

Invertebrate fauna and their ecological context on Whangaokena, East Cape

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Abstract

Invertebrates were collected from Whangaokena over a 2-day period in late March. Assemblages were examined and described in terms of taxonomy, provenance and function, and interpreted in terms of vegetation and ecological processes on the island. The influence of collection method and internal affinities of samples were also examined. Details of the ecological web were derived from species life histories, and prognoses for vegetation development and tuatara reintroduction were developed.

Caveats resulting from project constraints apply to the conclusions drawn. However, sample assemblages showed a close relationship with historical and current ecological influences on the island. This was apparent in high proportions of adventives and generalists, and a high abundance of grassland herbivores. The community associated with recycling litter and woody debris appeared depleted as a result of the transformation of island vegetation from native shrubland/forest to being dominated by European grassland.

Reintroduction of tuatara would benefit from an enhancement of successional processes of vegetation towards forest, which will otherwise be very slow. The restoration effort would benefit from enhancement of the invertebrate fauna at the community level. Explanation of, and practical steps for, initiation of restoration of a coastal forest system on the island are given.

Appendices to the report list species/recognisable taxonomic units collected, an updated (though not comprehensive) plant list, recce plots and detailed locations of collecting areas, and separate discussion of a standardised approach to the characterisation of insect communities of New Zealand ecosystems. The latter is required for defensible comparison of invertebrate fauna. It was developed by the author and has been applied successfully in many areas of ecological research in New Zealand.

1. Introduction

Whangaokena (East Island) lies about 2 km to the east of East Cape. It is composed of soft calcium-rich sedimentary mudstone and sandstone, and is bounded by a broken ledge of harder material at sea level. The island has a vegetated crest area of about 8 ha which is circumscribed by high steep crumbling cliffs. The crest forms a ridge lying NE-SW, with two peaks of unequal height, the northern one forming a plateau area where the old lighthouse and buildings were situated (Moors 1980).

Rats (kiore or Pacific rats, *Rattus exulans*) were eradicated from the island in August 1997, about two and a half years prior to the visit reported here (Peters 1997). Some form of ecological restoration is a management aim for the island, with rat removal providing the first step. Among other effects it is

thought that rat removal will help enhance the establishment and succession of indigenous woody plants on the island crest area.

It has been suggested that tuatara might be released on the island sometime in the future, and an entomological perspective on the current status and future trends of the island was sought from the author by Dr Chris Ward, DOC, Gisborne.

1.1 BRIEF

The brief given for this project was as follows.

Within constraints imposed by timing, resources and entomological knowledge:

- Describe the invertebrate fauna of the island as it stands, with comments on likely ongoing trends following kiore eradication.
- Describe the ecological web of this invertebrate fauna in relation to its environment, and comment on what may be missing from the fauna/ecological web, particularly in relation to what may be present on the mainland nearby.
- Determine whether there is likely to be a problem with a depauperate invertebrate fauna in respect of ecosystem restoration objectives for the island, including the potential to sustain a reintroduced population of tuatara in say 5-10 years time.
- If there is likely to be a problem, recommend what steps might be taken to remedy it, including if appropriate the reintroduction of invertebrates from the mainland to the island and how this might best be approached.

1.2 BACKGROUND

Insects form an integral part of all terrestrial and freshwater ecological systems, and their communities are distinctive for the various vegetation systems we recognise and manage (Hutcheson 1990,1996, Dugdale & Hutcheson 1997, Hutcheson 1999, Hutcheson & Kimberley 1999, Hutcheson & Jones 1999, Harris & Burns 2000). Because of their incredible species richness and abundance, insects totally dominate the biodiversity of terrestrial ecosystems. This dominance is associated with their role of performing the majority of the functional linkages that enable systems to persist and to change in a variable environment. Although we can understand such functional roles from study of single species (e.g. Hosking & Hutcheson 1986, Hutcheson 1991), investigation of insects at the level of the systems is much more difficult because of the enormity of the task and the lack of basic knowledge (Disney 1986). The only practical approach to the extensive comparison of biodiversity of systems lies in the use of a standardised sampling method that may be applied to

communities separated in time and space. An approach developed by the author, using Malaise-trapped beetles is summarised in Appendix 4, while extended discussion and logical justification is given in Hutcheson et al. (1999). For a number of reasons that approach was not possible in this instance.

It was acknowledged at the outset of this project that information would be constrained by the limited time and resources available. The autumn timing of the visit also placed constraints on what invertebrate fauna could be observed, as overall insect activity generally peaks in summer. However, it was felt that an entomological perspective would still provide useful information in the evaluation of current ecological status, future trends and options for management. Timing of the trip was designed to enable use of a helicopter involved in the control of boxthorn (*Lycium ferocissimum*).

2. Methods

Whangaokena was visited via helicopter from pm 28 March to am 30 March 2000. Personnel included Dr Chris Ward, (DOC, Gisborne); Hal (Stan) Hovell, of Te Whanau-a-Tuwhakairiora, Te Whanau-a-Hunaara, Te Whanau-a-Rakairoa (DOC Conservation Officer, TeAraroa); Tom O'Neill, of Te Whanaa-a-Takimoana and Whanau-a-Hunaara, and the author. The weather was fine and calm over the duration of the visit.

Vegetation of the island crest was briefly inspected before pitfall traps were placed in each of five general areas. These were concentrated on the top plateau and the access gully to the west of the island. This was a reflection of the topography and distribution of the island vegetation, and also the greater emphasis placed in these areas by previous management. Recce plots (Allen 1992) were recorded of the vegetation of these areas for future reference (Appendix 2). The pitfall traps ran for the period of the visit (two nights and the intervening day). Because of the short sampling period, traps were simply 400 ml polycarbonate jars containing 70% ethanol and buried flush with ground level; they were sheltered with cardboard squares set about 3 cm off the ground.

Leaf litter samples were also taken from selected locations in each of the five pitfall areas. These comprised three subsamples (including some surface soil), each of c. 20 cm diameter. Subsamples were bulked together into a sealed plastic bag. No attempt was made to separate humus, fermentation and litter layers and amounts of these layers varied with the amount of surface litter. Details of the pitfall and litter collection sites are given in Appendix 2.

A small Malaise-type trap was erected near the base of the old winching 'trench' (site C), and foliage beating, sweep netting and hand searching were conducted in various locations on the island crest. Results from these methods are included in the 'general' trapping category in Appendix 1. Note was also taken of presence or lack of monophages or their damage on particular plants.

Specimens captured were identified using external morphological characteristics to species or recognisable taxonomic unit (RTU) called species hereafter. An evaluation of the attributes of the assemblage collected and the affinities of samples was done. Attributes examined included identities, trophic groups and provenance (indigenous, Adventive or undetermined). Several species listed as indigenous occur naturally over areas broader than just New Zealand. Adventive is used to describe those species deliberately or accidentally introduced by humans.

The functional (trophic) diversity of sample groups was examined using summed abundance classes (SAC) (Hutcheson 1996), a diversity index which follows trend of more traditional indices, but which enables the description of biological attributes of samples. SAC is weighted toward species richness, but incorporates intra-species diversity through the inclusion of species abundance using a stepped series of classes. The classes used were those found by Hutcheson (1990) to provide best discrimination between beetle assemblages from different habitats. These are formed from cut levels at 0, 2, 5, 10 and 20 specimens, and are the default levels for the divisive multivariate classification procedure TWINSpan, showing utility for assemblage discrimination over a wide range of ecological data. Traditional diversity indices (e.g. H', J') do not enable species attributes such as identity, endemism or functional role to be included in interpretations, and so have been found to be of little real utility for purposes of discrimination, comparison or description of invertebrate assemblages (Hutcheson & Kimberley 1999).

The affinities of pitfall sample groups were assessed using indirect ordination (detrended correspondence analysis - DCA) to see if relative influence of general site and localised vegetation on samples was apparent.

3. Present invertebrate fauna and its ecological web

3.1 VEGETATION

The vegetation is the part of the biota that we use to categorise (and to manage) systems. It provides the context for understanding the invertebrate communities and their management.

The island's vegetation reflects its past occupation, and the destruction of the woody vegetation by humans, and particularly goats, which were introduced early in the 20th century and eradicated about 1960 (Moors 1980). The island crest (i.e. above the cliffs) is dominated by cocksfoot (*Dactylis glomerata*) grassland. This is interspersed with patches of clubbed rush (*Scirpus nodosus*), flax (*Phormium cookianum*), pohuehue (*Muehlenbeckia complexa*), and *Muehlenbeckia australis*, and individuals of taupata (*Coprosma repens*), tauhinu (*Cassinia leptophylla*) and koromiko (*Hebe stricta* var. *macroura*). Some pohutukawa (*Metrosideros excelsa*) were planted about

15 years ago and the biggest are now about 5 m high. These are mostly located in the old winching trench which was used to get loads (including the former lighthouse) up and down from the crest plateau. However, one large pohutukawa specimen is situated in the lower reaches of the western valley that meets the base of the winching trench at the old staging post. Behind this tree, a relatively sheltered area of the valley side-slope is covered with extensive patches of huruhuruwhenua (*Asplenium oblongifolium*), which otherwise only occurs as occasional individual clumps. A limited number of more recent pohutukawa plantings are widely scattered on the central part of the island crest and these are now nearly 1 m tall.

Anecdotal evidence (Hal Hovell, pers. comm.) suggests that the removal of rats has led to more successful grass seeding and germination, and the development of a more continuous grass cover. This accords with general impressions of change based on Peters & King (1997). Non-grassed weedy areas now mostly occur only where grass coverage has been broken through erosion or from spraying of boxthorn. Such areas are mostly located near the rim of the steep cliffs. An area of flowering Madeira vine (*Anredera cordifolia*) was present north of the lighthouse plateau area. It is only where shading from a thick cover of taupata, hebe or pohutukawa was present that heavy grass cover was absent and bare earth/litter zones were present. A few seedlings of taupata occur at the periphery of some of these 'shrub shadows'. An extensive area of *Muehlenbeckia australis* has spread through the grass cover in the northeastern slope of the crest, below the plateau and to the south of the Madeira vine. This will possibly develop into a thick scrambling 'shrub' area sufficient to suppress the grass cover, as has occurred with a patch in the western gully.

A list of plants on the island updated from Clarkson (1984), though not comprehensive, is presented in Appendix 3.

3.2 DESCRIPTION OF INVERTEBRATES COLLECTED

A total of 109 species from 72 families, comprising 20 orders in 9 groups of invertebrate were collected. These are listed in Appendix 1. The most species-rich groups were the insects and arachnids, comprising 73 and 24 species respectively. Richest orders were Araneae (spiders - 20 spp.), Coleoptera (beetles - 18 spp.), Diptera (flies - 17 spp.) and Lepidoptera (butterflies and moths - 15 spp.).

Most families were represented by only one or two species. The most species-rich were: Curculionidae (weevils - 6 spp.), Theridiidae (cobweb spiders - 5 spp.), Araneidae (orbweb spiders - 3 spp.), Tipulidae (craneflies - 3 spp.), Formicidae (ants - 3 spp.), Acrididae (grasshoppers - 3 spp.) and undetermined brachycerid flies (3 spp.).

3.3 PROVENANCE

Provenance of species collected, whether indigenous, adventive or undetermined, is listed in Appendix 1. Establishing provenance was most difficult for the spiders (Table 1), as the author is less familiar with this group. However, 13% were known to be adventive, 17% were indigenous and 71% were of undetermined provenance. For the most numerous group, the insects, these figures were 26%, 40% and 34% respectively. Both groups show relatively high proportions of non-indigenous fauna relative to studies of beetles the author has made in indigenous habitat, although results from studies using different methods are not comparable. It is possible that more definite taxonomy and more extensive collection over a complete summer would give a different picture of the relative proportions of adventive versus indigenous species. However, such a programme would require many more resources.

Within the insects captured (Table 2), the most species-rich were the beetles (Coleoptera) with 18 species. The majority of these (56%) were known to be indigenous. Lepidoptera were also found to be largely indigenous at 60%. The four orthopteran species were all indigenous, although it should be noted that the black field cricket (*Teleogryllus comodus*) is also found in Australia and the locust (*Locusta migratoria*) is relatively cosmopolitan.

3.4 FUNCTIONAL (TROPIC) STRUCTURE

The relative species richness of the four trophic groups: herbivores, detritivores, predators and scavengers from all collecting methods is plotted in Fig. 1. This shows major trophic groups to be represented relatively evenly, although the predatory fauna is slightly richer than the detritivore or herbivore components. There was a small but significant scavenger component in terms of species richness.

The figure also includes the provenance of the species and shows a strong presence of adventive species in all trophic groups. The higher level of undetermined provenance of species in the predator group is due to a higher proportion of spiders, a group with which the author is less familiar.

Functional diversity as measured by summed abundance classes (SAC) for trophic groups and their provenance components is given in Fig. 2. This enables a better reflection of the dominance of native herbivores (and especially grasshoppers) in the fauna. In combination with Fig. 1, it also shows that, although predators were species rich, they were of low abundance. In contrast, scavengers were species poor, but of high abundance.

The predatory component of the sample was much higher than that from other sampling the author has conducted. As various traps reflect activity in various parts of the invertebrate community, it was thought useful to examine the influence of trapping method on the depiction of relative functional diversity, and this is given in Fig. 3.

Figure 3(a) shows an increasing component of herbivores in the order of litter - pitfall - general collecting respectively, while detritivores increased in

the reverse order, with the least captured in general collecting and the most occurring in the litter samples. The predatory and scavenger component were highest in absolute terms in the general collecting but were much more constant across the different methods than either herbivores or detritivores. Functional subgroups were then plotted as relative proportions and are compared with total catch from all, methods in Fig. 3(b).

This showed relative proportions of scavengers and predators to be reasonably consistent across all sampling methods, with about 10% scavengers and close to 30% contributed by predators. Total catch from all methods showed relatively even proportions of c. 30% each of detritivores, herbivores and predators. The general collecting favoured herbivores while pitfall and litter sampling favoured detritivores.

This was mainly a reflection of the respective zones (foliage and litter layer) sampled. However, there was also likely to be influence from the very short sampling time. This is because, although a great many insect debris feeders (detritivores) do fly in the netted (i.e. foliage) zone, this may be for only a short time during their dispersal phase and was thus unlikely to coincide with the two-day visit in late March. These results help illustrate why the comparison of insect faunas requires standardised methodology (see Appendix 4).

3.5 AFFINITIES OF PITFALL SAMPLES

Ordination of the pitfall samples was conducted to see if sample affinities were more influenced by proximate vegetation or by the general collecting areas (Fig. 4). These plots show samples tending to group slightly more by general location than by specific site vegetation, although neither pattern is strongly defined. It is likely that the reasons for the lack of pattern definition are multifactorial, including there being insufficient data. However, the lack of strong site/habitat pattern also reflects the attributes of a small island biota that through anthropogenic influences appears largely reduced to generalists. Because of the island isolation, this fauna has not been able to recover from the destructive historical influences including fire, gardening, goat browsing and grazing, and fluctuating rat populations.

3.6 LITTER SAMPLE AFFINITIES

The litter samples were also subjected to DCA ordination to test the general trends of their affinities. This was done to see if they followed patterns interpretable in terms of vegetation succession. Once again the limited nature of the data needs to be taken into account in the interpretation.

The ordination of litter samples in Fig. 5 revealed logical successional trends, with a general movement from grass through pohuehue, pohutukawa, pohutukawa/taupata to taupata. The East Cape nikau/tawapou sample was closest to the pohutukawa/taupata and pohutukawa samples, but was somewhat distant to the general successional trend line of the island samples.

The position of the pohutukawa samples at an intermediate position in the successional trend may relate to two factors: (a) the pohutukawa are planted and currently do not appear to have at least some of their closely associated fauna, (b) the tree is an early colonist which germinates on micro-sites where there is no competition and therefore is not associated with the prior accumulation of a successional biotic community.

The single litter sample taken from nikau - tawapou forest at East Cape did not exhibit major differences to those taken from the island, being distinguished only by single specimens of a *Dimerogonus* sp. millipede and an undetermined hemipteran. However, other general fossicking in the East Cape forest revealed an abundance of Amphipoda (bush hoppers) that was not seen anywhere on the island. The mainland forest litter layer was particularly well developed, with nothing similar being present on the island.

3.7 ECOLOGICAL WEB

Reported ecological food webs are notoriously incomplete (Polis 1994). Usually the vertebrates are meticulously documented at the species and sometimes sub-species level, while the invertebrates are simply lumped as undefined and unquantified trophic groups such as 'soil invertebrates' or 'above ground herbivorous invertebrates' (e.g. Innes & Barker 1999). As a consequence food webs can appear at first sight to be very informative, but often simply perpetuate preconceived perceptions about the unimportance of invertebrates relative to vertebrates in systems.

The definition and relative measurement of functional diversity given above in Figure 2 can thus provide a more informative (and relatively quantified) summary of community trophic structure than the more normally hypothesised spider-web of generalised boxes and arrows. Were the invertebrates to be included in any detail in such diagrams, the diagrams would be completely unreadable.

As shown by the variation in community trophic attributes from the different sampling methods, a quantified 'trophic structure' approach is only really useful for comparative purposes when it is derived from standardised quantified sampling (see Appendix 4).

The general processes and agents of these in the island community are:

Accumulation	Agents
Seabird input (guano, bird deaths)	seabirds
Aerial flotsam	inverts/seeds/spores
Vegetation growth	plants/inverts/fungi/bacteria
Vegetation recycling detritivory	inverts/fungi/bacteria
predation	inverts/fungi/bacteria

While we can not hope to provide a completed food web, we can gain better understanding of the ecological relationships through detail provided by the life histories of particular species.

3.8 SELECTED THREADS FROM THE ECOLOGICAL WEB

Some of the informative threads from the ecological web of the island are discussed here, arranged according to features of the habitat, or trophic processes. Note that adventive species are designated by an asterisk (*).

As would be expected from the dominance of grassland, the fauna is currently dominated in terms of abundance by herbivorous species which are associated with grasses and which have rapid population growth. These include the grasshopper grass-leaf feeders and porina moth grass-root feeders. These species are likely to have provided a large food resource for the rats before their eradication, and it is unlikely that previous populations, particularly of the long-horned grasshopper (*Conocephalus semivittatus*), would have achieved the high abundance of sexually mature individuals that were seen on this visit. However, without pre- and post-rat eradication quantified sampling we cannot know this for certain.

Other herbivorous species associated with grasses include: a weevil (*Sitona discoideus**), a click beetle (*Conoderus exsul**), four moths (*Crambus flexuosellus*, *Leptomeris rubraria*, *Wiseana signata*, *Pseudoletia separata**), three grasshoppers (*Conocephalus semivittatus*, *Locusta migratoria*, *Phaulacridium marginale*) and a cricket (*Teleogryllus comodus*).

It was not only herbivores that showed strong association with vegetative habitat, however. The indigenous tailed grass spider *Argiope protensa* was not uncommon on the island. Other spiders were also strongly associated with habitat structure (and hence type). Females of the nursery web spider *Dolomedes minor* build clearly visible silken 'nurseries' to protect their eggs and hatchlings, and these were clearly visible in the terminals of koromiko and tauhinu shrubs. It was also noted that the orbweb spiders *Araneus crassus** and *A. pustulosus** consistently used the old flowerheads of flax for their web scaffolding.

The abundance of spiders, which dominated the predatory component of the island fauna, is a reflection of their dispersal methods. Young spiders climb up vegetation on breezy days and let out a line of silk. When the wind catches it they let go their perch and ride the wind wherever it takes them. This is called 'ballooning' by arachnologists and is a particularly effective, if indiscriminate, means of dispersal. Ballooning enables spiders to colonise widespread areas, and is reflected for example in the presence of the Australian orbweb araneids, *Araneus pustulosus** and *A. crassus**, which are also widespread on the mainland. Only one spider-hunting wasp was seen, however (*Priocnema nitida*). This was a little surprising considering the relatively rich spider fauna, and may reflect a relatively recent increase in spider abundance since rat eradication.

Ballooning carries less of a risk of ending up in a 'food-poor' environment than might be thought. This is because the young ballooning spiders form only a part of a significant 'aerial flotsam' which can provide food in the most inhospitable places. For example, spiders have been found living happily on small insect aerial flotsam on the surfaces of small and highly acid (pH 2.5) rainwater pools within the 'dead zone' of White Island, where no plants or

ground-based fauna could survive (Hutcheson 1992). The presence of the bottom trophic level (vegetation) is thus not necessary for members of the top trophic group (predators) to establish and persist in isolated systems. Food web theory does not often acknowledge the aerial flotsam and its effects on the predatory trophic group, more often simply relying on the more commonly observed sequence of plants, herbivores/detritivores, and then predators.

A more controlled part of the aerial flotsam was seen while on the island, with a large mating swarm of *Chelaner antarcticus*, the indigenous southern ant. The alates (winged forms) of the ant were being predated in the air by welcome swallows and a fantail, and were seen entangled in many spider webs.

Predators were also represented by a small hover fly (*Melanostoma fasciatum*), whose larvae feed on small sap-suckers such as aphids and psyllids. Recognised parasitoids (parasites which kill their prey) were represented by the tachinid fly *Trigonospilus brevifascies**. This species was introduced to try to control leafroller moths (Tortricidae) many years before the environmental risk management authority (ERMA) was established. Unfortunately the fly is a generalist and parasitises many native moth caterpillars. Two of the potential hosts recorded on the island were the native brown-headed leafroller (*Ctenopseustis obliquana*) and the cosmopolitan light brown apple moth (*Epiphyas postvittana**). Both of these moths have extremely wide host ranges, but are generally associated with more developed successional shrub or tree species.

The presence of seabirds nesting on the island was reflected in the abundance of the little pluteid moth *Monopis ethelella*, which constituted most of the small Malaise-trap catch but were also captured by pitfall samples and general netting. Larvae of this insect feed on keratin, and populations can be sustained on wool (or fur of dead rats). Goats were removed from the island about 1960 and rats have been gone for two years. The moth larvae are thus feeding on seabird feathers, which were particularly obvious around the nesting burrows of the birds.

Another noticeable reflection of seabird presence was the abundance of flies associated with carrion. These included the brown blowfly (*Calliphora stygia*) and the hairy maggot blowfly (*Chrysomya rufifascies**), green blowfly (*Lucilia sericata**) and stable fly (*Stomoxys calcitrans**).

The presence of still water (rainwater tanks) on the plateau camping area was reflected in the presence of the European drone fly (*Eristalis tenax**), whose larvae (the rat-tailed maggot) breed in still and stagnant water.

Indigenous species associated with herb growth include the indigenous magpie moth (*Nyctemera annulata*), which feeds on *Senecio* spp. and the common blue butterfly (*Zizina otis labradus*). Cosmopolitan species collected included the white butterfly *Pieris rapae**, which feeds on plants of the cabbage family (Cruciferae), and the white-fringed weevil (*Graphognathus leucoloma**) which has a wide host range, but was collected from flowering Madeira vine (*Anredera cordifolia*).

Species associated with more advanced native successional vegetation include monophage herbivores (i.e. specific to particular hosts) such as the common copper butterfly (*Helleia salustius*), which feeds on pohuehue; the three weevils *Andracalles* sp., *Novitas nigrans* and *Phloeophagasoma thoracicum*, which were consistently collected from flax; and a little flower weevil (*Peristoreus veronicae*), which feeds on koromiko.

Standardised sampling which focuses on beetles (see refs by author) show species associated with more advanced native successional vegetation to be generally dominated by detritivores involved in recycling woody material. These were relatively poorly represented in the samples, being limited to the two native longhorn beetles *Xylotelus laetus* and *Stenellipsis* sp. collected from koromiko, the small native anthribid (*Dysnocryptus pallidus*) and the three native weevils associated with flax mentioned in the previous paragraph. This suggests that the woody debris community may be particularly depleted on the island.

Dugdale (unpublished data), in extensive sampling in the East Cape area, recorded 12 species of Cerambycidae, which are associated with woody debris breakdown. The two species of this family collected on the island were both recorded at East Cape. It is not appropriate, however, to use the Dugdale list for definitive comparison, as sampling was much more extensive than on the island.

The large weevil *Hadracalles fuliginosus*, which feeds in dying/dead flax rhizome material, was also not found, despite specific searches being made. Other apparently 'missing' invertebrates included members of the Carabidae (ground beetles) that are largely predators at ground level.

Dugdale recorded 10 species of Carabidae from East Cape, while none were collected on this visit to the island. Although no tiger beetles (Carabidae - Cicindellinae) were seen on the island, they were also not seen on the adjacent mainland, or listed by Dugdale for East Cape.

No sign was seen of the weevil *Neomycta rubida* or associated damage on its host pohutukawa on the island, although this insect was widespread on trees along the adjacent mainland coastline. This small native weevil mines the newly flushed leaves of pohutukawa, resulting in them abscising from the tree a few weeks after the egg has been laid. Nor was evidence seen on the island pohutukawa of the small brentid weevil *Neocyba metrosideros*, which mines dying twigs of this tree. No evidence was seen of the large cryptorhynchine weevil *Strongylopterus hylobioides*, which feeds in woody debris of pohutukawa and other coastal species, and this was related to a general lack of woody debris of sufficient size to host this weevil.

3.9 INITIAL RESPONSE TO RAT ERADICATION AND ONGOING TRENDS

Responses of ecosystem components to the removal of rats are multifactorial. They depend on: (a) the degree to which a component was previously af-

fectured by the rats, (b) the amount of a component resource remaining on the island, (c) the ecological role of the component, and (d) its expansion potential. Ecological role is interrelated with point (d), which is also multifactorial. Expansion potential is dependent on time taken for a species to reach sexual maturity, its potential and realised fecundity, and the relative presence of other components which may be synergistic (e.g. symbiotic or mutualistic organisms), or antagonistic (e.g. predators, diseases, or competitive excluding organisms). Attempting to predict system responses from a single species perspective thus rapidly becomes extremely complex. Instead, components as used here may refer to groups of species. This approach enables a simplification of discussion of the ecological roles within systems, but extrapolation and predictions still carry caveats derived from the complexities listed above.

Anecdotal evidence (Hal Hovell pers. comm.) is that the grass cover has thickened since the eradication of the rats. Although not quantified in any fashion, this is a feasible initial outcome from rodent removal, as it is likely that all available food resources were utilised by the rodents, and grass seeds (cereals) are an exceptionally nutritious food source. These have, after all, been the main food source supporting the extraordinary success of the human species.

Cocksfoot grassland formed the dominant ground cover on the island before rat removal. Grasses have high potential fecundity, and rat removal will undoubtedly have increased the realised fecundity. This would therefore be expected to have enabled the grass cover to thicken up and to more successfully colonise bare ground and ground partially covered by annual herbs.

The development of a more dominant grass cover, while reducing erosion and establishing a grassland fauna, is likely to impede further successional vegetation development. Vegetation ecologists have long recognised that there is considerable inertia in successional development from European grass systems. Usually this can be attributed to mammalian grazers, which generally form an inseparable part of these systems, removing seedlings of woody growth in relation to their palatability and edibility. The presence of domestic stock, for example was found to be the dominant influence on lack of both pohutukawa and cabbage tree regeneration throughout much of their range (Hutcheson & Hosking 1994). Many woody 'weed' species in grazed land (e.g. gorse and briar) are simply the result of being the only successional species able to persist under a grazing regime.

Where grazers are not present, lack of successional development from grassland is usually attributed to lack of seeds of appropriate successional species, together with the physical vigour and dominance of the grasses (Grime 1976, Ian Atkinson pers. comm. 1996). However, there are strong reasons to believe that, because of inextricable relationships, all components of the grass system community are involved in the inhibition of further successional development. These components include groups of fungal, invertebrate and microbial organisms. The feasibility of this perception is supported by 'site capture' (sometimes referred to as 'competitive exclusion') being well known for fungi. This is the principle behind several biocontrols of fungal pests in horticulture, where one fungus is introduced in order to keep another, more troublesome one, from invading a site. Removal of rats from the island has there-

fore not necessarily accelerated successional processes beyond the dominance of European grassland to any great extent at this initial stage.

Other initial vegetation responses to rat eradication would be predicted to be an increased success of seeding and potential expansion of successional vegetation species with edible seeds and a relatively high presence on the island, such as taupata. However, realised regeneration success will be constrained by site availability as discussed above. Gradual successional development and expansion is expected, however, as very young seedlings of taupata were observed at the periphery of parent shrubs in grass-free 'shrub shadow' areas.

The benefiting of native woody shrub and forest species from reduced competition from the grass community has been recorded in many areas and under many woody species. Often these are referred to as 'nurse crops'. Many of the species which have shown great potential for accelerating successions past the 'grass barrier' are exotic in origin.

Initial responses of rat eradication within the island invertebrate fauna are also related to the four points listed at the beginning of this section, i.e. what's there, how suppressed they were by rats, their ecological role and their potential for expansion. Lack of comparable pre- and post-eradication sampling also inhibits interpretations that may be made in this area. In addition, ecological influences, including both the abiotic and biotic environment, can profoundly affect insect populations on a year to year basis. However, some tentative generalisations may be made, drawn from observations made and autecologies of species captured in this visit.

Anecdotal evidence also suggests that black field cricket populations were lower while rats were on the island (Chris Ward pers. comm.). This is entirely feasible, but it should be remembered that this insect has high intrinsic rate of increase, with females laying 500-1500 eggs (Smith & Harrow 1971) and can show high population increases in association with drought conditions relative to years of high rainfall (Blank 1987). Thus it would be difficult to draw firm conclusions of the effects of rat removal on crickets, even were some quantitative data available, without much more detailed study and consequent expenditure of resources.

These same caveats on measurement of insect population increase apply to most other species and are not limited simply to the ground fauna. High rainfall during the early instars of leaf feeding moths, for example, can also suppress populations on tall forest trees (Kay 1983). The interactions between insect populations, plants and weather may be further complicated by plant demography and site factors. Hosking & Hutcheson (1986) found that populations of the native weevil *Neomycta pulicaris* on hard beech (*Nothofagus truncata*) can increase markedly during drought seasons. In their study, this increase only occurred on canopy foliage of older trees where soil moisture retention capacity of the site was diminished. The situation becomes more complex as it is studied in more detail, and this has given rise to a formidable literature in the area of pest control in economic production systems. Hutcheson (1991) showed populations of the large native weevil (*Ectopsis ferrugalis*) increasing on five-finger (*Pseudopanax arboreus*) in the same general model of interacting: predisposing, inciting and contributing

factors to tree death as proposed by Mannion (1981) and supported by Hosking & Hutcheson (1986). In this model, predisposing factors are intrinsic to the system, such as site moisture retention capacity or tree age. Inciting factors are extrinsic changes to the growing rules the system is accustomed to, such as drought or other extreme environmental perturbations. Contributing factors are generally biotic, comprising insects, fungi and bacteria. Their involvement can be seen as an early stage of recycling processes operating within the system.

White (1993) supplied strong arguments that many of the increases in populations are related to food quality (rather than quantity) and that this is determined by availability of nitrogen. Note that his arguments stressed the crucial factor as being the availability of nitrogen to the organism rather than the total nitrogen present in the food source, and for herbivorous insects this was related to plant physiological responses to the abiotic environment.

The complexity of the interactions revealed by very extensive (and expensive) research in the field of pest control, must caution conservation managers from over-interpretation of management effects on populations from simple surveys. However, it also provides strong arguments against over-commitment of scarce resources in intensive reductionist research that is not directed at their broad aims, and which may eventually still prove inconclusive.

The apparent imbalance between the abundant spider presence and almost total lack of spider-hunting pompilid wasps may be due to a higher intrinsic rate of increase (assisted by 'ballooning' immigration) of spiders, compared with the wasp populations after the rat removal operation. An alternative explanation may be that constant immigration has kept spider numbers at a high level continuously, while adult wasp numbers may have appeared low because of time of year of the sampling visit.

My general observations of the island and the sampled invertebrate fauna lead me to the opinion that the likely ongoing system trends are for a very slow expansion of the native shrub cover because: the European grass system currently dominates the island vegetation, the grass cover forms such a thick and continuous mat, and because this system is known to inhibit most native woody regeneration. As a consequence of this, I feel that the grass-associated insect species (particularly grasshoppers, locusts and porina) although varying year-to-year with weather conditions, will also continue to dominate the island invertebrate fauna for some time.

4. Ecosystem restoration

Insect communities reflect qualities and processes of their habitat. If the habitat requirements of a species are not present, then species cannot persist in an area. The functional structure of insect communities changes with vegetation development. Herbivores dominate early successional vegetation, while predators and particularly detritivores increase as the vegetation systems develop through shrubland into forest (Hutcheson & Kimberley 1999).

The historical use of Whangaokena by humans and the associated goat and rat populations has had major impacts on the island ecosystem. This has occurred in a cascading manner, beginning with humans and goats destroying the original woody vegetation on the island. Goats then browsed most of the subsequent regeneration. Woody shrubland and forest plants are required to supply woody debris and litter to the forest floor detritivore community, and their numbers would have declined as their habitat diminished.

Predation by rats compounded the loss of forest floor fauna on the island. Although rats prey on all accessible parts of the invertebrate community, species associated with soil and early succession stages did not lose habitat to the same extent as those of the forest floor. Therefore they have had greater opportunity than the latter to persist until the recent rat eradication. Because of the island's isolation and the large size and flightless nature of many of these forest floor species, they have been unable to recover through immigration.

4.1 FOREST INVERTEBRATES

Although observations of the island and sampling of its fauna are limited, a number of factors suggest the invertebrate community associated with forest debris is depauperate: (a) the present habitat of requisite woody debris is very limited and of small diameter, (b) the largest woody vegetation is planted pohutukawa, and these are lacking some known herbivorous associates and a known woody debris feeding associate, (c) samples were generally dominated by herbivores associated with grass systems rather than detritivores associated with woody debris, (d) the larger ground-dwelling predatory community that preys upon many of the insects associated with recycling woody debris appeared extremely limited, e.g. no carabid beetles were seen.

Rats have long been implicated in the loss of larger invertebrates of specific conservation concern from islands (Watt 1975, Pyle et al. 1981, Scott & Emberson 1986, Ramsay et al. 1988). It should be noted that the evidence for these effects on invertebrates (like that for tuatara), has been largely circumstantial, in that rats are known to consume them and the presence of particular insects on islands has been dependent on the islands being rat-free. The predatory pressure exerted by high rat populations would have increased on the faunal community as the forest and associated woody debris habitat diminished. Rat populations increase rapidly with high food availability. When food availability in a locality falls, populations disperse. On an island, however, where rat dispersal is limited, the response of the rodents will be intensified search patterns for food.

4.2 EFFECTS ON FOREST HABITAT REGENERATION

Lack of fauna associated with recycling of woody debris can in turn affect successional development of woody vegetation. Although invertebrates provide a major food source for both adventive and native vertebrates, their major role is in nurturing system succession. We know that insects are crucial

for pollination, that they provide major influences on vegetation growth dynamics through the 'pruning and thinning' roles of herbivores, and that they provide self-regulating biocontrols through predation and parasitism. However, their most important influence is through the species associated with recycling the biomass that has been accumulated within systems. While system production can be seen as the current years' accumulation, the majority of the system resources are derived from previous accumulation. These form a resource reservoir that enables biotic systems to adjust to continually changing external conditions. Thus the majority of the 'cogs in the system' (the insects) are concerned with recycling and retention of products.

High correlation and integration has been recorded between the insects, bacteria, nematode, fungi and plant components of systems wherever any of these relationships have been examined in detail (e.g. Yeates 1991). Insects help transport fungi and bacteria into parts of the systems where they are functionally appropriate, whether this is for successional stages of decay pathways or for necessary symbiotic associations with plant growth. It is now known that the endophytic leaf fungi community of planted manuka may be generalist in nature compared with a more specialist endophytic community in the leaves of naturally seeded plants (Johnston 1998). It is also well known that specific fungal endophytes can influence both vertebrate and invertebrate herbivory (e.g. Prestidge et al. 1985). These plant/endophyte community interactions may explain why native plants in gardens seldom host associated monophagous insects, something that entomologists have long puzzled over. Conservation management implications from this are that, for example, rare herbivorous insects are often not easily maintained in artificial, i.e. planted garden, habitat (J. Dugdale pers. comm., Kuschel 1990).

While we know that particular insect species transport bacteria and fungi within and between systems, these interrelationships are relatively poorly studied at the system level, despite their potential for improving conservation/restoration management (or for understanding the ramifications from movement of genetically modified organisms from field trials). At this stage we can perhaps best describe the insects as providing many of the functional mechanisms that enable systems to continually adjust to changing external and internal conditions (e.g. Hosking & Hutcheson 1986, Hutcheson 1991). Reforestation management implications from this are that successional vegetation processes on an island with a depleted invertebrate litter/woody-debris fauna are also likely to be impeded.

4.3 TUATARA

The more abundant grass-associated invertebrates are potentially a major source of food for reintroduced tuatara (or skinks). However, sustaining a reptile population will depend upon whether: (a) insects are of a size to provide sufficient nutrient requirements, (b) food sources are available all year round, and, (c) the reptiles can find and catch available insects.

Only nine or ten species of the invertebrates sampled are likely to be available in some numbers to tuatara, and to grow beyond 10 mm (Chris Ward pers. comm.) suggested as a minimum size requirement for the reptiles. These

are the four species of Orthoptera (2 grasshopper spp., the migratory locust and the black field cricket), the pink porina moth and 4-5 species of spiders found at ground level (the Dipluridae sp., the nursery-web spider, 2 spp. of wolf spiders and the cobweb spider).

Assuming that tuatara do not actively burrow for soil-dwelling larvae, the pink porina moth (*Wiseana signata*), which feeds on grass roots, is likely to only be available when emerging from the soil after pupation. Barlow (1989) shows emergence series for *Wiseana* spp. of up to 5 months between the months of October to March for the southern North Island. It might be expected that Whangaokena populations would begin emergence relatively earlier because of the warmer temperatures on the island. However, the moths were captured in March, so it is possible that they would be available for most of the summer period.

The other species mentioned do not undergo complete metamorphosis (egg, larvae, pupae, and adult), but instead, after emergence from the egg, are continually active as increasingly sized nymphs to the final adult. Availability to tuatara is thus influenced by other considerations. The potential food species would still be likely to be unavailable over the winter period, but after hatching, the orthopterans would be available throughout the summer. However, their potential as a food source would depend on when they reached a sufficient size to be utilised by tuatara. This would possibly be from late spring (November), but may be earlier in a warm island climate. This would need to be directly observed in trials with the reptiles rather than based on supposition. The grasshoppers are quiescent at night, and their availability will further depend upon tuatara nocturnal foraging behaviour.

No sign was seen in the grasshopper populations of bacterial or fungal diseases, which can act as density-dependent biological controls on high populations of non-social insects. The possibility of a disease-driven crash of the grasshopper populations provides one argument for enhancing reforestation prior to reintroduction of tuatara. The broadening of the food web could provide alternative food streams for the reptiles, provided a sufficient section of the forest fauna can be successfully enhanced or re-established.

Grassland fauna tend to be much more seasonal than forest fauna, partly because environmental influences are not as extreme within the forest habitat (Hutcheson 1996). In addition and related to this, many of the forest dwellers are relatively long-lived (e.g. weta), and therefore are likely to be available to tuatara over a longer period than are the grassland fauna. Although tuatara, being cold-blooded, can survive on little food during cold periods, it is likely that they require access to some food over the winter period. For these reasons, it may be that a degree of reforestation is a major prerequisite to any tuatara release on the island. A review of habitats on other rat-free, offshore islands presently holding tuatara populations would assist in evaluating the likely success of a reintroduced tuatara population to Whangaokena with its present vegetation cover.

5. Remedies for any ecological restoration problems

From a system perspective, barriers to restoration success can be viewed in a hierarchical manner, with barriers needing to be overcome in a sequence that ensures resources employed in overcoming succeeding steps are not wasted. The barriers are listed below in a sequence derived from the authors' observations, trials and experience as a researcher in indigenous systems over 20 years. Apart from the first two, the significance of the barriers varies with location, and the objectives, perceptions and patience of those attempting the restoration.

5.1 BARRIERS TO REFORESTATION

1. Domestic stock
2. Feral stock and browsers
3. Dense non-indigenous grass systems
4. Moisture deficit
5. A depleted litter inhabiting invertebrate community

Barriers 1 and 2. Domestic and feral stock

On Whangaokena the first two barriers have been overcome and so the next steps depend on the objectives, perceptions and patience of managers involved.

It is generally recognised that undisturbed native forest communities are the most resistant to invasive plant species, in contrast with disturbed and pastoral systems, which enable the greatest degree of colonisation by adventive weed species. This pattern has also been documented for the insect communities, with highest proportions of adventive species found in pastoral and continually disturbed systems, while even small remnant native bush pockets can retain relatively high endemism (Kuschel 1990, Hutcheson 1998, 1999; Harris & Burns 2000). This is a reflection of the interrelationships discussed above, and of New Zealand having been mostly forested for most of its evolutionary history (McGlone 1989). This implies that the appropriate ecological restoration objective on the island would be reestablishment of a coastal forest system.

Barrier 3. Dense non-indigenous grasses

The dense sward of cocksfoot and other non-indigenous grasses will inhibit development of successional shrubland. Increasing cover of the shrub spe-

cies present will still occur unaided, although this will be very slow. Enhancing the speed at which it occurs can be achieved by planting of appropriate vascular species, several of which (e.g. tauhinu, flax, koromiko, taupata, and pohutukawa) are already present.

It should be noted that multiple indigenous successional pathways exist from bare ground to native forest, and that exotic plant species can also provide some of these pathways and often accelerate the time taken to late successional stages. For example, areas of the Rimutaka range which were covered in gorse 20 years ago have since succeeded to native shrub/forest after the removal of sheep. This same successional pathway (i.e. via gorse) is being used very successfully in Hinewai reserve on Banks Peninsula. Many woody weed species (e.g. buddleia, willow, *Hakea salicifolia*, eucalypts, *Lophanthra paraserianthus* and *Pinus radiata*) are now widely recognised as having potential to provide successional pathways to native forest when grazers are removed.

In addition, some fast-growing exotic vegetation types have been found to nurture very rich insect communities of a highly indigenous nature, e.g. pine forest (Hutcheson & Jones 1999). There is thus a strong argument for retention or use of such exotics as transitional nurse crops and grass suppressants for native successions, even on the conservation estate. Use of such systems, is, however, dependent upon their acceptability, which as noted above, depends upon the objectives and perceptions of managers.

Often, weed control measures, such as spraying herbicide, simply return successions to the beginning of the successional process. As early successional systems are highly susceptible to invasion of adventives, the manager is caught in a loop of resource consumption for no ecological (or aesthetic) gain. In addition, several of the crucial components of successional native shrublands, such as koromiko, are particularly susceptible to herbicide sprays such as 'Round-up', and this explains why koromiko, despite being a heavy seeding colonising plant, is now almost absent along most New Zealand roadsides. Weeding restoration areas with such sprays can have major negative effects on restoration efforts (Hutcheson pers. observ.). Even plant species with waxy leaves such as karamu (*Coprosma robusta*) will gradually die off with repeated application of 'Round-up' (Hutcheson pers. observ.).

Barrier 4. Moisture deficit

As would be expected, extreme moisture deficit is associated with very slow progression to New Zealand rain forest. This is exemplified by the difference in the relative rates of forest regeneration on the east and west coasts of the South Island. Desiccation is a product of rainfall rates, and water loss. The latter is affected by evaporation and soil moisture retention capacity. While nothing can be done about rainfall rates, water loss in restoration areas can be influenced by the siting, planting design and management.

Wind desiccation is a major influence on most New Zealand vegetation systems. This is as true for high-altitude beech systems, where desiccation is a function of water freezing, as it is for dry east-coast systems. For example, isolated beech stands on the Ruahines were found to be driven across the

tops by wind. They break down on the side of the prevailing westerly wind, and regenerate on their sheltered side. Their ultimate fate is dependent on whether they are moving into more exposed or more sheltered sites (Hosking et al. 1993). The problem of wind desiccation of New Zealand vegetation systems is countered naturally by the dense growth of vegetation that forms around the periphery of our forests. It is also sufficient explanation for the fine divaricating nature of many of the shrubs and juvenile forms of forest species, as this growth form provides the most effective windbreak.

The exposure of New Zealand to oceanic winds together with the subtropical nature of the vegetation systems has made our forest systems very susceptible to edge browse by domestic stock and goats, and canopy removal by possums. Where this occurs, the rapid loss of vegetative components requiring high humidity, such as ferns, is particularly noticeable (Hosking et al. 1989). In simple terms the vegetative structure can be envisaged in terms of a house. Knocking the walls out reduces the shelter value considerably. This functional structure contributes to the the design of restoration planting efforts.

On any given site the soil moisture retention capacity is controlled by leaching and run-off. These are both strongly influenced by the amount of organic material at the soil surface. This enables a buffering of extremes of water availability and is one of the reasons that organic mulches work so well for horticulture. All vegetation systems build up a litter layer, and where this is inadequate for buffering extreme drought events, the incumbent vegetation dies back. This process increases the organic material on the forest floor and its subsequent water-buffering capacity. This process may be beautifully tailored to the requirements of particular sites and seasons by insect herbivores (Hosking & Hutcheson 1986). Once again, the functional structure of the natural systems provides guidance for restoration efforts.

Barrier 5. A depleted litter-inhabiting invertebrate community

A crucial influence on the efficacy of the organic mulch of natural systems is the interface between it and the soil. The organic material needs to be in a continual state of breakdown so that the litter layer may be integrated with fermentation and humus layers. This process is controlled by the invertebrate and microbial communities within the organic layer. Where these are depleted or lacking, the organic mulch material will dry out and will not function well as a buffer of water availability.

In isolated systems where native invertebrate fauna appear depleted, such as on Whangaokena, the cryptic components will need to be enhanced by re-establishments. These cryptic components are extremely numerous and are little known, e.g. only about half of New Zealand insects are even described, and we have little idea of the ecological requirements of most species. Trying to re-establish invertebrates on a species by species basis, an approach used for vertebrates, would be extremely expensive and unreliable, and unable to rebuild the functions of this part of the forest system. As persistence of a species is dependent on appropriate habitat, a system approach which rebuilds habitats is a far more efficient approach.

The community-wide enhancement of the litter layer invertebrate and microbial communities of isolated sites such as islands, where immigration of many species is impossible, can only be achieved by 'seeding' restoration patches with duff (i.e. soil, leaf-litter and debris) from later indigenous successional stages. This can help restore whole communities of litter invertebrates and fungi relatively quickly, provided that it is done appropriately.

It may be that management will wish to consider the relative risks of introducing other unwanted adventive species to the island in the process of introducing duff and mulch material from the mainland. One such species noted as a problem in buildings is the Argentine ant, *Iridomyrmex bumilis* (Green 1992). Whether this species would become a problem in a restoration area on the island is debatable. The island already has a large number of adventive species from its historical use, and such risks should not prevent a restoration attempt from using methods that will enhance success of the project. However, if fears of such eventualities are high, and resources are sufficient, managers may wish to fund examination of samples of the material being transferred.

5.2 FOREST SYSTEM RESTORATION OF WHANGAOKENA

The general observations given above about how ecological systems work provides guidance for successful restoration efforts.

1. Planting design

The establishment of indigenous plantings in patches rather than spread through open grassed areas will assist in the necessary step of suppressing the grass system. It will also enable the cryptic components, such as insects and mycorrhizal fungi, to more easily expand throughout the plantings and interlock into a 'system'.

2. Choice of site

I suggest that an initial establishment be concentrated at the base of the western valley, where the isolated older pohutukawa is present. Further plantings of flax and pohutukawa across the valley entrance behind the pohuehue clumps would assist in reducing wind into the valley. Although the winching trench has been the focus of plantings in the past, it is not ideal because it forms an overly steep shaft down which the litter communities may be continually disturbed and even washed away during heavy rains.

In grassed landscapes, wind hugs the ground form, just as it does round a sail or aeroplane wing. Additional plantings of pohutukawa around the top of the valley rim will thus help break the flow of wind entering the valley. Pohutukawa is one of the few New Zealand trees that do not require the system conditions discussed above because of its ecological role as a coastal coloniser.

It should be borne in mind that flax has an enormous capacity to staunch surface movement of water, leaving down-slope zones relatively dry. However, they have also been observed providing nuclei for further successional development (Reay & Norton 1999). Flax would be particularly useful around the rim of the island crest, where they could help stabilise potential erosion sites as well as breaking the wind free of the ground form.

Pine bark is an easily available material that works well as organic mulch, whereas old grass turf or cuttings do not (Hutcheson pers. observ.). This lends further credence to the hypothesis of competitive exclusion of forest litter fungi systems by endophytic grass fungi. Bark which has been weathered for 12-18 months works best, because initially the polyphenols in the bark are unsaturated and the material is extremely demanding of nitrogen. Attempting to overcome this problem by addition of inorganic nitrogen such as urea will defeat the purpose of building up an organic system, as many fungi are suppressed by inorganic nitrogen. However, as noted above, the breakdown processes at the base of the bark mulch need to be initiated, and this can be achieved by the use of a fine layer of chicken manure spread prior to the bark layer.

A specific sequence of steps based on both theory and practice are suggested for Whangaokena as follows.

- Additional plantings of flax at the base of the western gully where it meets the base of the trench, particularly where boxthorn spraying has encouraged herbaceous weed species,
- Additional plantings of pohutukawa near the tree that is already there, and behind the pohuehue clumps, to assist in closing out westerly winds from the gully. Also pohutukawa plantings around the rim of the valley.
- Obtain quantities of pine bark and leave this to weather for 12-18 months (near or in an indigenous forested area if possible).
- Take cuttings and seeds of the island shrubs and 'grow them on'.
- Carefully hand-spray (on a windless day) an area of grass at the base of the valley which can be covered to a depth of c.100 mm by the planned helicopter loads of pre-weathered bark.
- Spread a fine layer of chicken manure and then c. 100 mm bark over the sprayed area between 1 day and 3 weeks after spraying.
- Plant out coastal shrubland successional species into the barked area, using the koromiko especially as a 'filler' at about 1 x 1 m spacing to attain rapid canopy coverage of the focal area. Transfer plants from accessible non-conservation sites where they have grown naturally (such as forestry roads), together with their root-ball soil. Do not use nursery plants, which are generally bereft of their soil symbionts due to being nurtured on inorganic fertiliser.

- Locate plants in appropriate sites for their autecological preferences. For example karamu (*Coprosma robusta*), a species whose fruit is fed on by silvereye, bellbird, tui and pigeon (*Hutcheson pes. obs.*) enjoys wetter sites than koromiko.
- Plant extra pohutukawa and flax around the periphery to help wind shelter and to shade grass out from the edges of the focal area.
- Spread and mix in some freshly collected duff from mainland shrubland and forest throughout the barked area when planting, and repeat at each island visit, particularly when shrubs have attained canopy closure.
- Adding fresh bags of duff, woody debris and transferred natural seedlings from mainland forest occasionally. Over time, extend plantings away from the focal area using plants appropriate to local site conditions, keeping grasses suppressed at the periphery.
- Do not use spray to weed within the restored area. I suggest it only be used to kill grass on the periphery if this can be done without spray drift, and if the newly killed area is to be immediately covered by more bark.
- At regular intervals after canopy closure (e.g. yearly after flowering), clip shrub canopies to keep them rejuvenated (like fruit trees) and to keep a continual addition of a twiggy debris resource entering the litter layer.

5.3 RESTORATION CODA

Another simple approach is to integrate fast-growing exotics into restoration projects to shade out grass and to prune for bulk cellulose/woody debris during later phases of the restoration. As mentioned above, such an approach requires an expanded perception of system restoration by both DOC managers and the public. However, there are several strong arguments (including both the relative cost and the enhanced success) that support this approach.

6. Conclusion

As repeatedly stated in the text, the interpretations of the invertebrate community given here are based on limited late-season and relatively unquantified sampling. If at some time in the future quantitative knowledge is required of management effects on the invertebrate biota, then standardised quantified sampling is necessary prior to, and at intervals after, initiation of restoration efforts. It should be noted, however, that inventories of all invertebrate species is impossible (Disney 1986, Hutcheson et al. 1999), and that such research is demanding of resources. Given limited resources, managers must decide whether their primary aims are for research knowledge or restoration.

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Table 1. Provenance of species by group.

Group	Adventive	Indigenous	Undetermined	Total
Amphipoda		1		1
Arachnida	3	4	17	24
Chilognatha		2		2
Collembola			2	2
Diplopoda		1		1
Insecta	19	29	25	73
Isopoda	1	1		2
Mollusca		3		3
Platyhelminths			1	1
Total	23	41	45	109

Table 2. Provenance of insect species captured.

Order	Adventive	Indigenous	Undetermined	Total
Coleoptera	4	10	4	18
Diptera	5	2	12	19
Hemiptera	2	1	3	6
Hymenoptera	4	3	3	10
Lepidoptera	3	9	3	15
Neuroptera	1			1
Orthoptera		4		4
Total	19	29	25	73

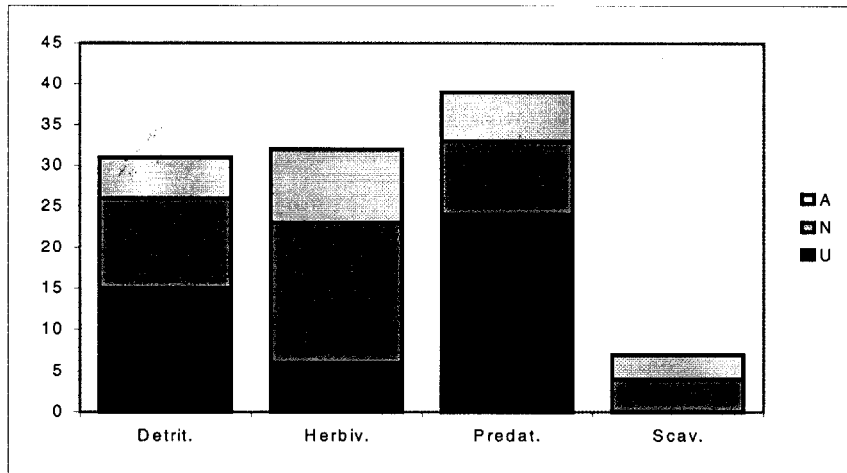


Figure 1. Species richness and provenance within four trophic groups.

A = adventive/introduced, N = native, U = undetermined. Detrit. = detritivores (including fungivores), Herbiv. = herbivores (including root feeders), predat. = predators (including parasitoids), Scav. = scavengers.

Note that the higher level of undetermined provenance of species in the predator group is related to a high proportion of spiders, a group with which the author is less familiar.

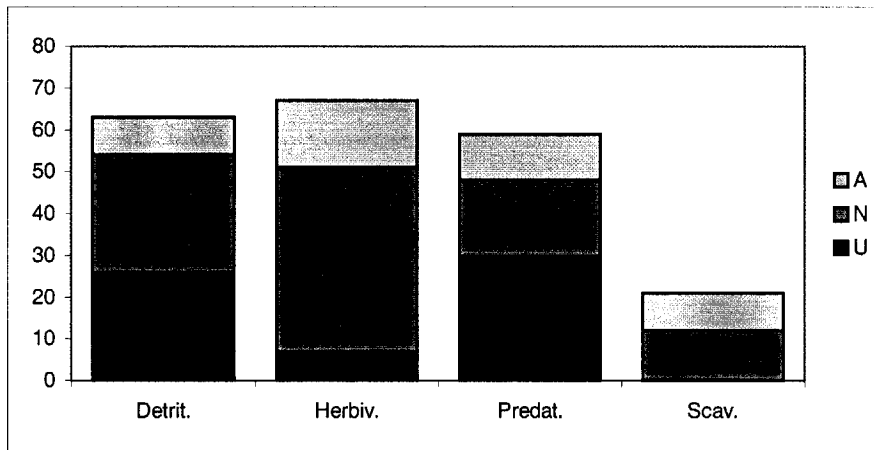


Figure 2. Relative diversity within provenance of the trophic groups. Key as for Figure 1. Diversity is measured as summed abundance classes (SAC), enabling inclusion of some influence of species abundance as well as species richness - see text for further detail.

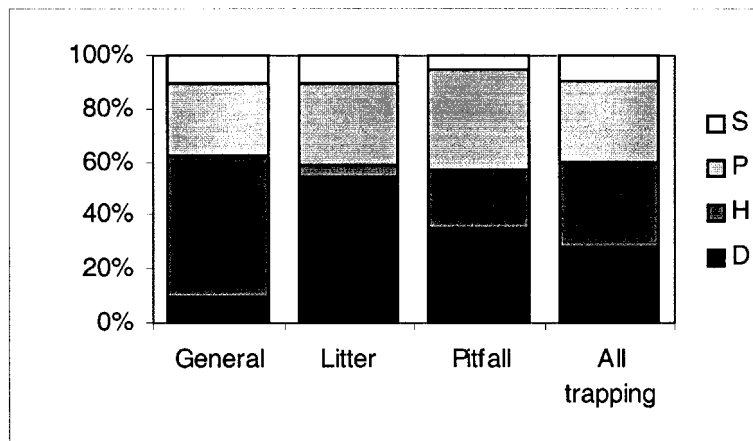
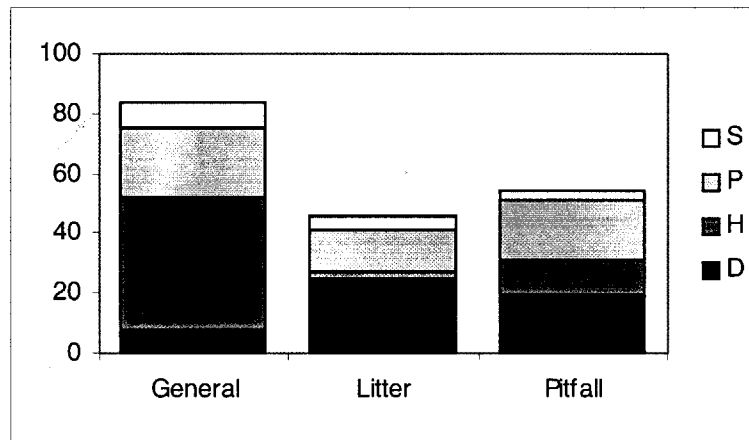


Figure 3. Functional diversity of assemblages captured by the different trapping methods. The general category includes sweep netting, beating, searching and a small Malaise-type trap. S = scavengers, P = predators, H = herbivores and D = detritivores.

(a, above) Functional diversity as summed abundance classes (SAC).

(b, below) Proportional functional diversity of the trapping methods in comparison with that of the total catch, derived from SAC.

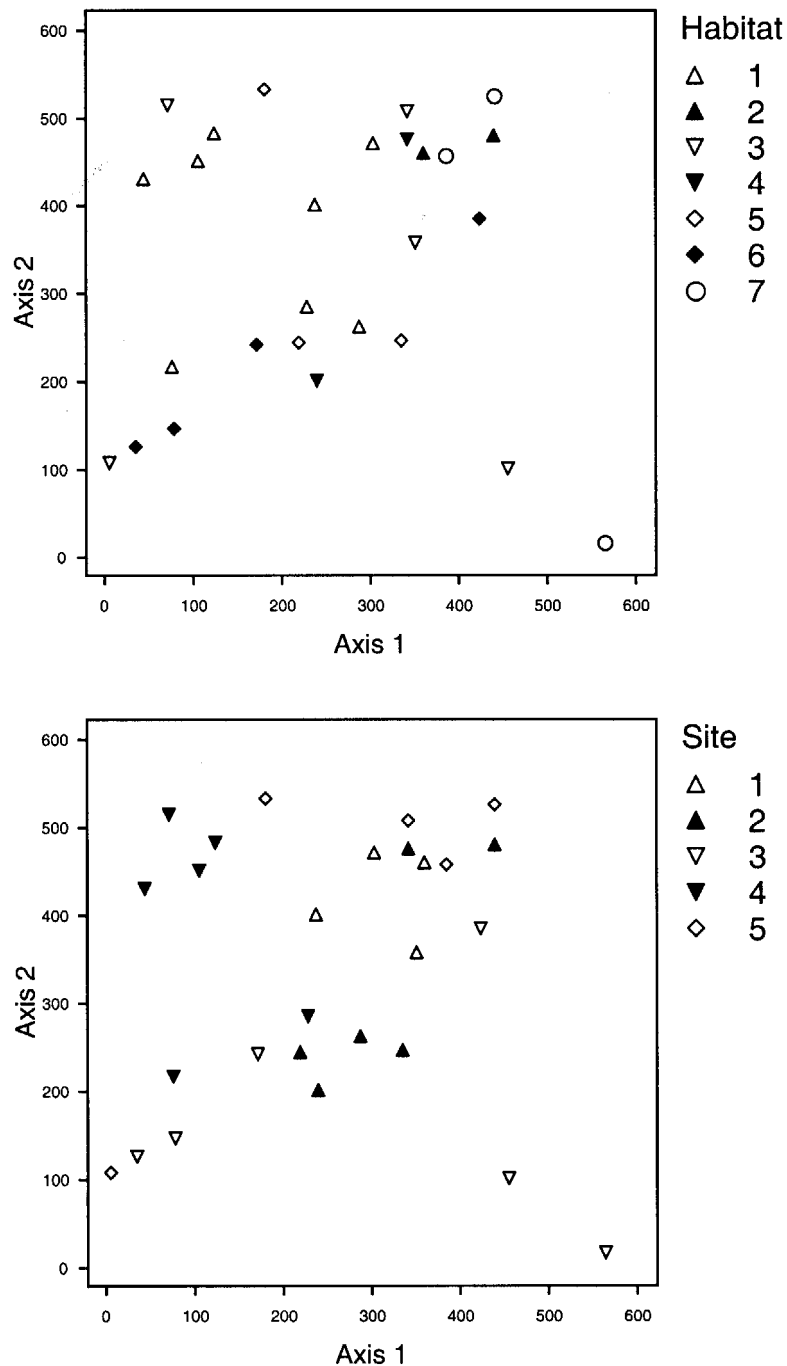


Figure 4. DCA Ordination of pitfall samples.

(a, above) Sample ordination labelled by habitat (i.e. vegetation directly above trap). 1 = grass, 2 = hebe, 3 = flax, 4 = dead boxthorn, 5 = taupata, 6 = pohuehue, 7 = pohutukawa.

(b, below) Pitfall sample ordination labelled by site (i.e. areas where traps were sited - corresponding to recce plots). 1 = A (south end of the camp plateau), 2 = B (below staging post), 3 = C (above staging post), 4 = D (North end of the knoll to the south of the camp plateau), 5 = E (near highest big pohutukawa mid-way down the trench).

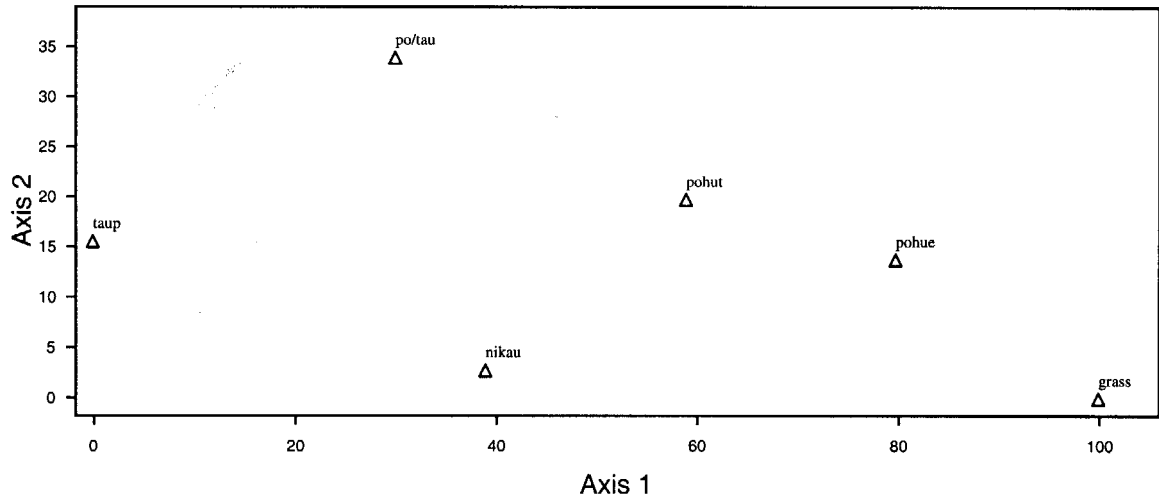


Figure 5. DCA ordination of litter samples (axes 1 & 2), to show general affinities. The flax/koromiko sample from site A was excluded as there were very few organisms present, and its consequent outlier position in the ordination distorted the relationships between the other samples.

Sample labels in ordination denote habitats and sites as follows: taup = taupata from site B; pohue = pohuehue also from site B; po/tau = pohutukawa/taupata from site C; grass = cocksfoot/ seabird burrows from site D; pohut = pohutukawa from site E; nikau = nikau/tawapou below East Cape lighthouse.

Appendix 1. List of invertebrates collected on East Island, 28-30 March 2000.

Ab = Abundance as categories 1-5 from low to high. Troph = trophic group, D = detritivores (incl. fungivores), H = herbivores (incl. all live plant feeders), P = predators (incl. parasites), S = scavengers. Pr = provenance, N = native, A = adventive, U = undetermined. Trap = collection method obtaining most Individuals of the species, p = pitfall, l = litter, g = general (includes sweep netting, beating, hand searching and a small Malaise-type trap).

Order	Family	Species	Common name	Ab	Troph	Pr	Trap
Amphipoda	Talitridae	sp.	bush hopper	4	D	N	l
Acari	Oribatidae	sp.	Oribatid mite	1	D	U	p
Acari	Acari1	sp.	carapace mite	1	P	U	l
Araneae	Agelinidae	sp 1		1	P	U	p
Araneae	Araneidae	Araneus crassus	whitebanded orbweb	2	P	A	g
Araneae	Araneidae	Araneus pustulosus	garden orbweb spider	3	P	A	g
Araneae	Araneidae	Argiope protensa	tailed grass spider	3	P	N	g
Araneae	Dipluridae	sp 1		2	P	U	p
Araneae	Lycosidae	Lycosa sp2	wolf spider	3	P	U	l
Araneae	Lycosidae	Lycosa sp1	wolf spider	2	P	U	p
Araneae	Pisauridae	Dolomedes minor	nurseryweb spider	4	P	N	g
Araneae	Salticidae	Undet sp	jumping spider	1	P	U	g
Araneae	Theridiidae	sp 1		1	P	U	p
Araneae	Theridiidae	sp 2		1	P	U	p
Araneae	Theridiidae	sp 3		1	P	U	p
Araneae	Theridiidae	sp 4		1	P	U	l
Araneae	Theridiidae	Steatoda sp.	cobweb spider	2	P	A	g
Araneae	Thomisidae	Sidymella sp1		1	P	U	g
Araneae	Thomisidae?	sp1		1	P	U	p
Araneae	Araneae1	sp2		1	P	U	g
Araneae	Araneae1	sp3		2	P	U	g
Araneae	Araneae2	sp4		1	P	U	g
Araneae	Araneae2	sp5		1	P	U	g
Chelonethi	Pseudoscorpion	sp 1	Pseudoscorpion	2	P	N	p
Laniatores	Laniatores1	sp 1	harvestman	1	P	N	p
Chilognatha	Chilognatha	Geophilomorpha sp	thread centipede	2	P	N	l
Chilognatha	Chilognatha1	sp1	centipede	3	P	N	l
Collembola	Isotomidae	Iso sp		5	D	U	p
Collembola	Sminthuridae	Smi sp		1	D	U	p
Diplopoda	Diplopoda	Icosodesmus sp	millipede	5	D	N	l
Coleoptera	Anthribidae	Dysnocryptus pallidus	fungus weevil	1	D	N	p
Coleoptera	Cerambycidae	Stenellipsis sp.	longhorn beetle	1	D	N	g
Coleoptera	Cerambycidae	Xylotelus laetus	longhorn beetle	1	D	N	g
Coleoptera	Coccinellidae	Scymnus loewi	native ladybird	1	P	N	g
Coleoptera	Corticariidae	Aridius trifasciatus	mould beetle	1	D	A	g
Coleoptera	Corylophidae	Holopsis sp.		1	D	N	l
Coleoptera	Curculionidae	Andracalles sp		3	D	N	g
Coleoptera	Curculionidae	Novitas nigrans		3	D	N	g
Coleoptera	Curculionidae	Graphognathus leucoloma	whitefringed weevil	1	H	A	g
Coleoptera	Curculionidae	Peristoreus veronicae		1	H	N	g
Coleoptera	Curculionidae	Phloeophagasoma thoracicum		2	D	N	G
Coleoptera	Curculionidae	Sitona discoideus	sitona weevil	3	H	A	g
Coleoptera	Elateridae	Conoderus exsul	pasture wireworm	2	H	A	g
Coleoptera	Leiodidae	Paracatops sp	small carrion beetle	1	S	N	p
Coleoptera	Mycetophagidae	sp1		4	D	U	g
Coleoptera	Staphylinidae	Tachyporinae sp.		1	D	U	l
Coleoptera	Staphylinidae	Osorininae sp1		2	D	U	p

Coleoptera	Col undet	larva		2	P	U	p
Diptera	Asilidae	pupal case		1	P	U	l
Diptera	Bracycera	Drosophilidae		1	D	U	p
Diptera	Bracycera	Simulidae sp1	sandfly	1	P	U	p
Diptera	Bracycera	Undet sp1		1	D	U	g
Diptera	Calliphoridae	Calliphora stygia	brown blow fly	3	S	N	p
Diptera	Calliphoridae	Chrysomya rufifascies	hairy maggot blow fly	3	S	A	g
Diptera	Cecidomyiidae	sp1	gall midge	2	H	U	p
Diptera	Nematocera	sp1		1	D	U	g
Diptera	Nematocera	sp2		1	D	U	g
Diptera	Syrphidae	Eristalis tenax	European drone fly	2	D	A	g
Diptera	Syrphidae	Melanostoma fasciatum	small hover fly	1	P	N	g
Diptera	Tachinidae	sp1	parasitic fly	1	P	U	g
Diptera	Tachinidae	Trigonospilus brevifascies	parasitic fly	2	P	A	g
Diptera	Tipulidae	sp1	crane fly	1	D	U	g
Diptera	Tipulidae	sp2	crane fly	1	D	U	g
Diptera	Tipulidae	sp3	crane fly	1	D	U	g
Diptera	Dip undet.	larvae		2	D	U	l
Diptera	Muscidae	Lucilia sericata	green blow fly	3	S	A	g
Diptera	Muscidae	Stomoxys calcitrans	stable fly	3	S	A	g
Hemiptera	Cicadellidae	Undet sp1		1	H	U	g
Hemiptera	Coccidae	Undet sp.1	scale insect	1	H	U	p
Hemiptera	Flatidae	Sephena cinerea	grey plant hopper	1	H	A	g
Hemiptera	Lygaeidae	Rhyodes clavicornis		1	H	N	g
Hemiptera	Nabidae	Tripicanabis nigrolineatus	pale damsel bug	1	P	A	g
Hemiptera	Hemiptera1	Undet sp.1		1	H	U	p
Hymenoptera	Apidae	Apis mellifera	honey bee	3	H	A	g
Hymenoptera	Bombidae	Bombus terrestris	large earth bumble bee	2	H	A	g
Hymenoptera	Chalcidae	Undet sp.1	a parasitoid wasp	1	P	U	p
Hymenoptera	Eulophidae	Undet sp.1	a parasitoid wasp?	1	P	U	p
Hymenoptera	Eulophidae?	Undet sp2		1	P	U	l
Hymenoptera	Formicidae	Amblyopone australis	an Australian ant	1	D	A	l
Hymenoptera	Formicidae	Chelaner antarcticus	Southern ant	5	S	N	l
Hymenoptera	Formicidae	Strumigenys perplexa	an Australian ant	3	D	A	l
Hymenoptera	Halictidae	Lasioglossum sp.	NZ halictid bee	3	H	N	g
Hymenoptera	Pompilidae	Priocnema nitida	golden hunting wasp	1	P	N	g
Lepidoptera	Arctiidae	Nyctemera annulata	magpie moth	2	H	N	g
Lepidoptera	Crambidae	Crambus flexuosellus	common grass moth	3	H	N	g
Lepidoptera	Geometridae	Leptomeris rubraria	common pasture moth	3	H	N	g
Lepidoptera	Hepialidae	Trioxycanus enysii	Dark crimson porina moth	1	H	N	g
Lepidoptera	Hepialidae	Wiseana signata	pink porina moth	3	H	N	g
Lepidoptera	Lycaenidae	Helleia salustius	common copper	3	H	N	g
Lepidoptera	Lycaenidae	Zizina otis labradus	common blue	3	H	N	g
Lepidoptera	Noctuidae	pupal case		3	D	U	l
Lepidoptera	Noctuidae	Undet pupal piece		1	H	U	p
Lepidoptera	Noctuidae	Pseudoletia separata	cosmopolitan armyworm	1	H	A	g
Lepidoptera	Pieridae	Pieris rapae	white butterfly	2	H	A	g
Lepidoptera	Plutellidae	Monopis ethelella	spot and cream stripe moth	3	S	N	p
Lepidoptera	Tineidae	Undet larvae		1	H	U	p
Lepidoptera	Tortricidae	Ctenopseustis obliquana	brown headed leafroller	1	H	N	p
Lepidoptera	Tortricidae	Epiphyas postvitana	light brown apple moth	1	H	A	g
Neuroptera	Hemerobiidae	Micromus tasmaniae	Tasmanian lacewing	1	P	A	g
Orthoptera	Acrididae	Conocephalus semivittatus	longhorned grasshopper	5	H	N	g
Orthoptera	Acrididae	Locusta migratoria	kapakapa	4	H	N	g

Orthoptera	Acrididae	Phaulacridium marginale	shorthorned grasshopper	4	H	N	g
Orthoptera	Gryllidae	Teleogryllus comodus	black field cricket	3	H	N	p
Isopoda	Isopoda	Porcellio scaber	European slater	2	D	A	l
Isopoda	Isopoda	Styloniscus sp?	Native slater	4	D	N	p
Sigmurethra	Arionidae	Arion sp?	introduced slug	2	H	N	p
Mollusca	Mollusca1	Undet sp 1	native snail (flat shape)	2	H	N	l
Mollusca	Mollusca1	Undet sp 2	native snail (whelk shape)	3	D	N	l
Planaria	Planaria	Undet sp.1	blue flatworm	1	P	U	p

Appendix 2. Recce plots of collection areas

EAST ISLAND VEG PLOT *A (Old lighthouse site)

Flax-Scirpus/cockfoot grassland

Date: 29. 3. 2000 **Personnel:** J.Hutcheson **Grid. ref.:**
Altitude: 100m **Aspect:** - **Slope:** 0 **Physiography:** plateau
Parent material: Calcium rich mud/sandstone **Drainage:** good **Cultural:** Old lighthouse site
Ground cover % , Vascular plants: 95 **Moss:** **Litter:** **Concrete:** 5 **Earth:**
Mean top height (m): 2 **Canopy %:** 95

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height					2m	
Density					4	6
					Pho coo 4	
					Heb str (m)1	
					Sci nod 4	
					Dac glo 2	6
						Pla Ian 1
						US herb 1
						Pas as 3
						US grass 2
Epiphytes						

NOTES: Water tanks to Nth of plot

Unhealthy:

Dead Stems:

Debris:

Fungi:

Leaf Litter: Old grass, flax & Scirpus foliage

ACCESS:

*A = Unquantified sampling from south of camp plateau area - East & Nth of lighthouse site

** Codes include first three letters of generic and specific names, full names are listed in Appendix 3.
 US = Undetermined sp.

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%

EAST ISLAND VEG PLOT *B (Below staging post winch)

Tarata/dead boxthorn/pohuehue/grass

Date: 29. 3. 2000 **Personnel:** J.Hutcheson **Grid. ref.:**
Altitude: 50m **Aspect:** W **Slope:** 15 **Physiography:** exposed valley outlet
Parent material: Calcium rich mud/sandstone **Drainage:** good **Cultural:** Old winch site / boxthorne spraying
Ground cover % , Vascular plants: 80 **Moss:** **Litter:** **Rock:** **Earth:** 20

Mean top height (m): 2 **Canopy %:** 85

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height					2m	
Density					3	6
					Cop rep 3	
					Heb str (m)2	
					Lyc fer (d) 3	
					Dac glo 4	5
					Mue com 3	
					Cir vul 2	
					Pic esc 2	
					Son lit 1	
						US herb 1
Epiphytes						

NOTES:

Unhealthy:

Dead Stems: Several (category 3) dead (sprayed) boxthorn bushes

Debris:

Fungi:

Leaf Litter:

ACCESS: Just above drop off to beach rocks, below winch staging post

*B = Unquantified sampling from below staging post

** Codes include first three letters of generic and specific names, full names are listed in Appendix 3.

US = Undetermined sp.

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%

EAST ISLAND VEG PLOT *C (Just above staging post winch)

Pohutukawa/Pohuehue/flax/grass

Date: 29. 3. 2000

Personnel: J.Hutcheson

Grid. ref.:

Altitude: 55m

Aspect: W

Slope: 10°

Physiography: side gully outlet

Parent material: Calcium rich mud/sandstone

Drainage: good

Cultural: Old winch site /staging post

Ground cover % , Vascular plants: 95

Moss:

Litter:

Rock:

Earth: 5

Mean top height (m): 2

Canopy %: 95

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height					2m	
Density					3	6
				Met exc 3		
					Mue corn 4	2
					Heb str (m) 1	
					Asp obl 2	
					Dac glo 3	3
					Sci nod 2	
					Pho coo 4	
					Son lit 1	
					Sen lau 2	
						Ger mol 1
						Carex sp 1
Epiphytes						

NOTES:

Unhealthy:

Dead Stems:

Debris:

Fungi:

Leaf Litter: Pohutukawa, and lower leaves of flax, mue com, Sci nod, Dac glo

ACCESS: Just above drop off to beach rocks and below winch staging post

*C = Unquantified sampling from above staging post winch

** Codes include first three letters of generic and specific names, full names are listed in Appendix 3.

US = Undetermined sp.

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%

EAST ISLAND VEG PLOT *D (Nth end of knoll to south of lighthouse site)

Scirpus- cocksfoot grassland

Date: 29. 3. 2000 **Personnel:** J.Hutcheson **Grid. ref.:**
Altitude: 105m **Aspect:** - **Slope:** 0' **Physiography:** knoll
Parent material: Calcium rich mud/sandstone **Drainage:** good **Cultural:** Above and Sth of lighthouse site
Ground cover % , Vascular plants: 95 **Moss:** **Litter:** **Rock:** **Earth:** 5

Mean top height (m): 1 **Canopy %:** 95

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height					2m	
Density					4	6
					Scir nod 4	
					Pho coo 2	
					Dac glo 3	5
						Hyp rad 2
						Sen lau 2
						US herb 1
Epiphytes						

NOTES:

Unhealthy:

Dead Stems:

Debris:

Fungi:

Leaf Litter: Old Scr nod, Dac glo, flax foliage

ACCESS: At Nth end of knoll to Sth of camp plateau

*D = Unquantified sampling from knoll to Sth of camp plateau, East Island, Mar 2000

** Codes include first three letters of generic and specific names, full names are listed in Appendix 3.

US = Undetermined sp.

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%

EAST ISLAND VEG PLOT *E (first big pohutukawa down trench)

Pohutukawa/Taupata /flax

Date: 29. 3. 2000 **Personnel:** J.Hutcheson **Grid. ref.:**
Altitude: 70m **Aspect:** W **Slope:** 10° **Physiography:** Old winching `trench' in gully
Parent material: Calcium rich mud/sandstone **Drainage:** good **Cultural:** Old winching `trench'
Ground cover % , Vascular plants: 80 **Moss:** **Litter:** 10 **Rock:** **Earth:** 10

Mean top height (m): 2 **Canopy %:** 95

	Tier 1 Emergent	Tier 2 12m +	Tier 3 12m-5m	Tier 4 5m-2m	Tier 5 2m-30cm	Tier 6 <30cm
Height					2m	
Density					3	6
				Met exc 3		
				Cop rep 3		1
					Heb str (m)1	
					Pho coo 3	
					As obl 2	1
					Dac glo 2	5
					Sci nod 2	
					Sen lau 1	
					Carmi sp. 1	
						Pla Ian 1
						Ger mol 1
						Cir vul 2
						Pol ric 1
						Asp flu 1
						Sola sp. 2
Epiphytes						

NOTES:

Unhealthy:

Dead Stems:

Debris:

Fungi:

Leaf Litter: Pohutukawa, and lower leaves of flax, mue corn, Sci nod, Dac glo

ACCESS: Just above drop off to beach rocks and below winch staging post

*E = Unquantified sampling from by highest big poutukawa in trench

** Codes include first three letters of generic and specific names, full names are listed in Appendix 3.

US = Undetermined sp.

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%

Details of pitfall trap and litter sample collection locations, and associated vegetation. A - E also refer to recce-plot sites (Appendix 2).

A South end of the camp plateau, including the old lighthouse site and NE surrounds

- 1 In front of low concrete wall (east end) in cocksfoot
 - 2 In front of low concrete wall (west end) in cocksfoot
 - 3 Under hebe 2m Nth of wall (West end)
 - 4 lost
 - 5 Under flax in front of east end of wall
 - 6 Under south flax at east end of wall
- Litter sample collected from underneath flax - hebe association

B Below staging post and above drop off to rocks

- 1 At base of 40cm drop formed by a small erosion cirque (in cocksfoot)
 - 2 Under dead boxthorn
 - 3 Edge of dead boxthorn
 - 4 Under taupata
 - 5 Under Hebe
 - 6 Under taupata
- Litter:(a) from beneath large taupata., (b) from beneath pohuehue

C Just above the old staging post at bottom of old winching `trench'

- 1 Under pohuehue
 - 2 Under Pohutukawa
 - 3 Under pohuehue
 - 4 At base of 1.5m bank overhung by flax
 - 5 Under pohuehue
 - 6 Under pohuehue
- Litter: from beneath pohutukawa -taupata

D On the Nth end of the knoll to the Sth of the camp plateau

- 1 In cocksfoot
 - 2 In cocksfoot
 - 3 in cocksfoot
 - 4 In cocksfoot
 - 5 At base of flax
 - 6 In cocksfoot
- Litter: from base of cocksfoot grass in region of seabird burrows.

E Under the first big pohutukawa down the trench

- 1 Under overhanging flax
 - 2 under Taupata
 - 3 under Taupata
 - 4 Under pohutukawa - uphill
 - 5 Under pohutukawa - uphill
 - 6 Under pohutukawa - downhill
- Litter: from beneath pohutukawa (in trench)

Additional East Cape litter sample taken from beneath mature *Planchonella costata* (tawapou) - *Rhopalostylis sapida* (nikau) association.

Appendix 3. Updated (but not comprehensive) list of plant species on Whangaokena (East Island). Prov = provenance: A = adventive, N = Native. * = recently planted/deliberately introduced

Prov.	Species	Common name	Habit
A	<i>Anagallis arvensis</i>	scarlet pimpernel	herb
A	<i>Anredera cordifolia</i>	Madeira vine	vine
N	<i>Apium australe</i>		
N	<i>Asplenium flaccidum</i> subsp. flaccidum	hanging spleenwort	epiphyte
N	<i>Asplenium oblongifolium</i>	Huruhuruwhenua / shining spleenwort	fern
A	<i>Aster</i> sp. subulata?		herb
N	<i>Blechnum fluviatile</i>	kiwakiwa	fern
N	<i>Calystegia tuguriorum</i>		
N	<i>Carex</i> sp.		sedge
N*	<i>Carmichaelia williamsi</i>	East Cape broom	shrub
N	<i>Cassinia leptophylla</i>	tauhinu	shrub
N	<i>Centella uniflora</i>		
A	<i>Cerastium fontanum</i> subsp. Triviale	common mouse-ear chickweed	herb
A	<i>Cirsium vulgare</i>	californian thistle	Herb
A	<i>Conyza floribunda</i>	fleabane	herb
N	<i>Coprosma repens</i>	karamu	Shrub
A	<i>Coronopus didymus</i>	lesser swinecress	herb
N	<i>Crassula</i> sp.		
A	<i>'Cyperus' ustulatus</i>		tall sedge
A	<i>Dactylis glomerata</i>	cocksfoot grass	grass
A	<i>Daucus</i> sp. carroa?	carrot	herb
N	<i>Dichondra repens</i>		herb
N	<i>Disphyma australe</i>		
N*	<i>Dysoxylon spectabile</i>	kohekohe (1 seedling)	tree
A	<i>Geranium molle</i>	dove's foot cranebill	herb
A	<i>Galium aparine</i>	cleavers	herb
N	<i>Gnaphalium</i> sp. (luteo-album agg.)		
N	<i>Haloragis erecta</i>		herb
N	<i>Hebe stricta</i> var. macrourea	koromiko	shrub
A	<i>Hypochoeris radicata</i>	cats ear	herb
A	<i>Lolium perenne</i>		grass
A	<i>Lotus pedunculatus?</i>	small, fine, yellow flowered	herb
A	<i>Lupinus arboreus</i>	tree lupin	shrub
A	<i>Lycium ferocissimum</i>	boxthorn	shrub
A	<i>Malva</i> sp. neglecta?	dwarf mallow	herb
N*	<i>Metrosideros excelsa</i>	pohutukawa	tree
N	<i>Microlaena stipoides</i>	bush rice grass	grass
N	<i>Muehlenbeckia complexa</i>	pohuehue	vine
N	<i>Muehlenbeckia australis</i>		vine
A	<i>Oxalis</i> sp. (yellow flowers)	oxalis	herb
A	<i>Paspalum paspalodes</i>	paspalum	grass
N	<i>Phormium cookianum</i>	mountain flax	flax
A	<i>Phytolacca octandra</i>		
A	<i>Picris echioides</i>	bristly ox-tongue	herb

Prov.	Species	Common name	Habit
A	<i>Plantago lanceolata</i>	plantain	herb
N	<i>Plantago picta</i>	native (rare) plantain	herb
N	<i>Poa anceps</i>		grass
A	<i>Poa annua</i>		grass
A	<i>Polycarpon tetraphylla</i>		
N	<i>Polystichum richardii</i>	pikopiko	fern
N	<i>Pyrrosia eleagnifolia</i>	leather leaf fern	epiphyte
A	<i>Raphanus</i> sp.	wild turnip? (seen)	herb
A	<i>Sagina procumbens</i>	procumbent pearlwort	herb
N	<i>Samolus repens</i>		herb
N	<i>Scirpus nodosus</i>	clubbed rush	reed
N	<i>Senecio lautus</i>		herb
A	<i>Solanum nigrum</i>	black nightshade	herb
A	<i>Solanum nodiflorum</i>		herb
N	<i>Sonchus littoralis</i>	puha	herb
A	<i>Stellaria media</i>	chickweed	herb
A	<i>Trifolium repens</i>	white clover	herb
A	<i>Vicia</i> sp.	vetch	herb
A	<i>Viola</i> sp.	violet	herb
A	<i>Zantedeschia aethiopica</i>	arum lilly	herb

Appendix 4. Malaise trapped beetles: A practical approach to comparing invertebrate biodiversity. (A brief summary, see Hutcheson et al (1999) for extended discussion).

John A Hutcheson

New Zealand has an estimated 20,000+ insect species and we currently know relatively little about most of them. It is impossible to study all insect species in any extensive piece of habitat (Disney 1986) so sampling is required to provide us with indications of the current attributes of insect communities. Many approaches to this problem have been attempted throughout the world. However, none could be robustly scientifically justified, applied to New Zealand situations and also applied in a relatively practical manner across a wide range of habitat types.

Protocols which provide samples characteristic for the communities from which they are drawn have been developed by the author. The approach enables pragmatic evaluation of comparative biodiversity, as well as community attributes in relation to habitat. Context, protocols and study results are discussed in greater detail in Hutcheson (1990), Hutcheson and Hosking (1994), Hutcheson (1996), Dugdale and Hutcheson (1997), Hutcheson and Jones (1999), Hutcheson and Kimberley (1999), Hutcheson et al. (1999). The approach is now being used by several CRIs, universities and government departments, and strong interest in the technique has been expressed from outside New Zealand.

The protocols use Malaise trapped beetles captured over a defined period in the annual cycle of adult beetle activity. Beetles were chosen because they comprise perhaps 50% of New Zealand insect species and range across all insect functions and terrestrial habitats. In contrast, many other groups are adapted for specific lifestyles or environments, and are thus unable to fully represent communities from a wide range of habitats. Beetles have been reported by several authors as representing the 'richness' of total insect fauna (e.g. Moeed and Meads 1985, Newmann 1979, Tanaka and Tanaka 1982). Review of a wide range of studies revealed that correlation of beetles with total invertebrate activity was related to sampling effort, and that the correlation was very high for Malaise trap samples (Hutcheson et al. 1999). Taxonomy of beetles and the dynamics of their sampling are also much better understood than for other species rich, multi-trophic insect groups. Where results from beetles have been compared with those drawn from other groups (e.g. Lepidoptera, (Dugdale and Hutcheson 1997)), there was considerable concordance of conclusions.

Malaise traps are simply gauze screens that passively intercept insects. A major virtue of the trap is that it operates independently of both the habitat and the researcher. Although the trap samples within about a meter of the ground, comparative sampling within the canopy of indigenous podocarp/broadleaf forest provided much smaller catches, of similar trophic structure to traps erected at ground level (Hutcheson 1996).

Sampling is conducted over the period that provides samples most characteristic for their communities (Hutcheson and Kimberley 1999). Multivariate analysis is used to evaluate spatial variation in relation to temporal variation over the sampling period, and thus to objectively discriminate between various communities. The attributes of sample groupings are then evaluated with reference to component species attributes. Sampling and analysis protocols, and the reasoning behind them are given in detail in Hutcheson et al. (1999).

The approach has now been validated in a range of New Zealand vegetation systems and although research is still at a relatively early stage, results to date provide a much-improved appreciation of the mechanisms shaping the attributes of insect biodiversity. The picture that is emerging from the data is in accord with general ecological theory, giving support to the validity of the methods.