* were captured here..

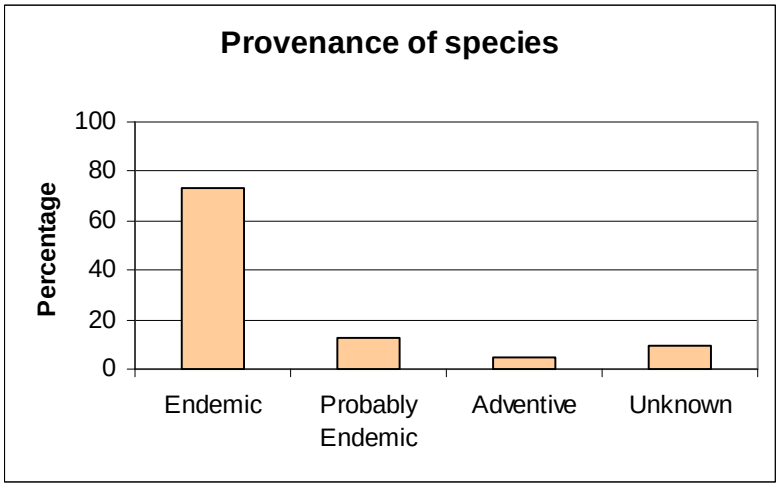


Figure 4. Provenance of species of Malaise trapped beetles from Ohope Reserve, December 2006. Endemic = New Zealand, Adventive = overseas.

Abundance distributions

As with all communities, Fig. 5 shows that few species are common, while the majority occur in low numbers.

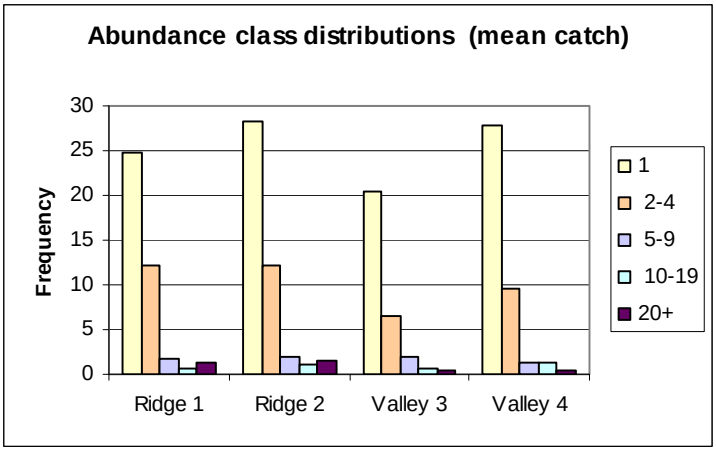


Figure 5. Abundance class distributions of 218 Malaise trapped beetle species from four trap-sites in Ohope Reserve December 2006, shown as mean weekly catch.

This makes it necessary to take large samples in order to represent sufficient of the low abundance species to enable good community characterization. [30] Figure 5 shows greater abundance in the samples from ridge sites 1 & 2, with higher number of common species (20+ specimens)

High abundance Generally only a very small number of species are very abundant, those whose ecological requirements match the prevailing habitat conditions well at the time of sampling.

Sample affinities

The total of 16 weekly catches divided cleanly at the first division of TWINSPAN into two groups of eight, corresponding to the ridge and valley areas (Fig. 6). The eigenvalue (a measure of the community variance accounted for by the division), was 0.45, showing that although the beetle communities of the two areas were identifiably different, considerable overlap of species occurred.

[30] Dugdale & Hutcheson 1997, Hutcheson et al 1999

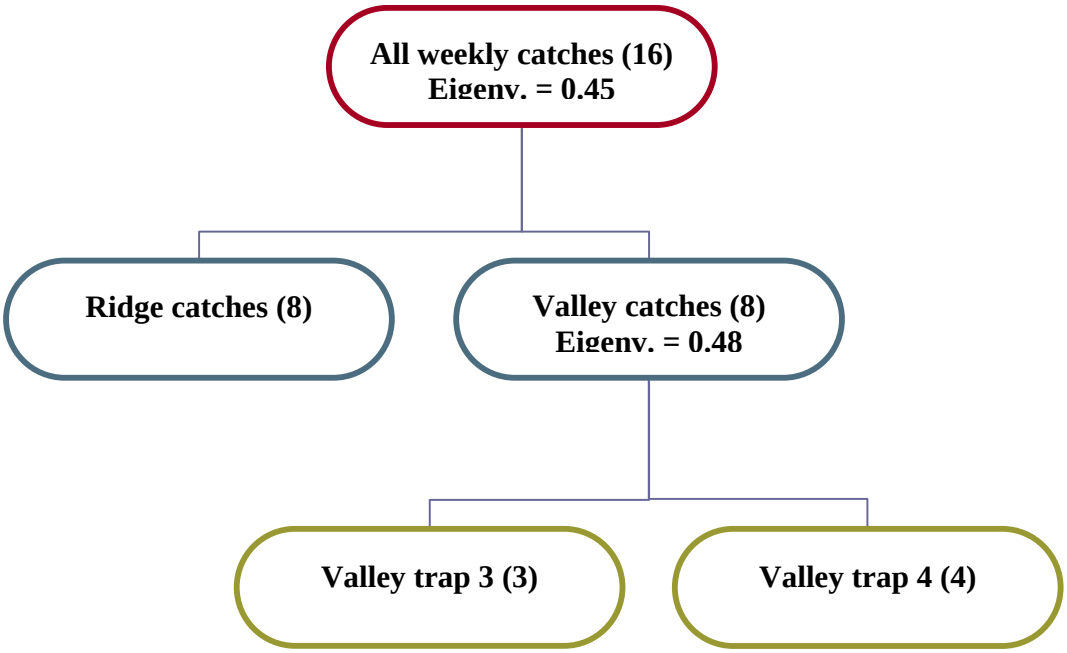


Figure 6. Divisive classification (TWINSPAN) of Malaise trapped beetle catches (catch = trap/week) from first sampling series of Ohope Reserve, December 2006. Ridge and valley communities were clearly discriminated, but the low eigenvalue indicates that considerable sharing of species occurs. The clearer discrimination of the valley site communities (after one anomalous catch was split off), showed them to be more different from each other than were the ridge site communities.

Further divisions suggested that community variation within each of the ridge sites over the 4-week sampling period was as great as that between sites. But while these communities were not as clearly distinctive as those from ridge and valley, differences could be discerned from the biologies of component species (as discussed below).

After the anomalous catch from valley site 3 had been divided off, catches from the two valley sites were also able to be discriminated (eigenvalue 0.48). The greater distinctiveness of the valley site catches in comparison with those from the ridge sites was also clearly evident from the DCA depiction of their relative ecological distances (Fig. 7).

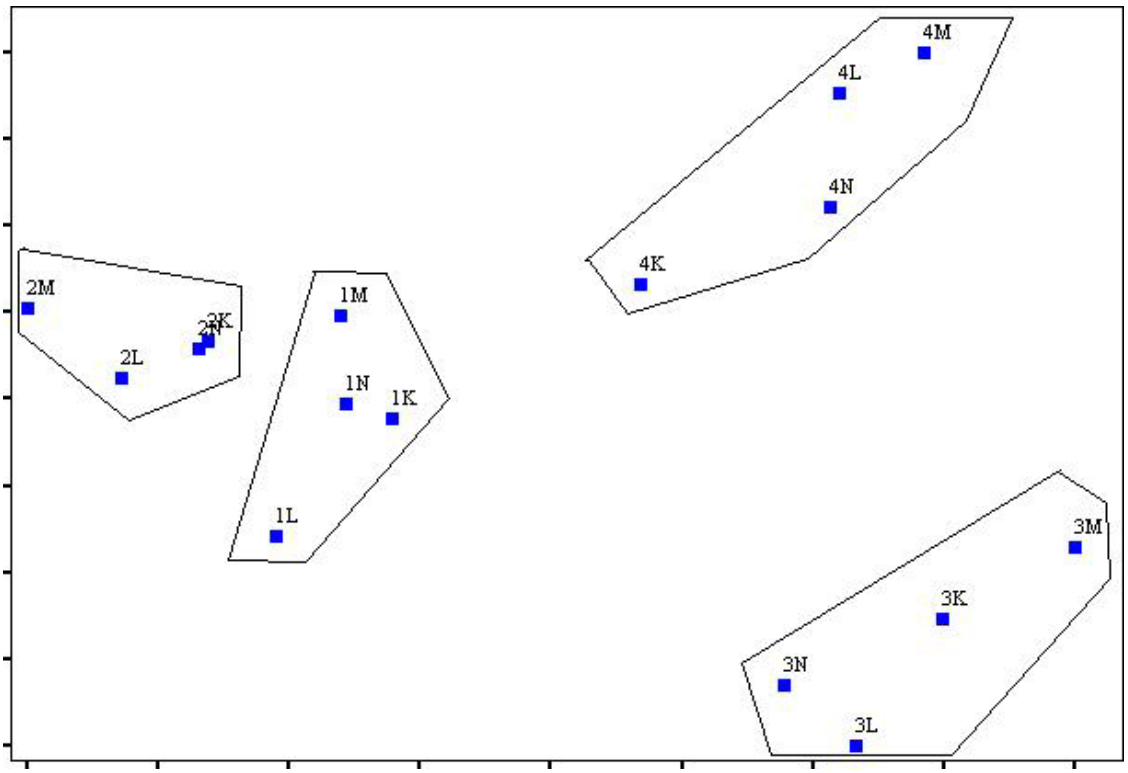


Figure 7. Detrended Correspondence Analysis (DCA) of the relative ecological distance (i.e. community affinities) between weekly Malaise trapped beetle catches from Ohope Reserve December 2006. Traps 1 & 2 are ridge sites, and traps 3 & 4 are valley sites. The letters K - N refer to weeks 1 to 4 over the sampling period in December 2006.

The weekly catches are grouped by trap-site rather than by date, objectively showing that greater difference existed between the site communities than within sites over the sampling period. Note that the ridge site communities were more similar than the valley site communities. These results are in accord with the divisive classification shown in Figure 6.

Community profiles

Diversities

Diversity indices are the traditional way in which extremely complex communities such as insects are compared. While these indices appear to offer useful comparisons, they essentially mask the biological meaning of data. Appendix 5 discusses the issue.

Figure 8 compares two standard diversity indices (Shannon's (H') and evenness (J), with species richness and with an index (SAC) that is derived from summing the abundance classes that have been found to give best discrimination of communities to habitat.[ii]

SAC thus uses a biologically meaningful transformation of abundance, in contrast to, say, log transformation (which is a function of our mathematics).

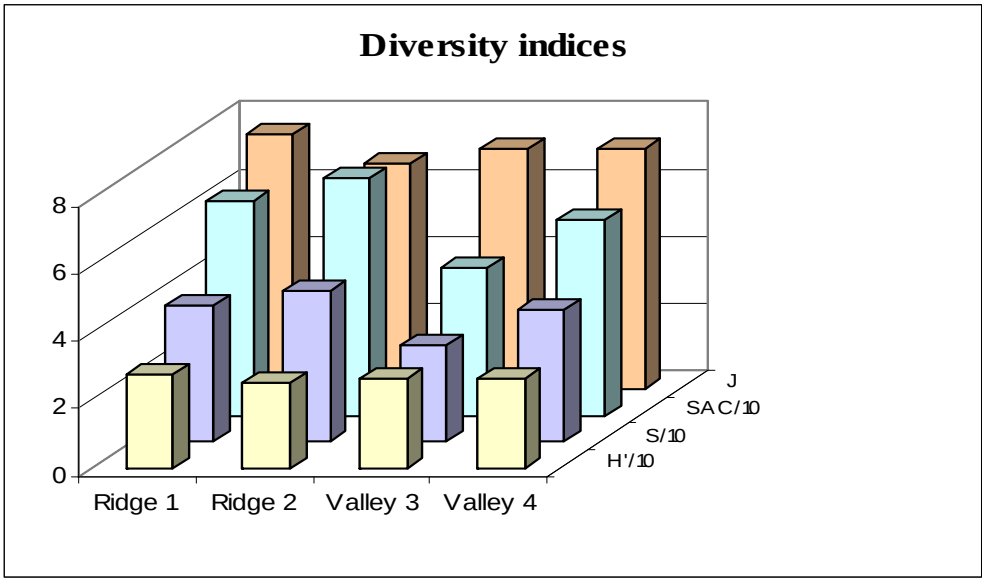


Figure 8. Comparison of a range of diversity indices compared with species richness (S). H' = Shannon's, J = evenness and SAC = Summed Abundance Classes. H', S & SAC are divided by 10 to make comparison with J easier. Note that different indices give different rankings of traps.

The major advantage of SAC derives from the ease with which biological qualities (e.g., trophic status) of the communities may be included in summations. This is shown in figure 9, where trophic groups are depicted in mean catch summations to illustrate the comparative functional diversity of the communities.

However the combining of species richness and abundance still obscures most of the information which assists in the interpretation and the understanding of the results.

This is demonstrated in figure 10 by the separation of abundance and species richness, enabling the community functional characteristics at these levels to be compared.

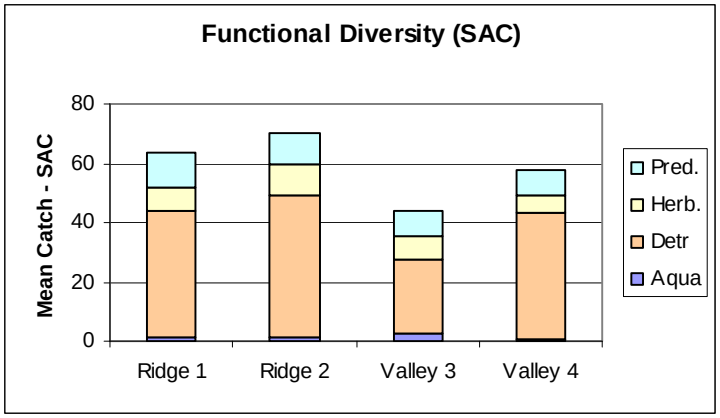
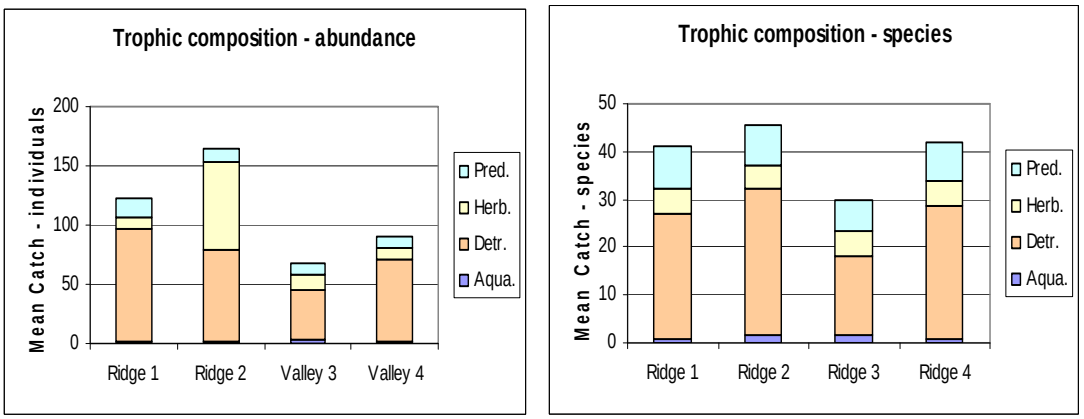


Figure 9. Functional diversity displayed as trophic distribution of Summed Abundance Classes (SAC)[iii]. SAC enables trophic (or other biological values) to be included in comparisons, thus beginning to introduce biological meaning into the summations of the communities.



(a) (b)

Figure 10. Trophic distribution displayed as mean catch of: (a) individuals, and (b) species.

Even the biologically meaningful diversity index SAC (Fig. 9) cannot provide the interpretable information that is available by simply comparing (a) & (b).

For example: (i) Ridge-site 2 shows an abundance of herbivorous individuals but not of species, indicating that the high herbivore population was due to a relatively small number of species in this trophic group, which was much more equal across the sites.
(ii) Valley site 3 had relatively low numbers of individuals compared with the other traps, but the relative difference is less at the level of species. This is in accord with the mean abundance distribution from this trap (Fig. 5).

While the sampled species richness for this trap-site was lower than from the other traps, it was the lower incidence of abundant species on this site that influenced the lower overall catch from this site.
(iii) Predators include a fairly consistent proportion of several species, generally of low abundance.

Dominant species
Communities are characterized by many species of low to moderate abundance. However it is the most abundant species that potentially provide the greatest understanding of how ecosystems function and can give insights into current ecological dynamics of the habitats.

Table 1. Most abundant beetle species captured in Malaise traps

(a) Species averaging abundance class 3 or over. (Abundance classes are defined as: class 1 = 1 specimen, 2 = 2-4, 3 = 5-9, 4 = 10-20 & 5 = 20+ specimens).

Note that very few species occur in high abundance. Traps 1 & 2 were ridge sites and 3 & 4 were valley sites. The trophic groups are broad and somewhat artificial divisions, e.g., detritivores are generally associated with fungi, but most of these ecological relationships are yet to be determined.

Family	Species	Traps	Total Abund.	Trophic designation
Curculionidae	Aneuma OHP sp 01	2	284	Herbivore
Mordellidae	Stenomordellaria neglecta	1 2	247	Detritivore?
Corylophidae	Sacina oblonga	1 2 3 4	222	Detritivore
Curculionidae	Tysius bicornis	4	53	Detritivore
Leiodidae	Colon hirtale	2	34	Detritivore
Chrysomelidae	Eucolaspis pallidipennis spp	3	29	Herbivore

Biological notes

The little weevil *Aneuma* OHP sp 01 (Curculionidae), was the most abundant species present in Malaise catches. Although captured on all sites it was only abundant in Ridge site two.

This weevil is either *Anuema fulvipes or A. rubricale* both of which feed on kohuhu (*Pittosporum tenuifolium*) on flowers buds and flowers respectively. [31] The recce plot from trap-site two shows kohuhu in tier 2 (i.e.12m + high) under the emergent pohutukawa and rewarewa. [32]

Like the other plant species recorded in tier two on this site (i.e., fivefinger and mingimingi), the kohuhu are very old shrubland and forest edge plants, indicating the relatively recent regrowth back to forest of the Reserve ecosystem. All of these shrubland plant species are now present in a tall over-mature sub-canopy, with the later successional (forest) species of mahoe and mangeao present in tier three and ready to form a new canopy. The very high abundance of this weevil thus signifies that an imminent phase shift may be about to occur in the ecosystem.

When plants are environmentally stressed (which occurs more easily as they age), they often flower and fruit more profusely. [33] Indigenous herbivorous insects have long been known to act as 'agents of change' in indigenous ecosystems [34], and this functional role is usually cued by the increased nutritional status of vegetation subjected to unfamiliar extremes in environmental parameters such as e.g. unseasonal drought. During such events, previously insoluble and unavailable nitrogen-rich plant resources are redeployed through solubilization. This makes the nitrogen more available to herbivores,[35] and the highly nutritious food increases the survival and fecundity (and hence populations) of insect herbivores.

These processes are continual and are influenced by factors intrinsic to the system, such as phase of successional development, age of trees, moisture retention capacity of sites and dynamic phases such as self-thinning and canopy gap occurrence.

Insects communities can thus be seen as a complex and finely tuned pruning and thinning gang, able to continually transform and reform the species mix in the population to quickly meet changing environmental needs. This permits the development of vegetation successions. The abundance of this little flower-feeding *Aneuma* weevil is therefore very likely to be signalling an imminent phase change in the vegetative habitat at site two.

From the above description, it can be appreciated that improving knowledge of the ecological interactions of Malaise trapped beetle species can benefit kiwi management through illustrating ecosystem status and dynamics, and enabling linkages to be formed between habitat phases and kiwi success rates.

---

31 May 1987
32 See Appendix 1
33 Hosking & Hutcheson 1992
34 Hosking and Hutcheson 1986, 1988, Hosking *et al.* 1990, Hosking 1993, Hutcheson 1991
35 White 1993, Hosking and Hutcheson 1979

Table 1(b) species in the two sampling zones that occurred in at least abundance class 3 (3+ specimens), in at least 1 catch over the four week sampling period. Abundance and biology are given where the latter are known. Only the first five letters of the family name are used for reasons of space.

Ridge sites	Abund.	Biology
Curcu *Aneuma* OHP sp 01	269	herbivore - fruit/flowers of Pittosporum tenuifolium
Morde *Stenomordellaria neglecta*	241	Detritvore?
Coryl *Sacina oblonga*	83	fungivore
Leiod *Colon hirtale*	17	Fungivore
Morde *Mordella* OHP sp 01	14	Detritvore?
Curcu *Microcryptorhynchus* spp	13	Species complex - dead phloem & leaf mines
Elate *Metablax cinctiger*	12	Predator? In dead wood
Scara *Odontria* OHP sp 02	11	Herbivore - root feeders as larvae, foliage as adult
Salpi *Salpingus bilunatus*	10	Predator
Curcu *Mecistostylus douei*	7	herbivore - live? phloem of Pseudopanax arboreum
Curcu *Peristoreus* OHP sp 01	7	Live drupes? (cf Praolepra spp. - Coprosma?)
Curcu *Tysius bicornis*	7	Dead twigs?
Cleri *Phymatophaea* OHP sp 01	6	Predator
Valley sites		
Coryl Sacina oblongatus	135	Fungivore
Chrys Eucolaspis pallidipennis spp	27	Herbivore - root feeders as larvae, foliage as adult
Crypt Micrambina helmsi	17	Fungivore
Crypt Paratomaria crowsoni	16	Fungivore
Corti Melanophthalma zealandica	10	Fungivore
Curcu Aneuma OHP sp 01	8	herbivore - fruit/flowers of Pittosporum tenuifolium
Curcu Psepholax macleayi	6	Dead wood (fungivore?)
Curcu Tysius bicornis	6	Sub-cortical in dead twigs?
Leiod Colon hirtale	6	Fungivore
Staph Pselaphinae OHP sp 02	6	Predator
Anthr Liromus pardalis	5	Fungivore
Curcu Sitona lepidus	5	Clover root weevil (spillover from farmland)

The biology of much of the family Mordellidae is presently very poorly defined. The endemic beetle *Stenomordellaria neglecta* feed on manuka flowers as adults and have been extracted (as adults?) from gorse (*Ulex europaea*) on the edge of native bush.[36]

[36] Kuschel 1990

The corylophid, *Sacina oblonga* appears to be a ubiquitous fungivore in indigenous systems throughout most of New Zealand.[37], but details of its fungal associations are as yet unknown.

The leiodid *Colon hirtale* was assigned detritovore status, with fungal/decay associates which are also currently undetermined.

The chrysomelid complex *Eucolaspis pallidepennis* spp. are a group of species not yet well defined taxonomically. They are root feeders as larvae and generalist foliage feeders as adults, and are generally associated with shrubland. Other sampling has indicated they are largely replaced by the larger *E. brunnea* spp. as ecosystems develop into tall forest. Two specimens of the latter were captured in valley site 3.

Further information is available from the biology of the more moderately abundant species listed in Table 1(b). These are species that occurred at least once in abundance class 3 (3+ specimens).

3.3 Characteristic beetle communities (Pitfall and other methods)

A total of 293 beetles were collected in the 32 pitfall trap catches between December 2006 and March 2007. Sixty five Recognizable Taxonomic Units in twenty three families are recognized.

Table 2: Most abundant pitfall trapped beetle species, i.e., those with more than 3 specimens over the period December 2006-January 2007. R1 and R2 are ridge sites, V3 and V4 are Valley sites.

Family	**Species**	**Traps**				**Total Abundance**	**Trophic designation**
		R1	R2	V3	V4		
Carabidae	*Mecodema capito*	27	23	2	6	58	Predator
Leiodidae	RTU 005 *Colon hirtale*	4		1		5	Detritovore
Staphylinidae:	Aleocharine sp.1 RTU 010	3		4	12	16	Detritovore
Staphlinidae	Pselaphine sp.1 RTU 035	3		3	4	10	Predator
Scarabaeidae	Odontria sp 1 RTU 016		3			3	Herbivore
Chrysomelidae	Eucolaspis pallidpennis RTU 007		2	5	1	8	Herbivore
Curculionidae	Cossoninae RTU 002	1	2	2	3	8	Herbivore

[37] Kuschel 1990, Brooks 2001

The list of RTUs, along with recognized species names is compiled in Appendix 4.

Taxonomic definition

Ground beetles (Carabidae) and rove beetles (Staphylinidae) were the predominant beetle groups in the pitfall trap samples. Assistance with identification is intended for the next stage of the project.

Eight of the 65 RTUs (12%) are currently identified to species level, and 19 (29%) to the level of genus. The remainder (58%) are currently identified to subfamily or family level.

Provenance

Provenance of the pitfall trapped Coleoptera will become clearer with further taxonomy. All non – weevil coleopterans so far identified appear to be indigenous, while none of the adventive weevils taken in Malaise traps occurred in pitfall trap samples.

Abundance

Only the Ridge sites had a species with an abundance class distribution greater than 20, the carabid, *Mecodema capito* (see Photo 5).

Some of the more abundant pitfall trapped beetle species are shown in Table 2.

A more integrated perspective will be available when the nature of relationships between Malaise and Pitfall trap sampling has been more fully evaluated. Some points of connection are already evident, e.g., the Chrysomelid *Eucolaspis pallidpennis* was present in both Malaise and pitfall samples from valley site 3. This species complex feed on roots as larvae and foliage as adults. Their capture in pitfall traps indicates they were either laying eggs or emerging from the pupal state. This beetle was only recorded in valley site 3 in the Malaise samples where numbers peaked during the third week of sampling. Other species such as *Mecodema capito* are strictly members of the ground community, and preferred the drier ridge sites.

Sample affinities

A broad summary of pitfall results by family is given in table 2, with further detail in Appendix 3.

Further analyses to evaluate similarities and differences between and within habitats, and to integrate results with those from the core Malaise dataset, await the next phase of the project.

Clear differences are evident in terms of species composition of pitfall trapped beetles between the ridge and valley habitats. These differences relate to the particular habitat niches available at the sites, e.g., tenebrionids in rotten logs on the ground (See Table 2 & Appendix 3).

Community profiles

Comparing broad trophic functions in terms of abundance and species richness provide indications of differences in functional diversity between sites and allow a preliminary description of community character and differences between habitats.

Valley sites have more detritovores, predators and herbivores than Ridge sites. Valley sites have the only possible aquatic class, to which Hydrophilids have been assigned.

Dominant species are indicated in Table 2 and comprise carabids, scarabaeids and staphylinids. Carabids dominate in terms of individual species numbers on Ridge sites, while staphylinids and curculionids have a larger number of species in Valley sites.

3.4 Kiwi food preferences and availability

Adequate food availability is one of the criteria used historically by DOC when assessing release sites for juvenile kiwi. [38] Assurance of adequate invertebrate food supplies in the Ohope Scenic Reserve is an important element for the kiwi population improvement project (Tansy Bliss pers. com. 2005).

Determining the type and availability of key kiwi food items in the Ohope Scenic Reserve is a primary objective of this study.

A similar range of invertebrates, to that found in earlier studies of kiwi food preferences, is indicated by samples collected from the coastal bush in the Ohope Scenic Reserve.

The Pilot study has demonstrated differences in food type and availability for moist and dry coastal bush sites.

[38] Colbourne 2005

Food availability in the Reserve

More than 60% of the beetle families captured in Pitfall traps found in the reserve are used by kiwi for food. This figure will increase once the number of beetles whose larvae live on the forest floor, but which were captured in Malaise traps, is determined.

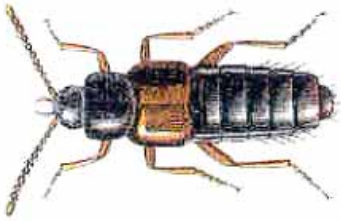
Table 3: Coleoptera – Total number, species in each family, family distribution by Habitat (December 06 – March 07)

FAMILY	*Number of Species*	*Total Individuals*	*Ridge Habitat Number*	*Valley Habitat Number*
1. ADULT COLEOPTERA				
Rhysodidae	*1*	*1*	*0*	*1*
Carabidae	*2*	*76*	*68*	*8*
Hydrophillidae	*2*	*3*	*0*	*3*
Ptliidae	*1*	*1*	*0*	*1*
Leiodidae	*2*	*6*	*4*	*2*
Scydmaenidae	*1*	*6*	*5*	*1*
Staphylinidae	*10*	*55*	*5*	*50*
Scarabaeidae	*2*	*6*	*5*	*2*
Elateridae	*1*	*3*	*2*	*1*
Cleridae	*1*	*5*	*3*	*2*
Silvanidae	*1*	*1*	*0*	*1*
Bothrideridae	*1*	*5*	*2*	*3*
Coccinellidae	*1*	*2*	*1*	*1*
Corylophidae	*1?*	*8*	*4*	*4*
Corticariidae	*3*	*5*	*4*	*1*
Mycetophagidae	*1*	*2*	*2*	*0*
Melandryidae	*1*	*1*	*1*	*0*
Colydiidae	*3*	*3*	*1*	*2*
Tenebrionidae	*1*	*4*	*1*	*3*
Anthicidae	*1*	*3*	*2*	*1*
Cerambycidae	*1*	*1*	*1*	*0*
Chrysomelidae	*2*	*11*	*2*	*9*
Anthribidae	*3?*	*4*	*1*	*3*
Brentidae	*1*	*1*	*0*	*1*
Curculionidae	*6*	*15*	*4*	*11*
TOTALS	*50*	*229*	*118*	*111*

Beetles or their larvae with a size greater than 5mm are eaten by kiwi. The average size for adult beetles in samples (4.2mm) appears low, probably due to the presence of rodent predators. [39]

[39] See Cooper & Johnston 2007

Photos 5-12: Beetles and beetle larvae favoured by kiwi for food. Rove beetles, photos 7(Aleocharine), 9 (Pselaphinid) commonest rove beetle groups.

Photo 5 Ground beetele (Carabidae) *Mecodema sp* 	Photo 6 Chafer beetle *Odontria sp.* 
Photo 7 Aleocharine Rove beetle *Atheta sp.* 	Photo 8 
Photo 9 Rove beetle *Eupines sp.* 	Photo 10 Click beetle *Conoderus exsul* 
Photo 11 Leaf beetle *Eucolaspis pallidipennis* 	Photo 12 Anthribid weevil 

Size as an element of food availability

Invertebrate food items range between 10-30mms in length, although favoured items such as cicada nymphs may be as small as 5.0mm.

Sixty nine species or species groups of beetle have been identified from pitfall trap samples: 25 or 39% are less than 3.0mm; 24 or 37.5% are 3.0 -5.0mm; 11 or 17% are more than 5.0mm (See Appendix 4).

The most frequent beetles above 10.0mm are ground beetles (carabids) and chafers (scarabids): one species of rove beetle is 10.0mm in length.

Within the 5 – 10mm range, families known to be taken as food include click beetles (elaterids), rove beetles (staphylinids), darkling beetles (tenebrionids) and some weevils.

Only 8% of the adult beetles collected are known to be taken as kiwi food. Larvae of these beetles were also taken from pitfall, litter, soil and rotten log samples and are known food items.

Moth and fly larvae or pupae, cicada nymphs, slugs and snails, centipedes, millipedes, weta, cockroaches and spiders that fall in the 5-10 and 10-30mm range are commonly recorded as or have the potential to be eaten by kiwi..

Seasonal availability

Insufficient data has been gathered during the Pilot study to comment on seasonal availability.

Impact of habitat on food availability

Feeding occurs in humus, litter, soil and decaying logs, indicating the habitats to be targeted to determine likely food items.[40]

Adult kiwi tend to occur in moister valley bottoms and juveniles on valley sides and ridges (Tansy Bliss pers.com.2006).

[40] See Kleinpaste 1990

Different communities of invertebrates are found in the moister valley bottoms and the drier ridge sites, a consequence of forest stage and soil moisture content. This influences food availability, particularly for juvenile kiwi with shorter, softer bills.

Table 4: Ridge and Valley distribution of major Coleopteran family groups in the Ohope Scenic Reserve.

SUPER FAMILY	NUMBER OF FAMILIES	NUMBER OF SPECIES	NUMBER OF INDIVIDUALS		
			Ridge	Valley	Total
Caraboidea (Ground beetles)	2	3	84	14	98
Hydrophiloidea	1	3	0	8	8
Staphylinoidea (Rove beetles)	4	15+	14	67	81
Scarabaeoidea (Chafer beetles)	1	2	8	14	22
Scirtoidea (Marsh beetles)	0	0	0	0	0
Buprestoidea	0	0	0	0	0
Byrrhoidea	0	0	0	0	0
Elateroidea (Click beetles)	1	1	2	2	4
Derodontoidea	1	1	4	0	4
Bostrichoidea	0	0	0	0	0
Cleroidea	2	2	6	8	14
Cucujoidea	6	7	10	5	15
Tenbrionoidea (Darkling beetles)	7	12	11	8	19
Chrysomeloidea (Leaf beetles)	2	3	3	5	8
Curculionoidea (Weevils)	3	18	7	23	30
	30	67	149	154	303

Table 4 indicates habitat differences for major beetle family groupings with, for example, ground and darkling beetles the main families on the drier ridge sites, scarabs, rove beetles and weevils occurring more often in the moist valley sites. Common names are given for those families containing most of the kiwi food species

Photos 13-16: Juvenile insects and other invertebrates favoured by kiwi for food

Photo 13 Land snail
Suteria ide

Photo 14 Cicada nymphs

Photo 15 American cockroach
Periplaneta americana

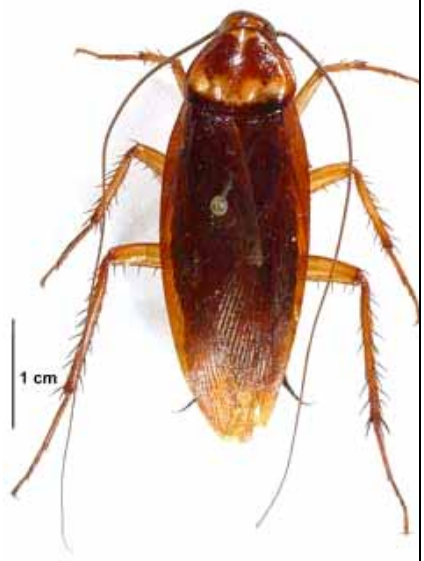


Photo 16 Auckland tree weta
Hemideina sp.

Photo 21 Banded tunnel web spider
Hexathele hochstetteri

Photo 22 Millipede

Chapter 4: Discussion

Environment Bay of Plenty are investigating whether Kiwi growth rates and breeding success in the Ohope Scenic Reserve will improve as a result of intense pest animal control.

The pilot study takes the first steps to fulfil this aim by providing an analytical context using a standardized methodology developed for New Zealand conditions.

The habitat, the invertebrate communities (particularly beetles) and the available food species provides a context for evaluating the success of pest control. Growth rate also provides an indicator of pest control success. Juvenile kiwi released into the Reserve, compared to those on Motuhora Island, appear to have a lower weight gain (pers.com. Tansy Bliss 2006). [41]

The monitoring approach provides confidence that samples are characteristic for their communities and so will better enable questions about the effectiveness of pest control for protection of kiwi and other native vertebrates to be addressed.

The database achieved has significant value for addressing other resource management issues.

4.1 Defining the key vegetation types in which kiwi live

Recce-plot analysis has provided a description of the vegetation type and successional stage in the areas of the reserve used frequently by kiwi (See Appendix 1)

4.2 Defining characteristic invertebrate communities for key vegetation types

Native forests are self-regulating, providing many ecosystems services that managers acknowledge as of benefit to community wellbeing and sustainability. [42] The retention of protection forests for minimizing erosion and for maintaining clean water supplies with moderated flow is a primary example.

---

41 Results from Moehau on the Coromandel indicate a significant weight gain for kiwi chicks following pest control. Pers.com., Pim de Monchy to David Paine, EBOP, 2007

42 The self-regulation of natural systems was documented by Lovelock 1979

Understanding the ecological processes behind natural environmental regulation is crucial to guide sustainable management.

Sustainable management of the kiwi population in the Ohope Scenic Reserve requires that we understand how insects and other bugs regulate and influence the environment in which they live.

This is a critical indicator of natural or imposed change and provides a context, together with the description of the bush habitat, allowing analysis of the effectiveness of pest control.

The Pilot study task was to provide a database useful in determining the value of the method and the effectiveness of Councils pest control programme.

The study relied on an understanding of the community of insects likely to be present, their functional roles and capacity that explained the present bush composition and the successional stage it is going through, the potential food resources available (or missing) for kiwi and competing pest predators.

Appropriate, justifiable and pragmatic approaches are required to do this and for a number of reasons this is much more possible here in New Zealand than perhaps anywhere else in the world [43]

4.3 Invertebrate samples from the Ohope Reserve

Species identification (Taxonomy)

The level of identification achieved for Malaise trapped beetles was good relative to the resources available.

Pitfall trapped beetles and other invertebrate groups known to be food items for kiwi, particularly immature forms from litter, soil and rotten log samples, have a higher percentage that are only identified to order or family level because taxonomic resources are poorer.

Presence of native and introduced species (Provenance)

The dominance of a wide range of endemic (native) species in samples is very encouraging, particularly given the burning and grazing of the reserve area in the past and the closeness of the valley trap-sites to the reserve edge.

[43] See Appendix 4

In the Whakatane region the extensive adjacent areas of remnant indigenous bush have helped to sustain the local biota, acting as reservoirs during recovery from burning and grazing. They are also a source for re-colonisation by species whose levels have been reduced by pest predation.
In comparison the Waikato, Hawkes Bay and Canterbury regions have had most of the indigenous components of the landscape removed during Lands and Survey farm development. There was no recognition during that period of the economic benefits to farmers of indigenous biodiversity in the agricultural landscapes. [44]

It is quite possible that some of the species found in Malaise trap samples are endemic to the local area. This is very difficult to ascertain with the limited resources available, and the current levels of knowledge of the New Zealand fauna. Similar sampling near Gisborne, for example, yielded nearly 10% of species that were not found in the New Zealand Arthropod Collection. [45]

The communities

Sampling of insect communities reveals that commonness is rare, whilst rarity is common. This highlights the fact that although species rarity is generally identified with conservation value, rarity may be due to a multitude of different factors, several of which may bear no relationship to the vulnerability of a species to extinction [46]. All species in ecosystems have functional roles and the most important factor affecting abundance is how well these roles match the particular ecosystem phases and dynamics prevailing at the time.

The study of abundant insect species can increase understanding of ecological functioning much more rapidly than can the study of rare species because habitat conditions need to be well matched to the ecological requirements of species for them to become common.

Ecosystems function through the organisms present, and thus habitat functional processes may be illustrated through the life histories of component species in communities.

Reasonable taxonomy and the consequent access to life history information of species associated with habitats is a primary requisite to understanding how the ecosystems operate. The Malaise trap sampling protocols thus highlight single species studies that can potentially be most useful to improving our understanding of ecosystem status and functioning.

---

44 See Hutcheson and Hosking 1994
45 Dugdale and Hutcheson 1994
46 Gaston 1994

There is only limited life history knowledge of many of the more common beetle species found in this sampling series and so the understanding of the Ohope Reserve ecosystem would be enhanced by selective single-species studies.

Species richness, abundance, species identity, functional roles(Diversities)

The purely quantitative approach to invertebrate community comparisons uses a range of diversity indices that deliver seemingly meaningful numbers to managers. [47] These indices combine the species and their abundances in varying ways, subsuming into one number all of the biological qualities of the entities involved. These include e.g., species identity, species abundance, species function and their wider functional relationships. Because it is possible to obtain the same diversity value from differing contributing factors, they are unhelpful to ecological or management evaluations.

Diversity indices have been known to be uninformative about ecosystem status or processes for many years, but their apparent offer of a simple, single number answer to questions about the relative biodiversity of ecosystems is very appealing to both science and management [48]. This apparent usefulness, together with the dominance of mathematics in science, has led to their retention long past their use-by date. An unfortunate effect of this has been to diminish the importance attributed to the biological (qualitative) aspects of ecological investigations, which has in turn contributed to the current astonishing scientific ignorance of ecosystem functioning.

As with measures of centrality or dispersion, different formulae for diversity (i.e. different ways of combining species richness and abundance distribution) will give differing rankings of communities sampled. This is illustrated in Figure 8, where the purely quantitative indices (H' and J) are shown relative to species richness (S) and summed abundance classes (SAC), both of which enable qualitative values such as species identity and functional groupings to be included in evaluations.

Although the simple diversity index SAC[iv] does enable the inclusion of qualitative values in terms of trophic status (Fig. 9), even this approach is less informative than a simple comparison of the trophic proportions of species and abundances displayed separately, as illustrated in Figure 10 (a & b).

---

47 These indices are derived from information theory and were originally designed for code-breaking (of limited alphabets). While they may be useful for seeing if the next letter is say 'e' in some limited message which uses a limited alphabet, they are ecologically meaningless in insect community ecology.

48 Samways 1984, Hutcheson 1990, Tokeshi 1993, Tonhaska 1994

The general principle emerging from this is that increasing the biological (qualitative) information available, increases the power to interpret the functional relationships between habitat and biodiversity.

Purely quantitative community summations are misleading and unhelpful to ecological understanding - and hence to management.

Community similarities and differences (Sample affinities)

It is the biological qualities of the community and their interconnections that maintain and develop ecosystems, and so sample affinities are best compared using the multivariate approaches that utilize the biological qualities of the species and abundance information. [49v]

Results from the Malaise data imply that a largely similar insect community extends throughout the reserve but that different species or species groups dominate in the different plant communities and habitats that together form the ecosystem mosaic.

As we link the communities of beetles to successional bush phases and their trophic groupings and to the kiwi food patterns depicted by the ground based sampling (pitfall, soil and litter sampling), we may combine this with kiwi habitat usage patterns which may develop after predator control.

As with other New Zealand birds, it can be expected that current kiwi habitat use is heavily influenced by predation, and that different patterns may develop after the intense pest control envisaged.

Understanding the ecological background that is accessible through component beetle species biologies can help to inform management for enhancing kiwi populations, not only within the reserve, but also for understanding the requirements of kiwi habitat elsewhere.

The immediate management concern is mammalian predator control, but a broader contextual understanding of what is going on in terms of biodiversity dynamics will assist with management of habitats not only for kiwi but for other

[49] Procedures such as TWINSPAN and DCA are now routinely used to evaluate affinities of all ecological communities, but divisive classification usually does not enable an objective evaluation of how many divisions are ecologically meaningful. The Malaise trap protocols overcome this deficiency, through their ability to use the change within the communities over time, as a relative measure of the differences between communities.

pressing management concerns – such as the evaluation of various land management regimes as options for sustaining indigenous biota.

The Malaise-trapped beetle sampling protocols provide us with an understanding of the functional dynamics and habitat phases of the coastal forest communities within the Ohope Scenic Reserve.

This is complemented through adjunct sampling of ground dwelling beetles and other invertebrates.

Together they provide a context for evaluating the impact of pest predators on invertebrate communities and the effectiveness of predator control in allowing their recovery and more successful breeding by kiwi.

4.4 The New Zealand biota and relevance to kiwi management

New Zealand's biodiversity is remarkably unique compared to most other areas of the world. For example, beetles here show over 90% endemicity compared to about 4% in Britain.

We wish to sustain kiwi because our national emblem symbolizes the unique heritage of New Zealand. The less visible components of our unique biological heritage are also precious, because they are the cogs that enable our ecosystems to function.

Enhancing the success of kiwi populations relies on an understanding of the habitat requirements that allow kiwi to thrive. Protection from introduced mammalian predators is a major habitat requirement, while others include e.g., appropriate nesting sites and an adequate food supply. The most nutritious food sources available to kiwi are invertebrates. These provide the major component of food for kiwi and other New Zealand birds - as well as a major part of the diet of most of their introduced predators.

The invertebrates therefore have direct and indirect influences on kiwi populations and knowing more about how invertebrate communities relate to their habitats will be helpful to management in many areas.

The absolute dominance by the insects of terrestrial biodiversity reflects the extent to which insects permeate through virtually all terrestrial ecological processes.

In addition to their consumption of live plant material they are involved in pollination, debris breakdown, soil formation, general scavenging, parasitism and

predation, as well as providing the dominant food for birds, lizards, and most freshwater fish. [50]

Insect involvement in almost all terrestrial functional processes also means that they have far greater potential to explain what is happening in terrestrial ecosystems, than do all other groups of organisms combined.

The standardized insect sampling protocols as used in the Ohope study therefore potentially open the largest possible window onto the way that New Zealand ecosystems function.

4.5 Implications for management

The primary role of the Kiwi food availability project Pilot Study is to deliver baseline information for evaluating management outcomes through the characteization of both the vegetation and the associated insect communities within the Ohope Scenic Reserve that are currently most productive for kiwi.

Report outcomes clearly have value for wider biodiversity understanding and monitoring.

Pest control monitoring

Invertebrate monitoring applies a new approach to determining the effect of current pest control programmes. The protocols have been designed to be pragmatic, yet to supply samples that are characteristic for the communities and habitats they were drawn from.

They enable documentation of the relationship between community structure and ecosystem functioning and the effect predators or their absence have on invertebrate communities.

This will allow an informed assessment of the affect predator presence or absence will have on kiwi breeding success.

Biodiversity evaluation and sustainability

The most powerful tool available for both conservation and for long term economic production is the use of invertebrate biodiversity to compare ecosystem functioning in natural and managed systems. The insects are the key

[50] Watt 1975

to achieving this aim because they actually form most of the biodiversity - and their functional pathways are recorded in the species biology.

This project is dependent on the development of a biodiversity context. This begins at the scale of the coastal forest habitat, and then steps down to the scale of the site habitat as recorded by the Recce-plots and then to the Malaise trapped beetle communities, which we know are integrated with both the local and the general habitat. The pitfall trap results and adjunct methods focus on the ground dwelling fauna and that of niche habitats i.e rotten logs that are more directly available to kiwi.

Malaise and pitfall traps are to be evaluated to determine their value as a combined monitoring tool, in conjunction with Recce-plot analysis of vegetation type.

This method has the potential to provide a cost effective biodiversity monitoring tool as recognition grows of the value of using the habitat-invertebrate community context:

a. to understand and evaluate the effect of natural and man made interventions;
b. to define animal biodiversity in significant vegetation types.

The methodology is being applied in other projects, either for pest control evaluation or for investigation of food availability for other native bird species.

Biodiversity in the agricultural landscape

Sustaining the more cryptic biota has economic as well as ecological implications and it is important to realize that these two perspectives are inextricably integrated. Economic productivity is utterly dependent on processes conducted by ecosystems, and these occur via the biodiversity present.

Market driven pressures to justify the quality of export products include assurances that biodiversity is not at risk or at least maintained or enhanced. This extends to requirements that monitoring protocols are robust, scientifically defensible, designed and developed under state of origin conditions.

Extensive (sheep and beef) intensive (dairying) and arable farming interests are investigating the value of this methodology to meet these requirements.

References

Allen, R.B. 1992: Recce: an inventory method for describing New Zealand vegetation. *FRI Bulletin no. 176.* Ministry of Forestry, Wellington, New Zealand.

Allen, R.B.; McLennan, M.J. 1983: Indigenous forest survey manual: Two inventory methods. New Zealand Forest Service, *FRI Bulletin No. 48.*

Atkinson, I.A.E., and D. R. Towns 2001. Advances in New Zealand mammalogy 1990-2000: Pacific rat. *Journal of the Royal Society of New Zealand* 31: 99-109

Beadel, S. M. 1998. Vegetation survey and monitoring in Ohope Scenic Reserve. *Report prepared for Department of Conservation, Whakatane.* Contract Report No.224.

Berry, R.J. 1982. *Neo-Darwinism*. The Institute of Biology's Studies in Biology No.144. Edward Arnold, London.

Bettesworth, D. J. and G. R. V. Anderson 1972. Diet of *Rattus norvegicus* on Whale Island, Bay of Plenty, New Zealand. *Tane* 18:189-195

Bremner, A. G., Butcher, C. F.; Patterson, G.B. 1984. The density of indigenous invertebrates on three islands in Breaksea Sound, Fiordland, in relation to the distribution of introduced mammals. *Journal of the Royal Society of New Zealand* 14: 379-86

Brooks, D.F. 2001. Selective logging in silver beech forest (*Nothofagus menziesii*): monitoring with beetles. (*B. Sc. Hons. Thesis*). School of Forestry, University of Canterbury, Christchurch, New Zealand.

Chapman, S; Alexander, J. and G. Ussher 2004. Sampling of terrestrial invertebrates to evaluate the effectiveness of pest control. Report prepared for Auckland Regional Council by Envirologic Ltd and G. Ussher.

Colbourne, R. and R. G. Powlesland, 1988: Diet of the Stewart Island Brown kiwi (Apteryx australis lawryi) at Scollay's Flat, southern Stewart Island. *New Zealand Journal of Ecology 11:99-104*

Cresswell, M.J. 1995. Malaise trap: collection attachment modification and collection fluid. *The Weta 18(1):* 10-11.

Daniel, M. J. 1978. Population ecology of ship and Norway rats in New Zealand. *In*: Dingwall, P.R.; Atkinson, I.A.E.; Hay, C. (Eds) *The Ecology and control of rodents in New Zealand nature reserves*. Pp. 135-141. DSIR Wellington.

Davies, P. 2002. Seven wonders, the seven biggest questions of physics. New Scientist, 21 Sept, 28-33.

Disney, R.H.L. 1986a: Inventory surveys of insect faunas: discussion of a particular attempt. *Antennae 10(3):* 112-116.

Dugdale, J.; Hutcheson, J. 1997. Invertebrate values of kanuka (*Kunzea ericoides*) stands, Gisborne Region. *Science for Conservation: 55.* New Zealand Department of Conservation, Wellington.

Emberson, R. 1994. Taxonomic impediments to the developments of sustainable practices in conservation and production. *Proceedings of the 43rd annual conference of the Entomological Society of New Zealand:* 71-78.

Fenchel, T. 1993. There are more small than large species? *Oikos 68 (2)* 375-378.

Gaston, K. 1994. *Rarity.* Population and Community Biology Series. Chapman and Hall, New York. 205p.

Hill, M.O. 1979a: *TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Cornell University, Ithaca, New York.

Hill, M.O. 1979b. *DECORANA - A FORTRAN program for Detrended Correspondence Analysis and reciprocal averaging.* Ithaca, N.Y., Cornell University.

Hosking, G.P. 1993. Seeing is not believing: insects as symptoms not causes. *New Zealand Entomologist 16:* 1-4.

Hosking G.P.; Hutcheson J.A., 1992: Sudden decline of cabbage trees: (ti kouka) how bad, how extensive? *What's New in Forest Research 227.*

Hosking G.P.; Mackenzie R.M.J.; Zondag R.; Hutcheson J.A., 1990: Effect of *Neomycta pulicaris* Pascoe (Coleoptera: Curculionidae) on hard beech (Nothofagus truncata). *Population dynamics of forest insects*. Intercept Ltd., Hampshire

Hosking G.P.; Hutcheson J.A., 1988: Mountain beech decline in the Kaweka Range, North Island, New Zealand. *New Zealand Journal of Botany 26*: 393-400.

Hosking G.P.; Hutcheson J.A., 1986: Hard beech (Nothofagus truncata) decline on the Mamaku Plateau, North Island, New Zealand. *New Zealand Journal of Botany 24:* 263-269.

Hosking G.P.; Hutcheson J.A., 1979: Nutritional basis for feeding zone preference of Arphopalus ferus (Coleoptera: Cerambycidae). *New Zealand Journal of Forestry Science 9* (2): 185-92.

Hurlbert, S. H. 1984: Pseudoreplication and the design of ecological field experiments. *Ecological Monographs 54(2):* 187-211.

Hurlbert, S.H.; White, M.D. 1993. Experiments with freshwater invertebrate zooplanktivores: quality of statistical analyses. *Bulletin of Marine Science 53(1):* 128-153.

Hutcheson, John 1990: Characterisation of terrestrial insect communities using Malaise trapped Coleoptera. *Ecological Entomology, 15(2):* 143-151.

Hutcheson J.A., 1991: Malaise trap collection jar: a cheap simple modification. *New Zealand Entomologist 14*: 48-49.

Hutcheson, J. A. 1996. Characteristics of insect communities of tawa forest in the Onaia Ecological Area using Malaise trapped beetles, and indications of influences, including 1080 operations, on these communities. *M. Phil thesis*, University of Waikato, New Zealand. (Unpublished).

Hutcheson, J.A. 1999. Characteristics of Mapara insect communities as depicted by Malaise trapped beetles: changes with time and animal control. *Science for Conservation 135*. Department of Conservation, Wellington New Zealand.

Hutcheson, J.A.; Hosking, G.P. 1994: Conserving insects through sustainable landuse: the case for forests. *Proceedings of 43rd annual conference of the New Zealand Entomological Society: Symposium - Entomology for sustainable landuse:* 59-70.

Hutcheson, J.; Jones, D. 1999. Spatial variability of insect communities in a homogenous system: Measuring biodiversity using Malaise trapped beetles in a *Pinus radiata* plantation in New Zealand. *Forest Ecology and Management 118:* 93-105.

Hutcheson J.A.; Kimberley, M.O. 1999: A pragmatic approach to insect community characterisation: Malaise trapped beetles. *New Zealand Journal of Ecology 23(1):* 69-79.

Hutcheson, J.; Walsh, P.; Given, D. 1999. The potential value of indicator species in New Zealand Conservation. *Science for Conservation 109*. Department of Conservation, Wellington, New Zealand. 90pp.

Hutcheson J.A., 1991: Notes on the ecology of Ectopsis ferrugalis Broun (Curculionidae). *New Zealand Entomologist 14:* 41-44.

Hutcheson J.A., 1991(a): Malaise trap collection jar: a cheap simple modification. *New Zealand Entomologist 14*: 48-49.

Innes, J. 1990. Ship rat. *In*: C.M. King. (Ed) *The Handbook of New Zealand Mammals* pp. 205-225. OUP. U.K.

Innes, J. 1992. An Introduction to rodents in New Zealand, **In** Veitch et al 1992. Proceedings of the National Predator Management Workshop. *Threatened Species Occasional Publication* No.3 November 1992

Innes, J.; Warburton, B.; Williams, D.; Speed, H and Bradfield. P. 1995. Large-scale poisoning of ship rats (Rattus rattus) in indigenous forests of the North Island, New Zealand. *New Zealand Journal of Ecology 19(1):* 5-18

Jones, C. and R. Toft 2006. Impacts of mice and hedgehogs on native forest invertebrates: a pilot study. *DOC Research and Development Series* 245

King, C. M. 1989. *The natural history of weasels and stoats*. Christopher Helm. London.

King, C. M. 1994. Monitoring and control of mustelids on conservation lands. Part I: planning and assessing an operation. *Department of Conservation technical series No. 3*.

Kleinpaste, R. 1990. Kiwis in pine forest. *In:* Errol Fuller (Ed.) A monograph of the family Apterygidae. Seto Publishing.

Kuschel, G. 1990: Beetles in a suburban environment: a New Zealand case study. *DSIR Plant Protection report no. 3.*

Leathwick, J. R. 1987. Waipapa Ecological Area: a study of vegetation pattern in a scientific reserve. *FRI Bulletin* No.130

Lovelock, J. E. 1979. Gaia: a New Look at Life on Earth. OUP, Oxford.

May, R.M. 1975. Patterns of species abundance and diversity. *In:* Cody, M.L. and J.M. Diamond (eds) *Ecology and evolution of communities.* Belknap/Harvard University Press, Cambridge, MA. 81-120.

May, B.M. 1987. Immature stages of Curculionoidae (Coleoptera): rearing records 1964-1986. *New Zealand Entomologist 9:* 44-56.

Miller C.J. ;Miller, T.K. 1995. Population dynamics and diet of rodents on Rangitoto Island, New Zealand, including the effect of a 1080 poison operation. *New Zealand Journal of Ecology 19(1):* 19-28.

Milligan, R.H. 1979. *Platypus apicalis* White*; Platypus* caviceps Broun; *Platypus gracilis* Broun; The native pinhole borers. *Forest and timber insects of New Zealand No. 37.* Forest Research Institute, New Zealand Forest Service.

Moed, A. and Meads, M. J. 1985. Seasonality of pitfall trapped Invertebrates in three types of native forest, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 12(): 17-53

Moed, A. and Meads, M. J. 1986. Seasonality of litter inhabiting invertebrates in two native forest communities of Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 13: 45-63

Moed, A. and Meads, M. J. 1987a. Seasonality and density of emerging insects of a mixed lowland broadleaf-podocarp forest floor, Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 14: 197-208

Moed, A. and Meads, M. J. 1987b. Seasonality of arthropods caught in a Malaise trap in mixed lowland forest of the Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 14(): 477-492

Moed, A. and Meads, M. J. 1987c. Seasonality and density of litter and humus invertebrates in broadleaf-podocarp and hard beech forests in Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology* 14(): 51-63

Moors, P.J. 1985. Norway rats (*Rattus norvegicus)* on the noises and Motukawao Islands, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* 8: 37-54

Owen, H. J. 1993. Mistletoe and the brushtailed possum in silver beech forest, South Westland New Zealand. Unpublished M. ForSc. Thesis. University of Canterbury, Christchurch, New Zealand.

Pyle, R.M.; Bentzien, M.; Opler, P.; 1981. Insect conservation. *Annual Review of Entomology 26:* 233-258.

Ramsay, G.W. 1978. A review of the effect of rodents on the new Zealand invertebrate fauna. ***In*** Dingwall, P. R.; Atkinson, I. A. E.; Hay, C. (Editors). The ecology and control of rodents in New Zealand nature reserves. Pp. 89-95. Department of Lands and Survey Information Series No.4

Rickard, C. 1996. Introduced small mammals and invertebrate conservation in a lowland Podocarp forest, South Westland, New Zealand. Unpublished M. Forestry Science Thesis. University of Canterbury. Christchurch, New Zealand.

Rose, P.S. 1997. Mutualistic biodiversity networks: the relationship between soil biodiversity and mutualism, and their importance to ecosystem function and structural organization. University of Manchester, UK. http://www.angelfire.com/sk/monkeypuzzle/mbionet.html

Samways, M.J. 1984. A practical comparison of diversity indices based upon a series of small agricultural ant communities. *Phytophylactica 16:* 275-278.

Scott, R.R.; Emberson, R.M. 1986. The status of rare and endangered species. *The Weta 9(2):* 68-74.

Smith, D.H.V.; Jamieson, I.G. and R.M.E. Peach 2005. Importance of ground weta (*Hemiandus spp*) in stoat (*Mustela erminea)* diet in small montane valleys and alpine grasslands. *New Zealand Journal of Ecology* 29(2):207-214

Tokeshi, M. 1993. Species abundance patterns and community structure. *Advances in Ecological Research*, 24. 111-186.

Tonhaska, A. Jnr. 1994. Diversity indices in the analysis of biological communities. *Ciencia Cultura Saude: 46(3):* 138-140.

Townes, H. 1972: A light-weight malaise trap *Entomological News 83:* 239-247.

Towns, D.R.; Simberloff, D.; Atkinson, I. A. E. 1997. Restoration of New Zealand Islands: redressing the effects of introduced species. *Pacific Conservation Biology 3: 99-124*

Walker, A.K.; Crosby, T.K. 1988. The preparation and curation of insects. New rev. Ed. Entomology Division, Department of Scientific and Industrial Research, Auckland, New Zealand. *DSIR Information Series 163.*

Ward, D. 2003. An introduction to invertebrates and their conservation on private land. Report prepared for the Biodiversity Advice Fund, Department of Conservation, Project No. 32

Watson, R.T.; Heywood, V.H.; Baaste, I.; Dias, B.; Gamez, R.; Janetos, T.; Reid, W.; Ruark, G. 1995. *Global Biodiversity Assessment. Summary for policy makers*. United Nations Environment Programme, Cambridge University Press, Cambridge.

Watt, J.C. 1975. The terrestrial insects. *In:* Kuschel, G. (ed.). *Biogeography and ecology in New Zealand.* Dr W. Junk b.v. The Hague, Netherlands 507-533.

Watt, J.C. 1980. Notes on pitfall trapping on Headlong Peak, Mount Aspiring National Park. *New Zealand Entomologist. 7:* 184-193.

Watt, J.C. 1982. New Zealand beetles. *New Zealand entomologist 7(3)*: 213-221.

Watt, J. C. 1986. Beetles (Coleoptera) of the offshore islands of northern New Zealand. *In* Wright, A. E.; Beaver, R. E. (Ed) The offshore islands of northern New Zealand. *Department of Lands and Survey Information Series* 16, Wellington New Zealand. Pp. 221-228.

Watts, C. 2001. Analysis of invertebrates in Mouse stomachs from Rotoiti Nature Recovery Project. Landcare Research Contract Report: LC0102/009. September 2001

White, T.C.R. 1993: *The inadequate environment, nitrogen and the abundance of animals.* Springer-Verlag, New York. 425pp.

Yom-Tov. Y.; Yom-Tov, S.; Moller, H. 1999. Competition, Coexistence, and adaptation amongst rodent invaders to Pacific and New Zealand Islands. *Journal of*

Biogeography 26: 947-958

Zak, J.C. 1992. Response of soil fungi communities to disturbance. *In:* Carroll, G.C.; Wicklow, D.T. (eds). *The Fungal Community: Its organisation and role in the ecosystem (2nd edition).* M. Dekker, Dordrecht, the Netherlands.

APPENDIX 1: Recce-plot analysis, sites 1-4, Ohope Scenic Reserve

VEG PLOT no. 1OHP 1*
****

Date: 15.12.2006 **Personnel:** J. Hutcheson **Grid. ref.:** E2863763, N6350483
Altitude: **Aspect:** S **Slope:** 5°
Physiography: Ridge flat
Parent material: Tephra **Drainage:** Good **Cultural:** Fire/Grazed ?35yrs ago
Ground cover % , Vascular plants: 40 **Moss:** **Litter:** 60 **Rock:** **Earth:**

Mean top height (m): 10m **Canopy %:** 65

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height	15m					
Density						
	Kni exc 3	3				2
		Ole ran 3		2		1
		Mel ram 3				
			Pit ten 3			
			Myr aus 3	4	4	2
			Cya dea 3		2	
			Hed arb 2		2	2
			Pse arb 2	3	3	2
			Cop luc 2	3	3	
				Dys spe 2		1
				Bra rep 2	2	
					Lit cal 2	3
					Lyc due 4	3
					Ble nov 2	
						Cop spa 1
						Pers sp 1
						Adi cun 2
						Unc unc 1
						Unc sp 1
Epiphytes						Orchid 1
						Herb1
Asp fla						
Asp obl						
Pyr ele						
Usnea						
Mosses/algae						

NOTES:
Unhealthy: Many Kni exc with exposure assoc. dieback. Several with broken tops
Dead Stems: Several Kni exc, some with final leaf browning &/or resin bleeding
Debris: <50mm (cover value =3), 50-150 (cv=4). Coarse woody debris (CWD) continuous. Old workings Ceram/Curcu
Fungi: White bracket, Brown knob & Black knob brackets
Leaf Litter: 50mm Kni exc – Mel ram –Cya dea etc. Continuous
ACCESS: Whakatane –Ohope Rd, Burma Rd. past tip. Track to left off Burma Rd parking area. Turn right onto unmarked track on ridge to left of top kiwi catchment.

* 1OHP = 1st sampling series from Ohope (kiwi) reserve, trap 1
** Codes include first three letters of generic and specific names, full names are listed below.
Cover values after names signify: 1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%. 6=75-95%, 7=95-100%

VEG PLOT no. 1OHP 2*
**

Date: 15.12.2006 **Personnel:** J. Hutcheson **Grid. ref.:** N6350522, E2863787
Altitude: **Aspect:** NE **Slope:** 5°
Physiography: Ridge roll
Parent material: Tephra **Drainage:** Good **Cultural:** Fire/Grazed ?35yrs ago
Ground cover % , Vascular plants: 60 **Moss:** **Litter:** 40 **Rock:** **Earth:**

Mean top height (m): 10m **Canopy %:** 80

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height	15m					
Density						
	Met exc 2					
	Kni exc 3					3
		Pse arb 2	2	3	2	2
		Leu fas 3				
		Pit ten 2	3	3		
			Myr aus 3	4	4	
			Lit cal 2	3	2	3
			Ole ran 2			
				Cor aus 1		
				Cop luc 3	4	3
				Gen lig 4	4	
				Mel ram 2		
					Hed arb 3	2
					Lyc deu 4	2
					Dia nig 1	
					Cor toi 1	
						Dys spe 1
Epiphytes						
Algae						
Lichen						

NOTES: Thick late shrub stage veg.
Unhealthy: Self thinning, Gen lig twig die back, suppression Pit ten etc.
Dead Stems: Some (<30cm)

Debris:<50mm (cv 3), 50-150 (cv 2)
Fungi:
Leaf Litter: c. 50mm. continuous
ACCESS: Whakatane –Ohope Rd, Burma Rd. past tip. Track to left off Burma Rd parking area. Turn right onto unmarked track on ridge to left of top kiwi catchment.

* 1OHP = 1st sampling series from Ohope (kiwi) reserve, trap 2
** Codes include first three letters of generic and specific names, full names are listed below.
Cover values after names signify: 1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%. 6=75-95%, 7=95-100%

VEG PLOT no. 1OHP 3*
**

Date: 15.12.2006 **Personnel:** J. Hutcheson **Grid. ref.:** E2864235, N6350806
Altitude: **Aspect:** N **Slope**: <5°
Physiography: stream terrace
Parent material: tephra **Drainage:** Good **Cultural:** Fire/Grazed ?35yrs ago
Ground cover % , Vascular plants: 45 **Moss:** 5 **Litter:**50 **Rock:** **Earth:**

Mean top height (m): 15 **Canopy %:** 65

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height						
Density						
	Kun eri 5					
		Mel ram 3		3	2	
			Cya dea 4	3		
			Hed arb 4	3	4	
			Cya cun 3	2		
			Lit cal 2		2	2
			Pse arb 2	3	2	
				Bra rep 2		
				Cop luc 2		
				Cop gra 2		1
				Sch dig 2	3	2
					Gen lig 2	
					Rho sap 3	2
					Asp obl 2	
					Myr aus 2	3
					Pers sp 1	1
					Pne pen 2	
					Adi cun 2	2
					Mac exc 2	1
Epiphytes					Bei taw 2	2
					Ble nov 2	
					Clem sp 1	
Phy div						Ale exc 2
Ble fil						Unc unc 2
Usnea						Ble cha 2
Gen lig						Phy div 2
Phy tri						Asp bul 2
Mosses (long)						Pte mac 2
Met dif						
? Linds sp.						

NOTES: 5m from stream gully cut (2m deep). Possum browse
Unhealthy:
Dead Stems: Some < 20cm
Debris: continuous (but more sparse than on ridge (OHP 1&2))
Fungi: Black bracket
Leaf Litter: 5cm, moist (cf. ridge)
ACCESS: Whakatane – Ohope Rd, Burma Rd. past tip. Track to left off Burma Rd parking area. Turn right onto unmarked track on ridge to left of top kiwi catchment. Follow ridge to valley bottom, trap 3 is to the right of track base, c. 30m

* 1OHP3 = 1st sampling series from Ohope (kiwi) reserve, trap 3
** Codes include first three letters of generic and specific names, full names are listed below
Cover values after names signify: 1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%. 6=75-95%, 7=95-100%

VEG PLOT no. 1OHP 4*
**

Date: 15.12.2006 **Personnel:** J. Hutcheson **Grid. ref.:** E2864198, N6350814
Altitude: **Aspect:** N **Slope:** -
Physiography: stream terrace
Parent material: **Drainage:** **Cultural:**
Fire/grazed 35? yrs ago
Ground cover % , Vascular plants: 40 **Moss:** **Litter:** 60 **Rock:** **Earth:**

Mean top height (m): 15m **Canopy %:** 75

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height	18m					
Density						
	Kni exc 2					2
	Kun eri 3					
	Lit cal 2					2
		Cya cun 3				1
		Mel ram 3	3	3	2	1
			Cya dea 3	3	4	2
			Rho sap 3	3	2	2
			Sch dig 3		2	2
			Gen lig 2	2		
			Myr aus 2	2	3	3
				Bra rep 3	2	1
				Hed arb 3	3	3
				Mac exc 2	2	1
				Bei taw 2	2	2
					Ale exc 1	
					Asp obl 1	1
					Ble nov 2	
						Met dif 3
						Dys spe 1
						Unc unc 2
Epiphytes						Unc sp 1
Met dif						Adi cun 2
Asp obl						Asp bul 1
Phy div						Pte mac 1
Lichens						
Mosses						

NOTES: 10m to stream gully (2m deep)

Unhealthy: Some suppression
Dead Stems: Some mahoe shoots
Debris: Rho sap fronds, considerable well rotted CWD & Kun eri tops and fines
Fungi: Brown bracket
Leaf Litter: 50mm Mel ram, Rho sap fronds
ACCESS: Whakatane – Ohope Rd, Burma Rd. past tip. Track to left off Burma Rd parking area. Turn right onto unmarked track on ridge to left of top kiwi catchment. Follow ridge to valley bottom, trap 4 is to the left c. 70m

* 1OHP4 = 1st sampling series from Ohope (kiwi) reserve, trap 4
** Codes include first three letters of generic and specific names, full names are listed below.
Cover values after names signify: 1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%. 6=75-95%, 7=95-100%

1OHP plant codes, species names and presence at trap sites

	X = Present			**Site**		
Code	**Botanical Name**	**Common name**	**Habit**	**1**	**2**	**3**
Adi cun	Adiantum cunninghamii	Maidenhair fern	Fern	X		X
Ale exc	Alectron excelsa	Titoki	Tree			X
Asp bul	Asplenium bulbiferum	Hen and chicken fern	Fern			X
Asp fla	Asplenium flaccidum	Hanging spleenwort	Fern	X		
Asp obl	Asplenium oblongifolium	Huruhuruwhenua	Fern	X		X
Bei taw	Beilschmiedia tawa	Tawa	Tree			X
Ble cha	Blechnum chambersii	Nini	Fern			X
Ble fil	Blechnum filiforme	Thread fern	Fern			X
Ble nov	Blechnum novae-zealandiae	Kio kio	Fern	X		X
Bra rep	Brachyglottis repanda	Rangiora	Shrub	X		X
Clem sp	Clematis sp.	Clematis	Vine			X
Cor aus	Cordyline australis	Ti, Cabbage tree	tree		X	
Cor toi	Gahnia sp.?	Tall grass	grass		X	
Cop gra	Coprosma grandifolia	Kanono	shrub			X
Cop luc	Coprosma lucida	Shining karamu	Shrub	X	X	
Cop spa	Coprosma spathulata		Shrub	X		
Cya dea	Cyathea dealbata	Ponga, Silver fern	Treefern	X		X
Cya cun	Cyathea cunninghamii	Punui, gully tree fern	Treefern	X		X
Dys spe	Dysoxylon spectabile	Kohekohe	Tree	X	X	
Dia nig	Dianella nigra	Turutu	lilly		X	
Gen lig	Geniostoma ligustrifolia	Hangehange, whiteywood	Shrub	X	X	X
Hed arb	Hedycarya arborea	Porokaiwhiri, pigeonwood	Tree	X	X	X
Herb1	Creeping, zigzag grass?	?	Herb	X		
Kni exc	Knightia excelsa	Rewarewa	Tree	X	X	X
Kun eri	Kunzea ericoides	Kanuka	Shrub			X
Leu fas	Leucopogon fasiculatus	Mingimingi	Shrub	X	X	
Lit cal	Litsea calicaris	Mangeao	Tree	X	X	X
Lind? sp	? Lindsaea sp	?	Epiphytic fern			X
Lyc due	Lycopodium deuterodensum	Puakarimu, Club moss	Club moss	X	X	
Mac exc	Macropiper excelsum	Kawakawa	Shrub			
Met exc	Metrosideros excelsa	Pothutukawa	Tree		X	
Met dif	Metrosideros diffusa	Climbing rata vine	Vine			
Mel ram	Melicytus ramiflorus	Mahoe	Tree	X	X	X
Myr aus	Myrsine australis	Red Matipo	Shrub	X	X	X
Ole ran	Olearia rani	Heketara	Shrub	X	X	
Orchid1	?Pterostylus type sp.	Orchid	Ground orchid	X		
Pers sp	Persoonia sp.	Climber	Climber	X		X
Phy div	Phymatosaurus diversifolius	Kowaowao, hounds tongue	Fern			X

Pit ten	Pittosporum tenuifolium	Kohuhu	Shrub	X	X	
Pne pen	Pneumatopteris pennigera	Pakauroharoha	Fern			X
Pse arb	Pseudopanax arborea	Puahou, Five finger	Shrub	X	X	X
Pte mac	Pteris macilenta	Sweet fern	Fern			X
Rho sap	Rhopalostylus sapida	Nikau	palm			X
Sch dig	Scheflera digitata	Pate	Shrub			X
Unc unc	Uncinia uncinia	Hook grass	Grass	X		X
Unc sp	Uncinia sp.		Grass	X		

Appendix 2: Malaise trapped beetle species list

Family	Code	Trophic Designation
Aderidae	OHP sp 01	D
Aderidae	OHP sp 02	D
Aderidae	OHP sp 03	D
Aderidae	OHP sp 04	D
Aderidae	*Xylophilus* OHP sp 01	D
Anobidae	OHP sp 01	D
Anobidae	OHP sp 02	D
Anobidae	*Xenogonus furcus*	D
Anthicidae	*Macratria exilis*	D
Anthribidae	*Cacephatus huttoni*	D
Anthribidae	*Euciodes suturalis*	D
Anthribidae	*Eugonissus conulus*	D
Anthribidae	*Hoploraphus spinifer*	D
Anthribidae	*Liromus pardalis*	D
Anthribidae	*Micranthribus atomus*	D
Anthribidae	*Notochoragus crassus*	D
Anthribidae	*Pleosporius bullatus*	D
Anthribidae	*Sharpius brouni*	D
Belidae	*Aralius wollastoni*	D
Byrrhidae	sp 04	H
Cantharidae	Asilis OHP sp 01	P
Cerambycidae	*Hybolasius cf simplex*	D
Cerambycidae	*Hybolasius simplex*	D
Cerambycidae	*Leptachrous strigipennis*	D
Cerambycidae	*Navomorpha sulcata*	D
Cerambycidae	*Oemona hirta*	H
Cerambycidae	*Oemona simplicollis*	D
Cerambycidae	*Somatidia antarctica*	D
Cerambycidae	*Stenellipsis cf parvula*	D
Cerambycidae	*Stenellipsis fragilis*	D
Cerambycidae	*Stenellipsis latipennis*	D
Cerambycidae	*Stenellipsis maculipennis*	D
Cerambycidae	*Stenellipsis* OHP sp 01	D
Cerambycidae	*Xylotoles laeta*	D
Chrysomelidae	*Adoxia vulgaris*	H
Chrysomelidae	*Eucolaspis brunnea* spp	H

Chrysomelidae	*Eucolaspis pallidipennis* spp	H
Clambidae	*Clambus domesticus*	D
Clambidae	*Sphaerothorax suffusus*	D
Cleridae	*Phymatophaea cf atrata*	P
Cleridae	*Phymatophaea electa*	P
Cleridae	*Phymatophaea ignea*	P
Cleridae	*Phymatophaea nigricornis*	P
Cleridae	*Phymatophaea* OHP sp 01	P
Cleridae	*Phymatophaea testacea*	P
Coccinellidae	*Halmus chalybeus*	P
Coccinellidae	*Rhyzobius acceptus*	P
Coccinellidae	*Rhyzobius consors*	P
Coccinellidae	*Rhyzobius minutulus*	P
Colydiidae	*Bitoma insularis*	P
Colydiidae	*Bitoma rugosa*	P
Colydiidae	*Notoulus* sp 01	P
Colydiidae	OHP sp 01	P
Colydiidae	*Pristoderes* OHP sp 01	P
Colydiidae	*Tarphiomimus indentatus*	P
Corticariidae	*Aridius costatus*	D
Corticariidae	*Bicava illustris*	D
Corticariidae	*Enicmus bifoveatus*	D
Corticariidae	*Enicmus floridus*	D
Corticariidae	*Enicmus foveatus*	D
Corticariidae	*Melanophthalma puber*	D
Corticariidae	*Melanophthalma pudibunda*	D
Corticariidae	*Melanophthalma* sp 13	D
Corticariidae	*Melanophthalma zealandica*	D
Corticariidae	*Rethusus fulvescens*	D
Corylophidae	*Anistomeristes thoracicus*	D
Corylophidae	*Holopsis* OHP sp 01	D
Corylophidae	*Holopsis* OHP sp 02	D
Corylophidae	*Holopsis* OHP sp 03	D
Corylophidae	*Holopsis* OHP sp 04	D
Corylophidae	OHP sp 01	D
Corylophidae	*Sacina oblonga*	D
Cryptophagidae	*Atomaria lewisi*	D
Cryptophagidae	*Micrambina helmsi*	D
Cryptophagidae	*Micrambina insignis*	D
Cryptophagidae	*Micrambina* OHP sp 01	D
Cryptophagidae	*Paratomaria crowsoni*	D
Curculionidae	*Agastegnus simulans*	D
Curculionidae	*Amasa truncata*	D
Curculionidae	*Andracalles horridus*	D
Curculionidae	*Andracalles* OHP sp 01	D
Curculionidae	*Andracalles spurcus*	D
Curculionidae	*Andracalles vividus*	D
Curculionidae	*Aneuma* OHP sp 01	H
Curculionidae	*Aneuma* OHP sp 02	H
Curculionidae	*Arecophaga varia*	D

Curculionidae	Coss. Pentarthrides OHP sp 01	D
Curculionidae	Cossoninae OHP sp 01	D
Curculionidae	*Dendrotrupes minor*	D
Curculionidae	*Dermothrius* OHP sp 01	D
Curculionidae	*Didymus erroneus*	D
Curculionidae	*Eiratus suavis*	D
Curculionidae	*Euophryum* OHP sp 01	D
Curculionidae	*Hoplocneme hookeri*	D
Curculionidae	*Indecentia nubila*	D
Curculionidae	*Irenimus* OHP sp 01 (nr *compressus*)	H
Curculionidae	*Mecistostylus douei*	H
Curculionidae	*Mesoreda* OHP sp 01	D
Curculionidae	*Microcryptorhynchine* OHP sp 01	D
Curculionidae	*Microcryptorhynchus* spp	D
Curculionidae	*Mitrastethus baridioides*	D
Curculionidae	*Omoeacalles crisioides*	D
Curculionidae	*Omoeacalles* OHP sp 01	D
Curculionidae	*Pachyops dubius*	D
Curculionidae	*Pactola variabilis*	D
Curculionidae	*Peristoreus* OHP sp 01	H
Curculionidae	*Phloeophagasoma thoracicum*	D
Curculionidae	*Praolepra squamosa*	H
Curculionidae	*Psepholax macleayi*	D
Curculionidae	*Psepholax simplex*	D
Curculionidae	*Psepholax sulcatus*	D
Curculionidae	*Ptelobius mundulus*	D
Curculionidae	*Rhinocyllus conicus*	H
Curculionidae	*Rhopalomerus picipennis*	D
Curculionidae	*Scolopterus aequus*	D
Curculionidae	*Scolopterus penicillatus*	D
Curculionidae	*Sitona lepidus*	H
Curculionidae	*Stephanorhynchus curvipes*	D
Curculionidae	*Stephanorhynchus lawsoni*	D
Curculionidae	*Strongylopterus hylobioides*	D
Curculionidae	*Synacalles cingulatus*	D
Curculionidae	*Synacalles dorsalis*	D
Curculionidae	*Toura sharpiana*	D
Curculionidae	*Tysius bicornis*	D
Dermestidae	*Trichelodes* OHP sp 01	D
Dermestidae	*Trogoderma signatum*	D
Elateridae	*Aglophus* OHP sp 01	P
Elateridae	*Aglophus* OHP sp 02	P
Elateridae	*Conoderus exsul*	H
Elateridae	*Ctenicera olivescens*	H
Elateridae	*Lomemus nr elegans*	P
Elateridae	*Lomemus* OHP sp 01	P
Elateridae	*Lomemus* OHP sp 02	P
Elateridae	*Lomemus* OHP sp 03	P
Elateridae	*Lomemus* OHP sp 04	P
Elateridae	*Lomemus* OHP sp 05	P

Elateridae	*Lomemus* OHP sp 06	P
Elateridae	*Lomemus* OHP sp 07	P
Elateridae	*Metablax cinctiger*	P
Elateridae	*Panspoeus guttatus*	P
Elateridae	*Parinus villosus*	H
Elateridae	*Protelater elongatus*	P
Elateridae	*Protelater opacus*	P
Elateridae	*Sphaenelater collaris*	P
Elateridae	*Sphaenelater liniecollis*	P
Eucnemidae	*Adalba* sp 09	D
Eucnemidae	OHP sp 01	D
Languridae	*Hapalips prolixus*	H
Leiodidae	*Argyrtodes* OHP sp 01	D
Leiodidae	*Colon hirtale*	D
Leiodidae	*Paracatops lugubris*	D
Leiodidae	*Zeagyrtoma* sp 09	D
Leiodidae	*Zearagytodes maculifer*	D
Lucanidae	*Mitophyllus* OHP sp 01	D
Melandryidae	*Axylita sericophora*	D
Melandryidae	*Mecorchesia* OHP sp 01	D
Melandryidae	OHP sp 01	D
Melandryidae	OHP sp 02	D
Melyridae	OHP sp 01	P
Mordellidae	*Mordella detracta*	D
Mordellidae	*Mordella jacunda*	D
Mordellidae	*Mordella* OHP sp 01	D
Mordellidae	*Stenomordellaria neglecta*	D
Mycetophagidae	OHP sp 01	D
Mycetophagidae	OHP sp 02	D
Mycetophagidae	*Triphillus hispidellus*	D
Nitidulidae	*Soronia hystrix*	H
Anobiidae	*Ptinus speciosa*	D
Pyrochroidae	*Techmessa longicollis*	D
Salpingidae	*Salpingus bilunatus*	P
Salpingidae	*Salpingus hirtus*	P
Salpingidae	*Salpingus* OHP sp 01	P
Salpingidae	*Salpingus perpunctatus*	P
Salpingidae	*Salpingus quisquilius*	P
Salpingidae	*Salpingus* sp 06	P
Scarabaeidae	*Odontria* OHP sp 01	H
Scarabaeidae	*Odontria* OHP sp 02	H
Scarabaeidae	*Odontria* OHP sp 03	H
Scarabaeidae	*Pyronota festiva*	H
Scarabaeidae	*Sericospilus aenealis*	H
Scarabaeidae	*Stethaspis longicornis*	H
Scirtidae	*Cyphon genalis*	A
Scirtidae	*Cyphon nr genalis*	A
Scirtidae	*Cyphon* OHP sp 02	A
Scirtidae	*Cyphon* OHP sp 03	A
Scirtidae	*Cyphon*? OHP sp 04	A

Scraptiidae	*Nothotelus nigellus*	D
Scraptiidae	*Nothotelus* OHP sp 01	D
Scraptiidae	*Nothotelus* OHP sp 02	D
Scraptiidae	*Nothotelus* OHP sp 03	D
Silvanidae	OHP sp 01	D
Staphylinidae	Aleocharinae OHP sp 01	P
Staphylinidae	Aleocharinae OHP sp 02	P
Staphylinidae	Aleocharinae OHP sp 03	P
Staphylinidae	Aleocharinae OHP sp 05	P
Staphylinidae	Aleocharinae OHP sp 06 (nr sp 01)	P
Staphylinidae	Athetini OHP sp 01	P
Staphylinidae	*Hypomendon zealandica*	P
Staphylinidae	*Ocalea* OHP sp 01	P
Staphylinidae	*Ocalea socialis*	P
Staphylinidae	Omaliinae OHP sp 01	D
Staphylinidae	Pselaphinae OHP sp 01	P
Staphylinidae	Pselaphinae OHP sp 02	P
Staphylinidae	Pselaphinae OHP sp 03	P
Staphylinidae	Scaphidiinae OHP sp 01	D
Staphylinidae	*Sepedophilus ascerbus*	D
Staphylinidae	*Sepedophilus auricomus*	D
Staphylinidae	*Sepedophilus cf largulus*	D
Staphylinidae	*Sepedophilus flavithorax*	D
Staphylinidae	*Sepedophilus helmsi*	D
Staphylinidae	*Sepedophilus maculosus*	D
Staphylinidae	Tachyporinae OHP sp 01	D
Staphylinidae	*Thyreocephalus orthodoxus*	P
Tenebrionidae	*Artystona rugiceps*	D
Tenebrionidae	*Tanychilus metalicus*	D
Tenebrionidae	*Xylochus dentipes*	D
Tenebrionidae	*Xylochus tibialis*	D
Trogossitidae	*Australiodes vestitus*	P

Appendix 3-1: Beetle species (RTUs) collected in Pitfall traps and by other methods, December 2006 – March 2007: Trophic class, size and collection sites. R = Ridge sites, V = Valley sites, T = Total

COLEOPTERA FAMILY	*RTU CODE*	*TROPHIC CLASS*	*< 3mm*	*3 – 5mm*	*> 5mm*	*COLLECTION SITE*													
						Pitfall trap			*Litter*		*Soil*		*Rotten Log*		*Under Dead*		*Bark-Tree*		*Nikau Litter*
						R	*V*	*T*	*R*	*V*	*R*	*V*	*R*	*V*	*R*	*V*	*R*	*V*	*V*
Rhysodidae	**Col.019**	***Detritovore -Fungi***			***6.0***		***1***	***1***											
Carabidae	Col. 001	***Predator***			***25.0***	***70***	***13***	***83***											
	Col. 006	***Predator***			***13.0***	***14***		***14***						***1***					
Hydrophilidae	Col. 020	***Herbivorous orScavengers***		***5.0***			***3***	***3***											
Hydrophilidae	Col. 029	***“***	***2.5***				***1***	***1***						***1***					
Hydrophilidae	Col. 063	***“***		***4.0***			***3***	***3***											
Ptilidae	Col. 034		***1.0***											***1***			***2***		
Leiodidae	Col.005	***Detritovore***		***3.5***		***4***	***10***	***16***											
	Col. 026	***Detritovore***		***4.3***			***9***	***9***											
Staphylinidae Scaphidinae	Col 046 Staph. 10	***Detritovore?***	***2.6***			***1***	***2***	***3***									***1***		
Staphylinidae: Aleocharinae	Col.010 Staph. 1	***Detritovore***		***3-4.0***		***5***	***19***	***24***											
Staphylinidae: Aleocharinae	Col.025 Staph.6	***Detritovore -Fungus***			***6-8.0***		***1***	***1***											
Staphylinidae: Omalinae?	Col.028 Staph.7	***Predator***		***5.0***			***1***	***1***											
Staphylinidae; Paederinae	Col.012 Staph. 2	***Detritovore -Fungus?***			***10.0***		***4***	***4***											
Staphylinidae: Pselaphinae	Col.013 Staph.3	***Predators***		***3.3***			***4***	***4***					***1***						
Staphylinidae: Pselaphinae	Col. 035 Staph. 4	***Predators***	***2.6***			***2***	***6***	***8***											

Appendix 3-2: Beetle species (RTUs) collected in Pitfall traps and by other methods, December 2006 – March 2007: Trophic class, size and collection sites. R = Ridge sites, V = Valley sites, T = Total

COLEOPTERA FAMILY	*RTU CODE*	*TROPHIC CLASS*	*< 3mm*	*3 – 5mm*	*> 5mm*	*COLLECTION SITE*											
						Pitfall trap			*Litter*		*Soil*		*Rotten Log*		*Under Bark-Dead Tree*		*Nikau Litter*
						R	*V*	*T*	*R*	*V*	*R*	*V*	*R*	*V*	*R*	*V*	*V*
Staphylinidae:	Col.036	**Predator**	***2.3***				***1***	***1***									
Pselaphinae?	Staph. 5																
Staphylinidae:	Col. 038	**Predator**	***2.8***										***1***				
Tachyporinae	***Sepedophilus sp.1***																
Staphylinidae:	Col. 050	**Predator**	***2.8***										***3***				
Tachyporinae	***Sepedophilus sp.2***																
Staphylinidae:	Col.062	**Predator**		***4.0***			***1***	***1***									
Tachyporinae	***Sepedophilus sp.3***																
Scarabaeidae	Col.016	**Herbivores**			***10.0***	***8***	***1***	***9***			***1***						
Melolonthinae	***Odontria sp.1***																
Scarabaeidae	Col. 040	**Herbivores**		***3.0***			***12***	***12***									
Scarabaeinaee	***Saphobius sp.***																
Elateridae	Col.031	**Herbivores**			***9.0***	***2***	***2***	***4***									
Derodontidae	Col. 069	**Detritovores -Fungus**	***1.5***			***4***		***4***									
	Nothoderodontus sp.																
Bostrichidae:	Col.004	**Detritovore**	***1.6***			***4***	***5***	***9***									
Lyctinae	***cf Lyctus brunneus***																
Cleridae	Col. 023	**Predators**		***3.0***		***6***		***6***									
Phycosecidae?	Col.041	**Predators**	***2.0***				***8***	***8***									
	cf Phycosecis limbata																
Silvanidae	Col. 021	**Detritovores -fungi**			***10.0***		***1***	***1***									
	Brentopriscus pluralis																
Bothrideridae	Col. 022	**Predators**		***3.0***									***2***	***3***			
Coccinellidae	Col. 052	**Predators**		***3.0?***					***1***		***1***						***1***
	Halmus chalybeus																
Corylophidae?	Col. 048	**Detritovores -fungi**	***1.0***			***5***	***4***	***9***									

Appendix 3-3: Beetle species (RTUs) collected in Pitfall traps and by other methods, December 2006 – March 2007: Trophic class, size and collection sites. R = Ridge sites, V = Valley sites, T = Total

COLEOPTERA FAMILY	*RTU CODE*	*TROPHIC CLASS*	*< 3mm*	*3 – 5mm*	*> 5mm*	*COLLECTION SITE*									
						Pitfall trap			*Litter*	*Soil*	*Rotten Log*		*Under Bark-Dead Tree*		*Nikau Litter*
						R	*V*	*T*	*R V*	*R V*	*R*	*V*	*R*	*V*	
Corticariidae	Col.004	**Detritovores -Fungi**	***1.8***			***2***		***2***							
	Col. 015	**Detritovores -Fungi**	***1.5***			***2***		***2***							
	Col. 024	**Detritovores -Fungi**	***1.5***			***1***		***1***							
Mycetophagidae	Col.008	**Detritovores -Fungi**	***1.5***			***2***		***2***							
	Col.039	**Detritovores -Fungi**	***1.7***			***2***		***2***							
Colydiidae	Col.011 ***Enarsus bakewellei***	**Detritovores -Fungi**			***7.5***		***1***	***1***							
	Col.049 ***cf Pristoderus s***	**Detritovores -Fungi**	***2.5***				***1***	***1***							
	Col. 051	**Detritovores -Fungi**											***1***		
	Col.056 ***cf Pseudodestes sp***	**Detritovores -Fungi**			***11.0***		***1***	***1***							
Melandryidae	Col.042	**Detritovores -Fungi**				***1***		***1***							
Rhipiphoridae	Col.058	**Predator**		***4.0***			***1***	***1***							
Tenebrionidae	Col. 014	**Detritovores -Fungi**				***2***		***2***			***1***	***3***			
Anthicidae	Col. 043	**Scavengers**	***1.8***			***1***	***1***	***2***					***1***		

Appendix 3-4: Beetle species (RTUs) collected in Pitfall traps and by other methods, December 2006 – March 2007: Trophic class, size and collection sites. R = Ridge sites, V = Valley sites, T = Total

COLEOPTERA FAMILY	*RTU CODE*	*TROPHIC CLASS*	*< 3mm*	*3 – 5mm*	*> 5mm*	*COLLECTION SITE*										
						Pitfall trap			*Litter*		*Soil*		*Rotten Log*		*Bark-Dead Tree*		*Nikau Litter*
						R	*V*	*T*	*R*	*V*	*R*	*V*	*R*	*V*	*R*	*V*	
Unknown	Col.047		***2.0***				***1***	***1***									
Salpingidae	Col.053 ***cf Salpingus 1***			***4.0***													
	Col.070 ***cf Salpingus 2***		***1.7***														
Cerambycidae	Col. 054	**Detritovores -Fungi**		***5.0***		***1***											
Chrysomelidae	Col. 007	**Herbivores**			***7.0***	***1***	***5***	***6***									
	Col. 009	**Herbivores**											***1***				
Brentidae	Col. 018 ***Lasiorhynchus barbicornis***						***1***	***1***									
Curculionid: Brachycerinae	Col.027 ***Geochus sp.***		***1.8***				***2***	***2***									
Weevil	Col .032		***3.0***			***1***		***1***									
	Col. 053			***4.0***													
Curculionidae Rhynchophorinae	Col.017		***2.2***				***4***	***4***									
Curculionidae Rhynchophorinae	Col.030			***3.2***		***1***		***1***									
Curculionidae:Cu Cryptorhinchini	Col.033			***5.0***			***1***	***1***									
Curculionidae: Cryptorhinchini	Col.037		***1.8***												***1***		

Appendix 3-5: Beetle species (RTUs) collected in Pitfall traps and by other methods, December 2006 – March 2007: Trophic class, size and collection sites. R = Ridge sites, V = Valley sites, T = Total

COLEOPTERA FAMILY	*RTU CODE*	*TROPHIC CLASS*	*< 3mm*	*3 – 5mm*	*> 5mm*	*COLLECTION SITE*										
						Pitfall trap			*Litter*		*Soil*		*Rotten Log*		*Bark-Dead Tree*		*Nikau Litter*
						R	*V*	*T*	*R*	*V*	*R*	*V*	*R*	*V*	*R*	*V*	
Curculionidae: Cossoninae	Col.002			*4.0*		*3*	*5*	*8*									
Anthribidae: Choraginae	Col.044 ***Notochoragus sp.***		*1.7*			*1*		*1*									
Curculionidae	Col.061				*5-5.5*		*2*	*2*									
Curculionidae	Col.064			*4.0*			*2*	*2*									
Curculionidae	Col.065			*3.5*			*1*	*1*									
Curculionidae	Col.066			*4.0*			*2*	*2*									
Curculionidae	Col.067				*7.0*		*1*	*1*									
Curculionidae	Col.068		*1.5*				*1*	*1*									
Curculionidae	Col. 072			*5.0*			*1*	*1*									
Anthribidae	Col.073 ***Lawsonia sp.***			*3.5*		*1*		*1*									

Appendix 4: Advantages of New Zealand for the study of biodiversity ecology

All land-based economic production entails modification of the natural systems, and comparisons of insect communities can document the relative effects of various management options on both the status and the functioning of biodiversity to a degree of accuracy and understanding that is simply not possible in any other way. This is relatively simple here in New Zealand using the Malaise trapped beetle protocols demonstrated in the Ohope project. The component species reveal their relationship to the host system functioning via their biological qualities, a rich source of information. This approach does not depend on the misapplication of the inferential statistical tools of linear systems to the non-linear communities of natural ecological systems, and so does not demand an inappropriate sampling approach which inevitably obscures the relationships being sought.

Protocols for site-related Malaise trapped beetle sampling for characterising and comparing insect communities have been developed within New Zealand habitats and are perhaps uniquely suited to them (Hutcheson 1990, 1996, Hutcheson and Kimberley 1999, Hutcheson and Jones 1999, Hutcheson et al. 1999). But it has become increasingly apparent that New Zealand offers particular advantages for documenting habitat - insect biodiversity relationships, thus contributing to the explanation of why science knows so little about the functional ecology of natural systems. Some of these reasons are as follows:

- New Zealand ecosystems lie mostly within the sub-tropical/temperate forested biome. This ensures that, of the three main hyper-diverse, multi-trophic insect groups, it is the beetles (Coleoptera) that dominate here, supplying over 40% of our insect species. Of the other hyper-diverse multi-trophic groups, The flies (Diptera) dominate in non-forest tundra, while the ants (Hymenoptera) dominate in the arid zones. Beetles are more species rich, better known, can show higher association with habitat and occur in lower abundance than the others, thus strongly enhancing the logistics and interpretability of sampling

- The ancient origins, long and distant isolation and reasonably large island status have endowed the New Zealand beetle fauna with very high endemism (c. >90%, c.f. Britain with c. 4%). This enables evaluation of the various effects of land management regimes on the sustainability of indigenous biodiversity communities in a manner that is simply not possible where anthropogenic influence mixing has been occurring for tens of thousands of years.

- The long period of island evolution has also induced strong ‘bottom-up’ influences (i.e. plant physiological resistance to herbivory), contrasting with the stronger ‘top down’ (predatory) influences that develop where

plant species have much wider distributions. (My former colleague Malcolm Kay elegantly demonstrated this using Nothofagus species, after finding that the generalist lymantriid moths that invaded Auckland were not surviving on healthy New Zealand beech). This enables relationships between vegetation physiological states and insect community responses to be more easily observed (and interpreted) here in New Zealand.

- The peak pulse of insect activity in NZ ecosystems correlates reasonably well with time of year (i.e. with day-length), rather than with, e.g., rainfall - as occurs in arid systems, or being continuously active - as occurs in moist tropical systems. This seasonal pulse of activity here means that samples which are most characteristic for a habitat may be obtained from a relatively short and predictable period (Hutcheson 1990). Community variation over this short 'most characteristic' period may then be used to evaluate relative spatial variation. This forms an extremely useful analytical tool that is not available to workers in most other groups.

- The enormous influence of wind on our southern latitude island ecology not only shapes our natural systems (e.g. Hosking et al. 1993, Hosking and Hutcheson 1998), but also constrains much of the insect activity to the high humidity (or fern) zone (Hutcheson 1996). Canopy communities in central North Island podocarp/broadleaf forest have been found to be small subsets of the communities captured in ground based Malaise traps (Hutcheson 1996 and unpublished data). This spatial constraint eases sampling logistics and enhances the reliability of information available from the Malaise traps.

- The relatively recent human colonisation of New Zealand and extensive rugged terrain has enabled the persistence of significant areas of relatively natural indigenous systems for comparison with the wide range of systems that have been modified for economic production. This has potential to show how best to integrate our indigenous heritage throughout our economic landscape.

- Despite the recent colonization of New Zealand we have access to the fruits of labour of a series of wonderfully astute and productive taxonomists and systematicists. Great progress has thus been made in building the taxonomic dictionary which provides the only access to the life histories which describe the functional pathways of ecological systems.

For at least the above reasons, New Zealand offers far greater ecological explanatory power for effort expended than is possible in most other places in the world.

Appendix 5: Unabridged section on Diversity Indices

4.2.5 Community profiles

4.2.5.1 Diversities

Diversity indices are the traditional way in which extremely complex communities such as insects are compared. The most commonly used indices were developed from information theory (code breaking) and these simply combine species richness and abundance distributions in various ways. Just as with measures of centrality or dispersion, different measures give different rankings. While these indices appear to offer useful comparisons, they essentially deliver mathematical constructs stripped of their biological meaning.
Such diversity indices generally subsume all the useful biological information (species richness, species abundance, species identity, their functional roles, interrelationships and interactions) into a single number. These may not be interpreted in any meaningful way, and it is quite possible for different configurations of species richness and abundance distributions to give the same 'diversity'.

Figure 8 compares two standard diversity indices (Shannon's (H') and evenness (J), with species richness and with an index (SAC) that is derived from summing the abundance classes that have been found to give best discrimination of communities to habitat.[vi] SAC thus uses a biologically meaningful transformation of abundance, in contrast to, say, log transformation (which is a function of our mathematics).

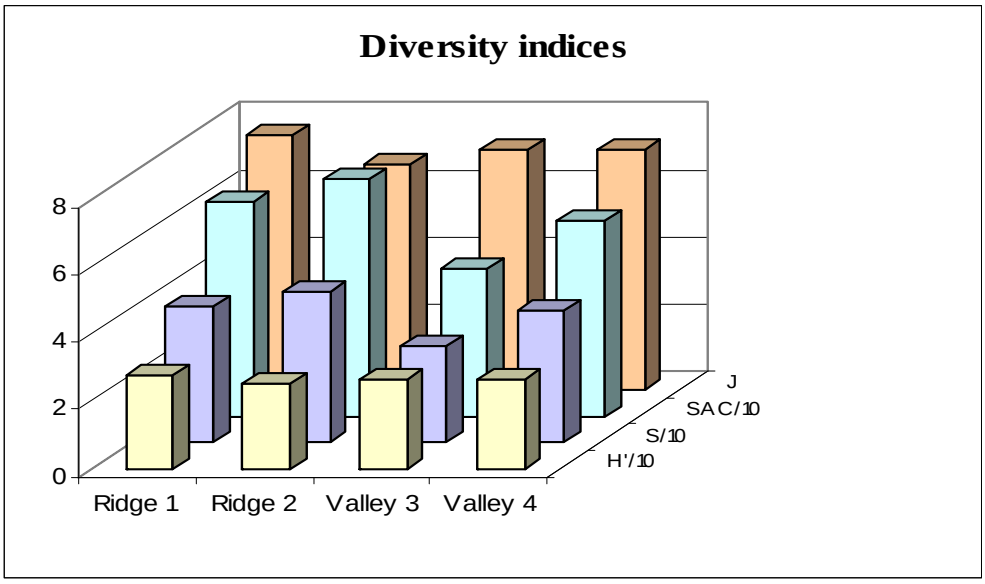


Figure 8. Comparison of a range of diversity indices compared with species richness (S). H' = Shannon's, J = evenness and SAC = Summed Abundance Classes. H', S & SAC are divided by 10 to make comparison with J easier. Note that different indices give different rankings of traps.

SAC gives less weight to abundance than to species richness which is accepted as the more important component of diversity. Note that this contrasts with H' which is mostly influenced by species of intermediate abundance, and J, which reaches its highest value when all species are equal.

The major advantage of SAC derives from the ease with which biological qualities (e.g., trophic status) of the communities may be included in summations. This is shown in figure 9, where trophic groups are depicted in mean catch summations to illustrate the comparative functional diversity of the communities.

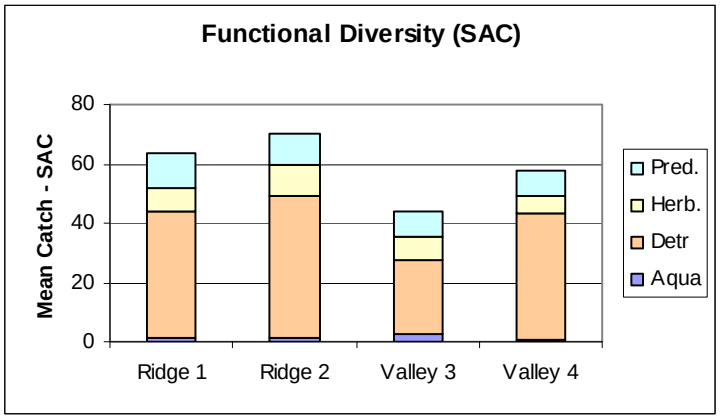
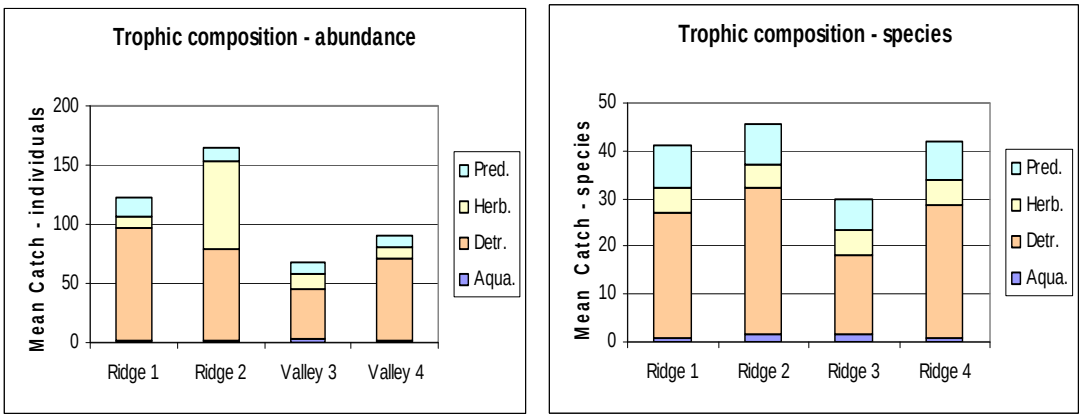


Figure 9. Functional diversity displayed as trophic distribution of Summed Abundance Classes (SAC)[vii]. SAC enables trophic (or other biological values) to be included in comparisons, thus beginning to introduce biological meaning into the summations of the communities.

However the combining of species richness and abundance still obscures most of the information which assists in the interpretation and the understanding of the results.

This is demonstrated in figure 10 by the separation of abundance and species richness, enabling the community functional characteristics at these levels to be compared.



(a) (b)

Figure 10. Trophic distribution displayed as mean catch of: (a) individuals, and (b) species.

Even the biologically meaningful diversity index SAC (Fig. 9) cannot provide the interpretable information that is available by simply comparing (a) & (b).

For example: (i) Ridge-site 2 shows an abundance of herbivorous individuals but not of species, indicating that the high herbivore population was due to a relatively small number of species in this trophic group, which was much more equal across the sites.
(ii) Valley site 3 had relatively low numbers of individuals compared with the other traps, but the relative difference is less at the level of species. This is in accord with the mean abundance distribution from this trap (Fig. 5). While the sampled species richness for this trap-site was lower than from the other traps, it was the lower incidence of abundant species on this site that influenced the lower overall catch from this site.
(iii) Predators include a fairly consistent proportion of several species, generally of low abundance.

[ii] Hutcheson 1990
[iii] Hutcheson 1996
[iv] Hutcheson 1986

[vi] Hutcheson 1990
[vii] Hutcheson 1996