Baseline Survey for the Punakaiki Coastal Restoration Project

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Prepared for:
Rio Tinto
&
Conservation Volunteers

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1. EXECUTIVE SUMMARY

Aims

- To collect baseline data on biodiversity and soils to allow comparison of changes over time
- To investigate reliable indicators of successful ecological restoration
- To establish a checklist of species present in restored and reference areas

Methods

- 4 transects that included unplanted (grassland), restored (recently planted) and mature (forest reference) were established to compare their biodiversity and soil characteristics
- 84 pitfall traps, 48 wooden discs, 36 weta motels, 24 lizard lodges, 16 foam wraps, 36 earthworm digs, 12 leaf litter samples, 4 moth trapping sites, 2 malaise traps were used to compare fauna in the transects above
- Birds, fish, aquatic invertebrates, plants and bats were also surveyed
- Soil nutrients and characteristics were also analysed throughout the transects

Results

- Giant springtail *Holacanthella* ?*paucispinosa* found which has conservation significance
- Pitfall traps had more beetles in mature sites than restored or unplanted sites
- Spotted earthworms, ants, weevils, snails and centipedes were only found in leaf litter from mature sites. Beetles were almost exclusively found in mature leaf litter
- Earthworm numbers from wooden discs, pitfalls and earthworm digs all had a decreasing trend from unplanted to mature sites
- Light trapping showed different moth species in mature and restored sites
- Numbers and biomass of endemic earthworm reflects the restoration gradient towards mature forest
- The taxa above may be good indicators of mature forests
- Interesting finds were: 3 species of weta, a giant springtail, 5 species of native snails, a minute ground beetle, mite and harvestman species and 7 potential endemic earthworms
- More native birds were found in the mature sites & more exotic birds in restored sites
- Soil analysis showed that mature sand plain forest at the Nikau Scenic Reserve exists on a poorly physically-developed gravelly soil in acidic, low-organic matter, low-nitrogen, low-phosphorus and low-potassium conditions. Restoration of these conditions is feasible.

Discussion

- Earthworms, beetles ants and snails all warrant future monitoring as indicator taxa
- Bird monitoring needs to be continued with sampling throughout year
- Light trapping of moths shows good potential but requires further investigation
- The survey has provided baseline results and guidance towards focussing research on biodiversity criteria that should be used to inform a successful restoration

Recommendation

- The sand-plain forest at Punakaiki is a unique habitat that provides an opportunity to quantify restoration success through measuring biodiversity gradients. We recommend this baseline survey is extended into a full research programme (see separate proposal)

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2. INTRODUCTION

The Punakaiki Coastal Restoration Project (PCRP) is a partnership between the Department of Conservation, Rio Tinto and Conservation Volunteers. Conservation Volunteers is a non-government environmental organisation operating in Australia and New Zealand utilising volunteer input from overseas visitors and local communities. Conservation Volunteers are responsible for project management and implementation. The 80ha property was gifted to the Department of Conservation in 2010. Rio Tinto Ltd previously owned the property and are funding the restoration project, which aims to plant 100,000 trees over 5 years. Planting started in May 2009 and 64,000 trees had been planted by the end of Feb 2012.

The site is approximately 4 km South of Punakaiki on State Highway 6, the main West Coast road. The larger part of the property is on the seaward side of the road, bordering on the northern boundary of the Nikau Scenic Reserve. The other part of the property is on the inland side of the road. The slopes to the east are regenerated native bush, (farmed until about 1970). Further up the valley there is mature forest, in a block owned by the Forest and Bird Society, and the Paparoa National Park beyond that, where the nesting ground of the Westland petrel (*Procellaria westlandica,* Tāiko) is located. This is the only remaining petrel breeding site on mainland New Zealand.

The first goal of the PCRP is to create a forested corridor between the sea and the petrel breeding ground, to protect their flight path westward to the sea. The petrel fledglings are particularly vulnerable on their first flight from their burrows to the sea. Lights from cars, buildings, etc, can disorientate them and cause them to become grounded and vulnerable to predators, traffic, and other threats.

The PCRP site is within the Punakaiki Ecological District and is the most northern part of the Barrytown flats, which is a strip of coastal plain between the foothills of the Paparoa range and the Tasman Sea, stretching from a little South of Barrytown (25.5km North of Greymouth) to Punakaiki (42km North of Greymouth). The Barrytown flats are comprised of a complex sequence of old dune ridges and alluvial deposits, which originally would have been entirely covered in forest and wetland (Boffa Miskell, 2007). Nearly all of the Barrytown flats have been modified by forest clearance and drainage for timber harvesting, mining, and farming. Most of this area has at some time been under licence for prospecting ilmenite and gold (Wilms, 1985).

The climate on this part of the West Coast is warm/temperate and wet, with mean annual rainfall between 2,000 mm and 4,000 mm; means annual temperature of 10 - 12˚C; and mean annual sunshine hours of 1,600 – 1,800 (www.niwa.co.nz, 2012).

The Nikau Scenic Reserve, adjacent to the PCRP site is a rare remnant of flat, lowland, fertile, coastal forest. Almost everywhere else in NZ this type of land has been cleared for farming. The reserve is 20.2 ha and was established in 1961 (Don, 1986), although it has been protected informally for considerably longer.

On the western side of the site there is a long narrow tapering strip of coastal reserve which forms a corridor between the Nikau Reserve, and Conservation land at the Northern end of the flats. This strip is established native vegetation on gravel.

The purpose of this study is to collect baseline data relating to biodiversity on the restoration site, and in adjacent forest remnants. Biodiversity re-establishment in the restoration area was monitored and compared with remaining unplanted pasture areas, and the mature forest in the Nikau Scenic Reserve. These baseline data should be of value when the survey is repeated in the future and will help assessing restoration success.

Previous ecological studies have been carried out in the region – most significantly the Barrytown Flat Baseline Biological Survey 1985-1986 which included the Nikau Scenic Reserve (Don, 1986). This was a large and thorough study which included water quality, aquatic flora and invertebrates, fish, terrestrial vegetation, birds, reptiles and mammals, but no terrestrial invertebrates. More recently, the Grey District Council has commissioned significant natural area assessments for a number of sites close to this study site (Boffa Miskell, 2006, 2007a, 2007b). These focused on vegetation, birds, fish, reptiles, and mammals.

Our study has a strong focus on terrestrial invertebrates, but also includes aquatic invertebrates, freshwater fish, birds, bats, lizards and soils. Monitoring plots were established in the restoration plantings to measure growth and survival rates of the woody species that have been planted. If monitoring is repeated in the future, the located plant plots will also show changes in other biodiversity indicators such as coarse woody debris, naturally regenerating seedlings, and ferns (Kanowski and Catteral, 2007).

3. METHODS

Transect comparisons of soil nutrients, pitfalls, wooden discs, weta motels, lizard lodges, foam wraps, leaf litter and earthworms

Data was collected from soil samples, pitfall traps, wooden discs, weta motels, lizard lodges, foam wraps, leaf litter, and earthworm digs.

The design used for this part of the project was four transects, each with three treatments, making a total of twelve plots. The transects were all roughly in a North/South direction in an attempt to obtain similar soil substrate within each treatment. All transects were established in the block of land between the road and the sea (Figure 1).

Descriptions are given below along with abbreviations used.

The treatments are: M = Mature forest (existing forest)

R = Restored (recently planted areas)

U = Unplanted (exotic grass)

The purpose of this design was initially to show a comparison between existing forest and the areas recently planted by Conservation Volunteers. Unplanted exotic grassland areas (near restoration planted areas) were used as controls. There were four replicates of each treatment to enable meaningful statistical analysis.

Yellow, orange, and blue flagging tape was used to mark our plots and sampling devices.

In each of the 12 plots there are the devices listed below, which we monitored but also left in place for future monitoring:

7 x Pitfall Traps (PF) to catch ground dwelling invertebrates. Labelled PF A, PF B, PF C, PF D, PF E, PF F, PF G, from South to North.

4 x Wooden Discs (WD) to imitate fallen logs, and monitor ground dwelling invertebrates. Labelled WD A, WD B, WD C, WD D, from South to North.

3 x Weta Motels (WM) to monitor weta and invertebrates. In Mature forest sites the weta motels are attached to trees. In the restored and unplanted sites the weta motels are attached to wooden stakes. Labelled WM A, WM B, WM C, from South to North.

2 x Lizard Lodges (LL) to monitor lizard and invertebrates. Not labelled.

In each of the Mature Forest plots only there are also:

4 x Foam Wraps (FW) around tree trunks to monitor lizards and invertebrates. Not Labelled.

The Mature forest plots are marked with only 2 or 3 pieces of orange flagging tape. It is generally easier to see the traps etc in the leaf litter than in long grass. In the Restored and Unplanted plots pitfall traps are marked with bamboo canes with yellow or pink tape and wooden discs and lizard lodges are marked with blue. The outside corners of the Unplanted plots are marked with 4 tall bamboo canes with orange and yellow tape. In the Restored plots, the corners of 10m x 10m plant plots are marked by bamboo with orange tape.

Figure 1: Aerial photo showing position of 12 plots (as in Table 1 below)

Table 1: GPS coordinates of the 12 plots (see Figure1 above)

Site code	Description	GPS coordinates
Pmat1	Mature 1	S42 08.641 E171 19.839
Pmat2	Mature 2	S42 08.635 E171 19.777
Pmat3	Mature 3	S42 08.632 E171 19.606
Pmat4	Mature 4	S42 08.153 E171 19.755
Pres1	Restored 1	S42 08.619 E171 19.841
Pres2	Restored 2	S42 08.593 E171 19.783
Pres3	Restored 3	S42 08.593 E171 19.622
Pres4	Restored 4	S42 08.259 E171 19.692
Punp1	Unplanted 1	S42 08.469 E171 19.847
Punp2	Unplanted 2	S42 08.501 E171 19.773
Punp3	Unplanted 3	S42 08.500 E171 19.635
Punp4	Unplanted 4	S42 08.208 E171 19.722

DoC Permit no. WC-32962-RES was obtained for lizard, fish and moth sampling and permit CA-28815-FAU was used for invertebrate sampling.

3.01 Pitfall traps

Pitfall traps (Figure 2) for monitoring ground-dwelling invertebrates (Southwood and Henderson, 2000) were set using an 80mm dia. soil corer. A plastic tube was inserted into the hole to maintain the hole for future monitoring, and inside this a 350ml plastic honey pot containing 100ml of Monopropylene Glycol (antifreeze) as a preservative. A galvanised steel roof 180mm x 180mm with four wire legs was erected over each pitfall trap to reduce rain and leaves from entering the trap. Seven pitfall traps were set 4m apart in a straight line in each plot. The traps were set for 29 days from 13th December 2011 to 11th January 2012. The Kruskal-Wallis Test was used to determine if the vegetation types contained significantly different numbers.

Figure 2: Pitfall trap for sampling ground dwelling invertebrates

3.02 Leaf litter invertebrates

Leaf litter samples from an area approximately 200mm x 300mm were collected from each plot and put into Tullgren funnels (Southwood, 1978) for seven days to extract ground-dwelling micro-invertebrates into 70% ethanol. Leaf litter samples from transect 1 were collected on 2nd Dec 2011, from transect 2 on 8th Dec 2011, from transect 3 on 6th Jan 2012, and from transect 4 on 30th Dec 2011.

3.03 Foam wraps

Foam wraps (Bell, 2009) for monitoring forest geckos and arboreal invertebrates were made from pieces of thin (3mm) high density closed cell foam 500mm x 400mm wrapped around tree trunks at approximately chest height and attached with four galvanised nails. Foam wraps were set out between 1st and 8th of December 2012, and monitored on 12th and 13th Jan 2012.

3.04 Lizard lodges

Lizard lodges (Figure 3; Lettink and Cree, 2007) were made from 2 pieces of corrugated brown Onduline (400mm x 500mm). One piece had 6 short pieces of dowelling (10mm dia) glued on the bottom to create a narrow space for lizards when the two pieces were placed together on the ground. Some small rocks were placed on top to stop it blowing away. Lizard lodges were set out between 1st and 8th of December 2012, and monitored on 12th and 13th Jan 2012.

Figure 3: Example of lizard lodge used at Punakaiki

3.05 Weta motels

Weta motels (Bowie et al. 2006) were made of untreated pine with an entrance hole in the bottom (Figure 4). They are 50 x 50 x 250mm with a 15mmØ hole. Weta motels were used to monitor tree weta, cave weta, and other arboreal invertebrates including spiders, leaf-vein slugs, and beetles. Three in each plot were attached to trees in mature sites and to stakes in restored and unplanted sites using lacing wire. Weta motels were set out on 30th Nov and 1st of Dec 2011, and were monitored on 12th and 13th Jan, 2012.

Figure 4: Close up of weta motel design used and shown attached to stake in unplanted site

3.06 Wooden discs

Wooden discs for monitoring ground-dwelling invertebrates and lizards (Bowie and Frampton, 2003) were cut from a *Pinus radiata* tree on site (Figure 5). The diameter of the discs varied between 320mm and 460mm. Ground cover was removed so discs are in direct contact with soil. Four discs were used in each plot. A mixture of sizes were used in each plot so the total area of ground covered by discs was approximately $0.47m^2$ per plot. Wooden discs were set out on 1st Dec, 2011, and monitored on 12th and 13th Jan, 2012.

Figure 5: Wooden disc used at Punakaiki for sampling beetles, worms, spiders, etc

3.07 Earthworm sampling

Earthworms were sampled by digging and careful hand-sorting three soil samples, each 200mm x 200mm x 200mm in each plot (3 x $0.008m^3$ of soil). The holes were dug in line with the pitfall traps, between pitfall traps B and C, C and D, and D and E. Earthworms were removed and sorted (Figure 6), weighed and identified to Recognizable Taxonomic Units (RTUs) or named species where possible. DNA was determined on some specimens to aid identification. Specimens were collected on 10th and 11th of January 2012. Worm data was analysed using ANOVA and TUKEY tests.

Figure 6: Searching for worms in soil samples

3.08 Moth light trapping

Light trapping for moths was done in January after the Westland petrels had vacated their breeding site. Two identical light traps were set up in plots M1 and R1 on the evening of the 10th of Jan 2012. The light traps each containing a 60W bulb were powered by a generator which would run for approximately three hours on a full tank of petrol. Traps were retrieved and moths collected the following morning. On 11th Jan 2012 the two light traps were set up in plots M3 and R3, as described above (locations shown in Figure 7) .

Figure 7: Sites of moth light traps, fish and aquatic invertebrate surveys

3.09 Aquatic invertebrates

Aquatic invertebrates were sampled twice on 11th Jan 2012 at three locations (see Figure 7; Table 2). An aquatic D-shaped kick net was used to sample stream invertebrates. In the shingle-bottomed Scotsman's Creek crossing site the net was placed on the bottom and stones were kicked/disturbed directly in front (upstream) of the net for 30 seconds. This was repeated in another spot 1-2m away, photographed and GPSed for future comparison (Table 2). This method was repeated on the same creek approximately 30m below the main road bridge in Nikau Scenic Reserve (Figure 8). The third site was within the planted areas west of the road at the second bridge (Table 2).

Figure 8: Nikau Scenic Reserve aquatic invertebrate site downstream of Scotsmans Creek Bridge

Table 2: Description of aquatic invertebrate sample sites

Site	Description	GPS	Depth	Substrate
Scotsman's Creek #1	East of main road 4 m below crossing	S42 08.768 E171 19.905	2-3cm	Shingle
Scotsman's Creek #2	East of main road 2 m below crossing	S42 08.768 E171 19.905	2-3cm	Shingle
Nikau Reserve #1 below Scotsman's Bridge (see Figure 8)	~ 30m west of main road bridge at bend between Nikau & large broadleaf tree	S42 08.756 E171 19.829	3cm	Shingle
Nikau Reserve #2 (see above)	1 m upstream from Nikau Reserve #1	S42 08.756 E171 19.829	3cm	Shingle
Restoration planting #1	2nd bridge on track. 0.5 m downstream below bridge	S42 08.534 E171 19.728		Sand and lots of weed
Restoration planting #2	2nd bridge on track. 10 m downstream below bridge	S42 08.538 E171 19.72		Sand and lots of weed

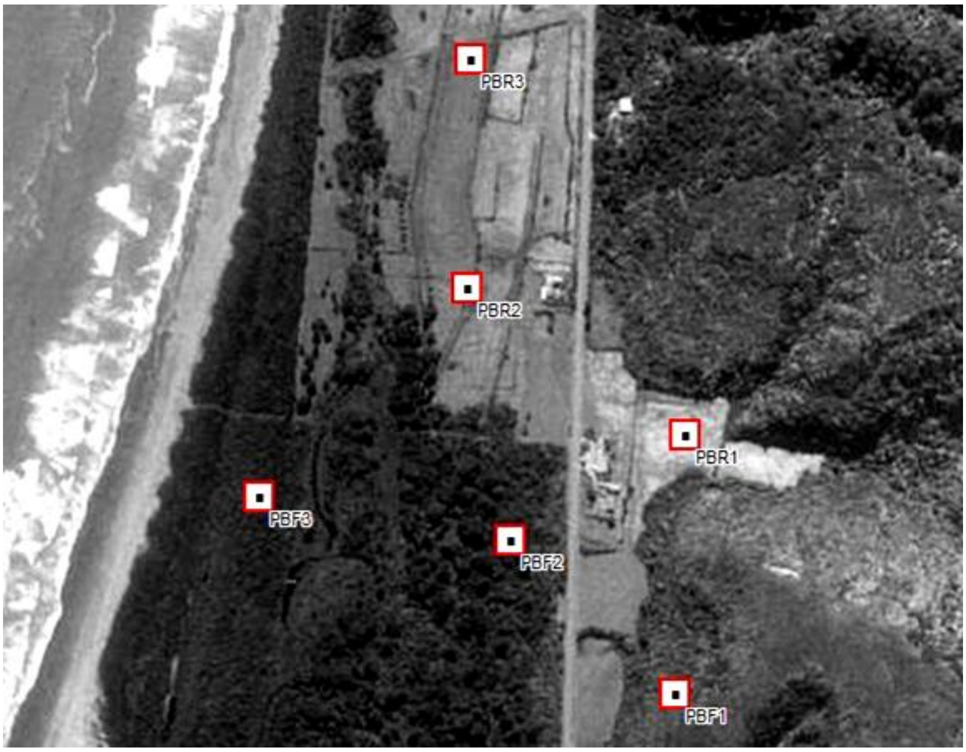
3.10 Freshwater fish

Two creeks were investigated at night with lights and nets. The first was above the Scotsman's Creek crossing east of the road (S42 08.768, E171 19.905) and the second was west of the road in a small pool near the second bridge within the restoration plantings (S42 08.534, E171 19.728).

3.11 Birds

Five minute bird counts (Dawson and Bull, 1975) were completed in three mature forest sites, and three "restored" sites (Figure 9). These sites do not correlate exactly with the four transects and 12 plots used to monitor invertebrates and lizards because they needed to be at least 250m apart. As well as the 5 minute bird counts, an extra 20 minutes of observations were made at each site to augment to the species list. The procedure was repeated at each of the 6 sites on 3 consecutive days, 4th, 5th, and 6th of January 2012. Data was analysed with ANOVA.

Figure 9: Bird observation sites (three forest and three restoration areas)



3.12 Bats

We searched for bats in the Nikau Scenic Reserve on a single night using a hand-held Batbox bat detector (Stag Electronics) which makes bats echo-location signals audible to humans.

3.13 Restoration plantings

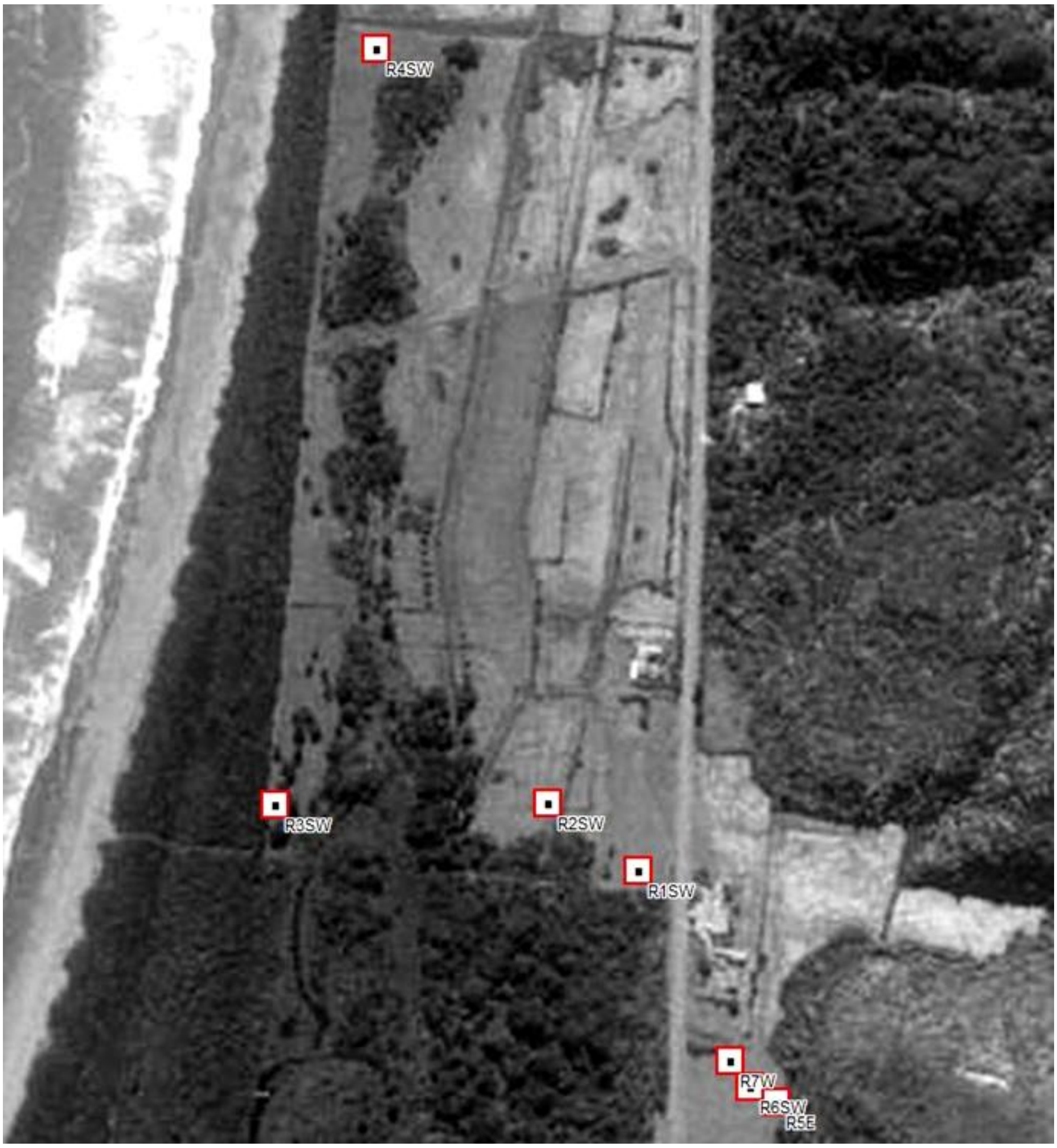
The methods used for monitoring of plants that are part of the restoration project were adapted from Kanowski and Catteral (2007).

10m x 10m monitoring plots were set out in each of the four restored plots of the design. R1, R2, R3, R4 (Figure 10). All live trees and shrubs were labelled with a nursery plant tag, identified for species and measured for height, maximum width, minimum width, basal diameter (using callipers). Dead trees were recorded and measured for height only. In future, when the trees are bigger DBH (Diameter at Breast Height) will be measured also. The maximum and minimum widths were used to calculate the area of an ellipse (Area = π x max radius x min radius; radius = width/2). This area is used as a measure of ground cover or canopy cover.

The four corners of each plot were marked with bamboo canes and orange flagging tape.
In the centre of each 10m x 10m plot a 1m x 1m plot was laid out and an assessment made of the ground cover – i.e. percentage of grass and herbs. Other categories of ground cover will be included in the future (e.g. bare ground, seedlings). These plots were not marked, so cannot be repeated in exactly the same place. Photos were taken of the 10m x 10m plots and of the 1m x 1m plots.

In the recently planted area on the inland side of the road, and South of the buildings, we set out a 50m transect with three 10m x 10m plots along it. The plants in the plots were measured as described above, and 1m x1m quadrats set out in the middle. In R5, R6, R7 the 1m x 1m plots were marked with a bamboo cane in the centre. The transect line was surveyed for woody debris.

Figure 10: Map of seven plant monitoring sites



3.14 Soil analysis

Sampling was carried out on 10-11th January 2012, with 19 samples collected as defined in Table 3. All samples were bulked samples of five 10cm depth (20 mm diameter) cores using a stainless steel corer. The five soil sampling points for these cores (x) were located in the centre of the 7 sampling points, each approximately 5m apart (. .x.x.x.x.x. .) [Note that the centre three points (x) were also sampled for earthworms].

Table 3: Description of soil sampling protocol used at the sites

Site code		Description
M1		Mature bush: Nikau Scenic Reserve (upper section)
M2[#]	Upper	Mature bush: Nikau Scenic Reserve (lower section)
	Middle	
	Lower	
M3		Rocky coastal mature bush
M4	1	Replicates taken in random places around the Mature remnant (each sample is a composite of 5)
	2	
	3	
	4	
	5	
R1		
R2	Upper	Samples taken in 3 parallel rows, with the additional rows located 1 m to the north and 1m to the south of the main sampling points.
	Middle	
	Lower	
R3		
R4		
U1		Unplanted grassland
U2		
U3		
U4		

3.15 Malaise traps

Two Malaise traps (Figure 11) were erected in existing forest to collect flying insects: one in the Nikau Reserve near the road, plot M1 was set on 29th Nov 2011; the other in the coastal strip near the sea – near, but not in plot M3 was set on 7th Dec 2011. Both malaise traps were dismantled and invertebrates collected on 12th Jan 2012.

Figure 11: Malaise trap in mature site (M1) near main road

4. RESULTS

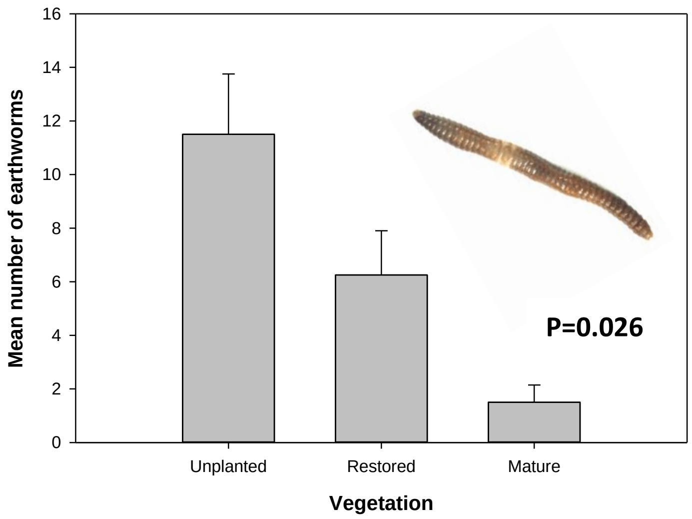
4.01 Pitfall traps

A giant orange springtail (Collembola) *Holacanthella ?paucispinosa* (on cover of report) was a significant find in conservation terms.

Earthworms

A mean of 11.5 earthworms were found in pitfall traps of unplanted sites, which dropped to 6.25 and 1.5 for restored and mature sites respectively (Figure 12). Earthworm abundance between the vegetation treatments was significantly different (P=0.026).

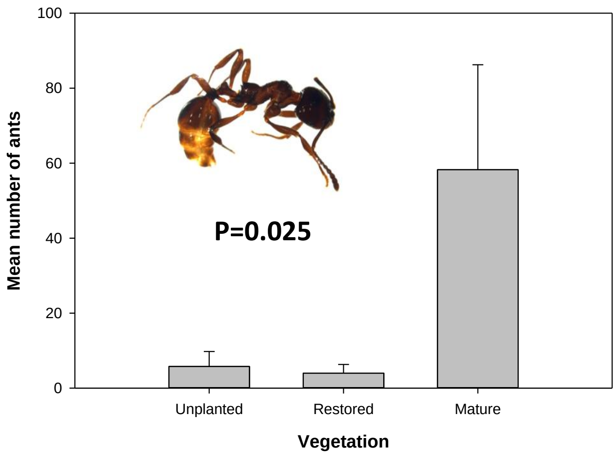
Figure 12: **E**arthworm numbers in pitfall traps of the three vegetation types (mean ± S.E.)



Ants

Several species of ants were found in pitfall traps but the mature sites had significantly more in the unplanted and restored sites (P=0.025)(Figure 13).

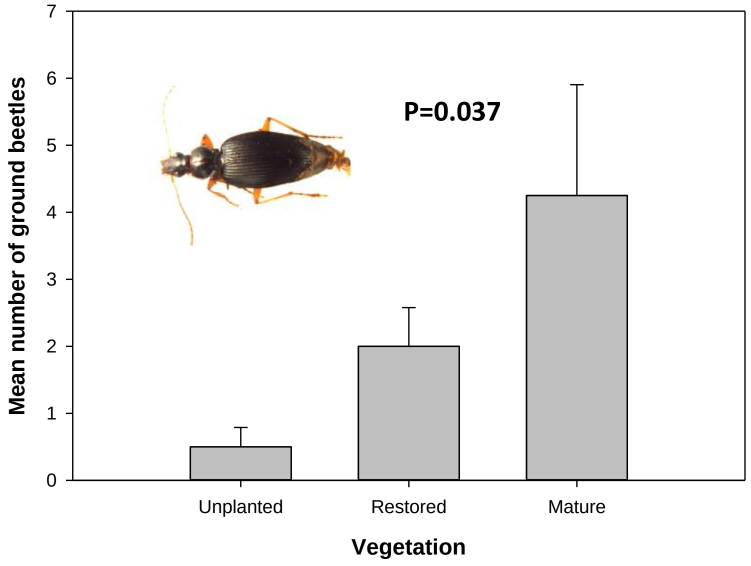
Figure 13: Ant numbers in the three vegetation types (mean ± S.E.)



Ground beetles (Carabidae)

At least five species of ground beetles were found with total numbers significantly different between vegetation treatments (P=0.037); increasing from a mean of 0.5/trap in unplanted sites to four in mature sites (Figure 14). One interesting species found was a minute ground beetle *Nesamblyops oreobius* which is thought to have a very narrow range of conditions it can survive.

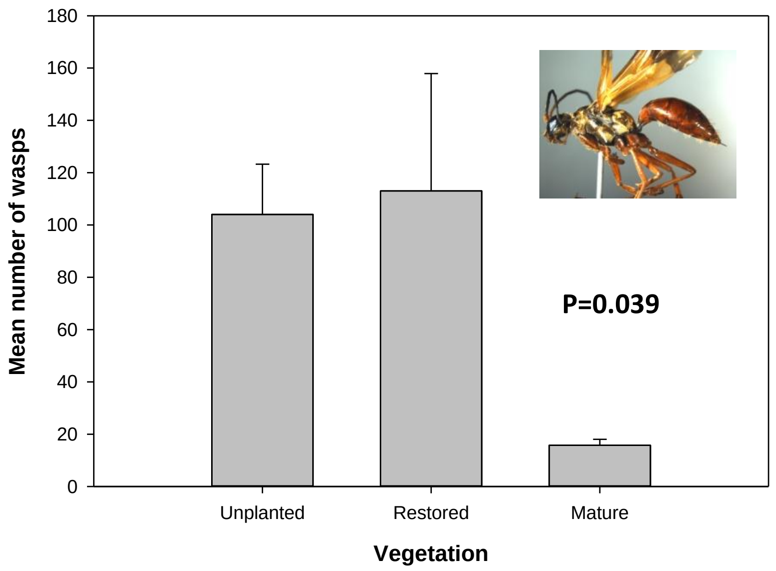
Figure 14: Ground beetle numbers in the three vegetation types (mean ± S.E.)



Wasps

Wasps were generally in large numbers (>100/trap) in unplanted and restored sites but a mean of only 15.75/trap in mature sites (Figure 15). The wasp numbers were significantly different between vegetation treatments (P=0.039).

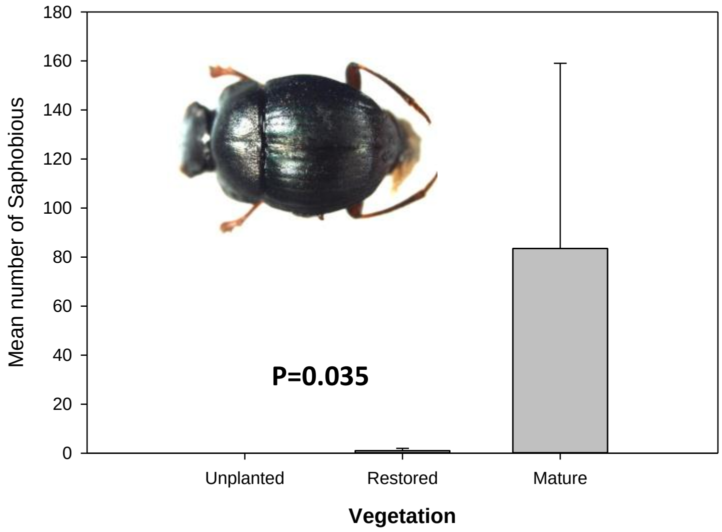
Figure 15: Wasp numbers in the three vegetation types (mean ± S.E.)



Dung beetle (*Saphobious* sp.)

A mean of 83.5 dung beetles/trap were found in mature vegetation compared to only a single specimen in the restored site and none in the unplanted (Figure 16). Although the standard error was high due to large numbers in site M4, the difference between the vegetation types was statistically significant (P=0.035).

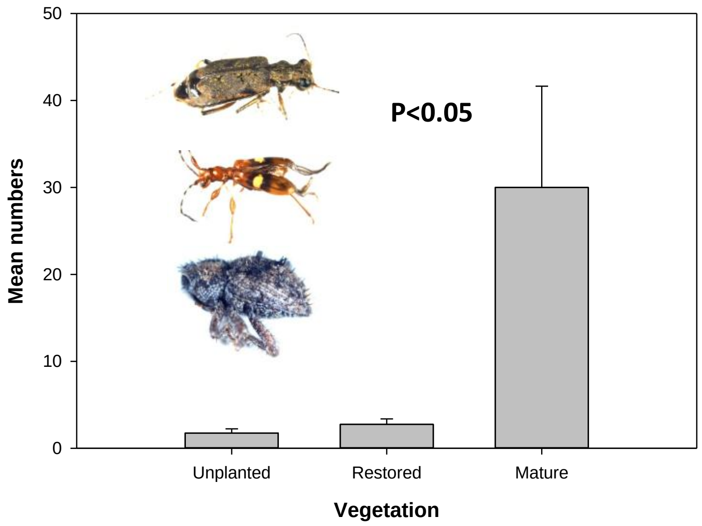
Figure 16: Dung beetle (*Saphobious* sp.) numbers in the three vegetation types (mean ± S.E.)



Other beetles

Beetles made up a high proportion of the diversity. Staphylinidae (rove beetles) were found in high numbers through all of the vegetation types and *Saphobious* dung beetles are shown above. Excluding these two taxa the mean beetle numbers in mature were significantly more abundant (P<0.05) than the numbers found in unplanted and restored vegetation.

Figure 17: Number of beetles (excluding Staphylinidae & *Saphobious* sp.) caught in pitfall traps in the three vegetation types (mean ± S.E.)



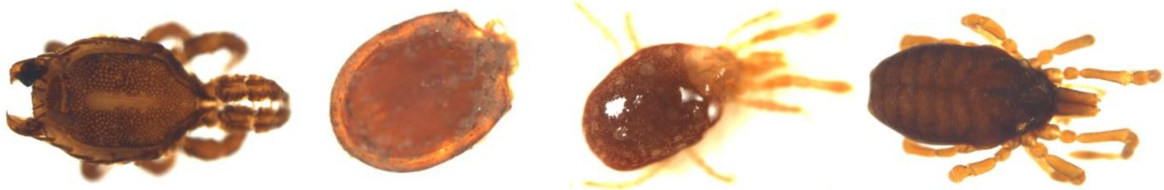
Snails

An exotic snail *Oxychilus* sp. as big a 10mm was found mainly in the restored and unplanted sites. Most of those found in the mature sites were native species.

4.02 Leaf litter invertebrates

Large differences were found between the three vegetation types for some taxa. Small native corn cob-like earthworms, ants, weevils, snails and centipedes were only found in litter of the mature sites. Large numbers and diversity of mites were found. Some of the larger mite species were only found in mature sites. A mite-like harvestmen *Aoraki denticulata* (Cyphophthalmi) was also found (Figure 18).

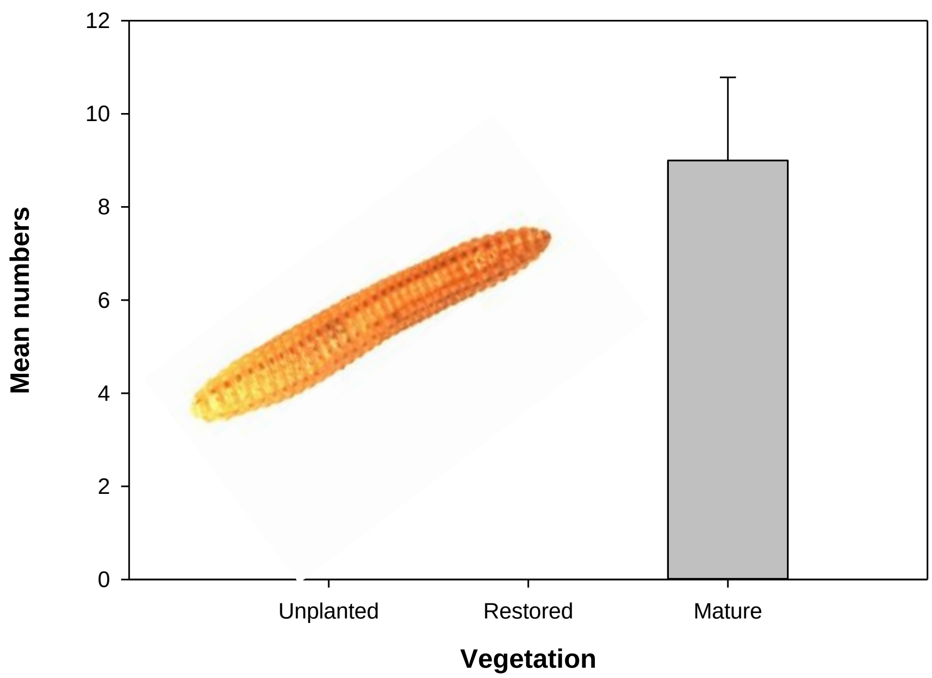
Figure 18: Three mite species and a mite-like harvestman (right) only found in mature leaf litter



Spotted earthworms

Small, native 'spotted' earthworms (resembling corn-cobs in texture) were only found in leaf litter of mature sites (Figure 19).

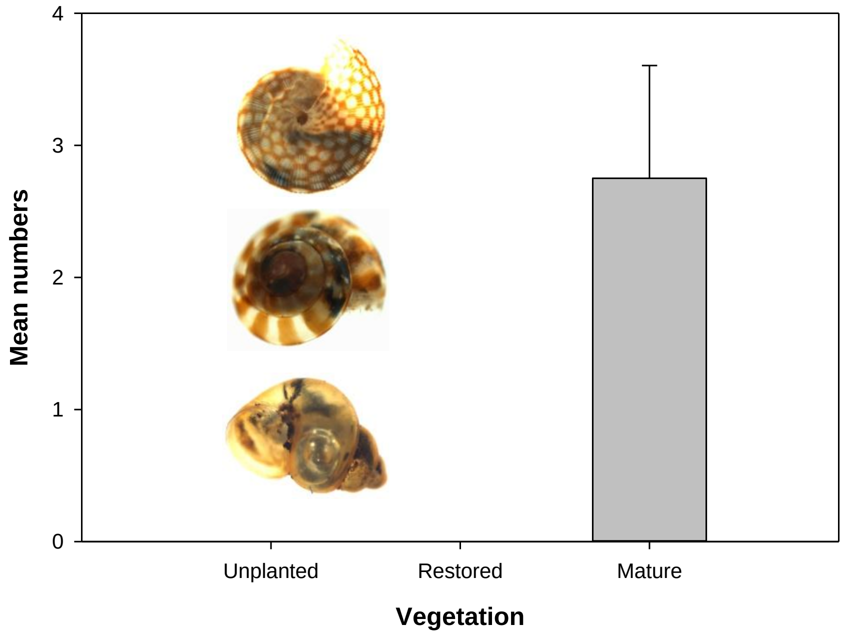
Figure 19: Numbers of 'spotted' earthworms in leaf litter of three vegetation types (mean ± S.E.)



Snails

Snails were only found in leaf litter from mature forest sites (Figure 20). All three snail species were small, native species - *Allodiscus punakaiki*, *Georissa purchasi* and *Phrixgnathus celia.*

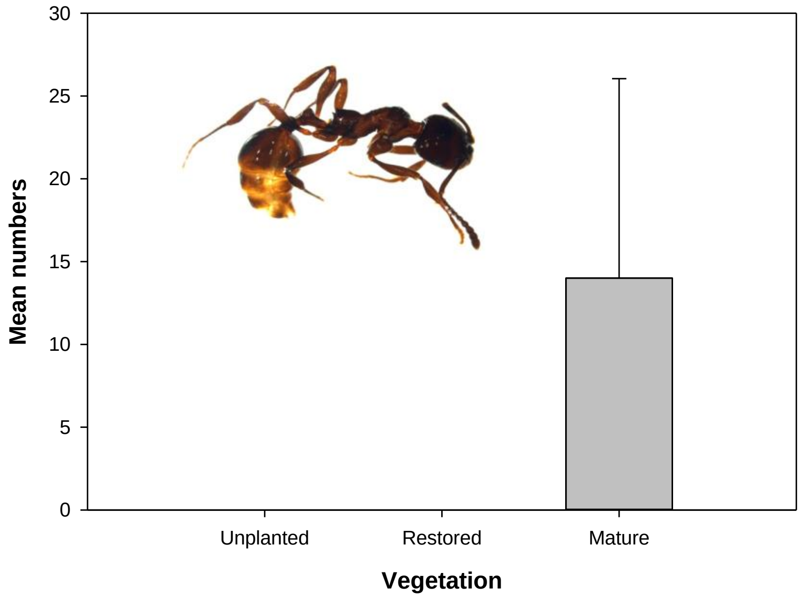
Figure 20: Snail numbers found in leaf litter at three vegetation types (mean ± S.E.)



Ants

Ants were only found in litter collected from mature sites (Figure 21).

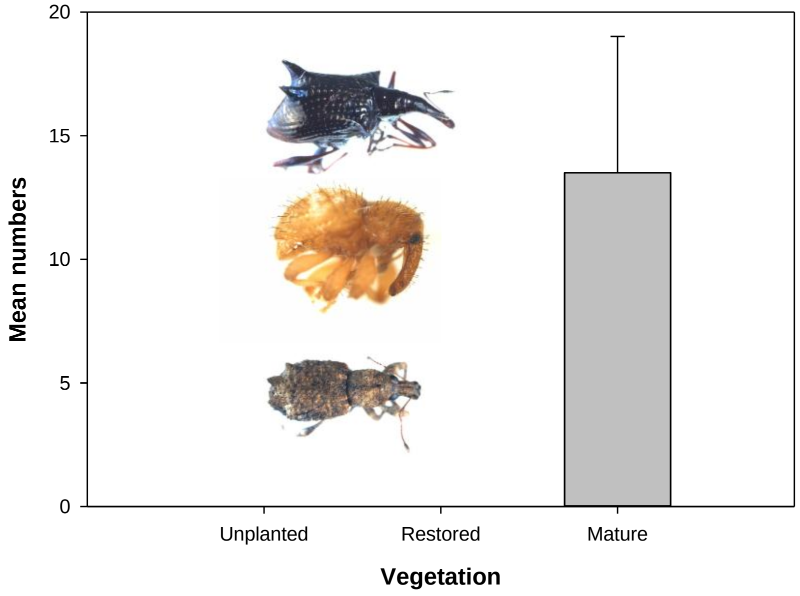
Figure 21: Ant numbers collected in leaf litter from three vegetation types (mean ± S.E.)



Weevils

Weevils were only found in leaf litter collected from mature sites at a mean of 13.5 per transect (Figure 22).

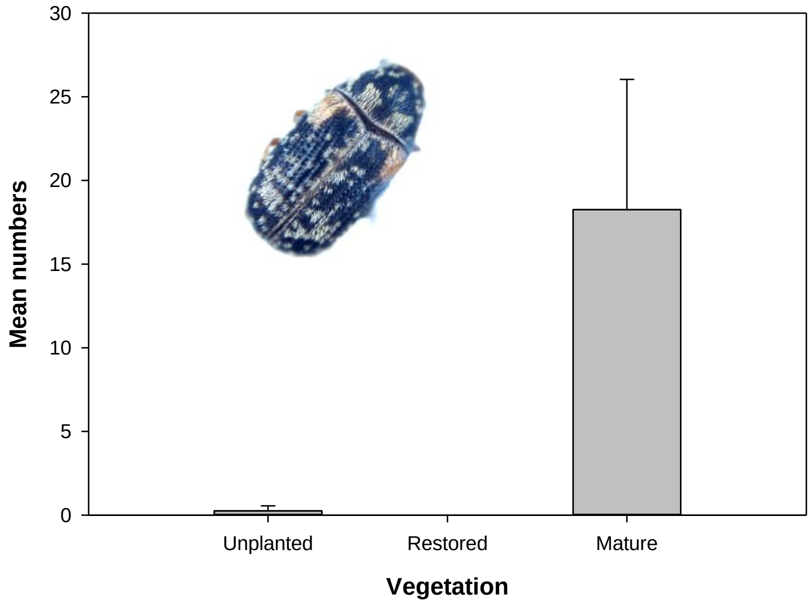
Figure 22: Weevil numbers in leaf litter in the three vegetation types (mean ± S.E.)



Beetles

Beetles (excluding Staphylinidae) were only found in the mature forest litter apart from a single specimen in the unplanted grass sites (Figure 23). Mature sites had a mean of 18.25 beetles per site.

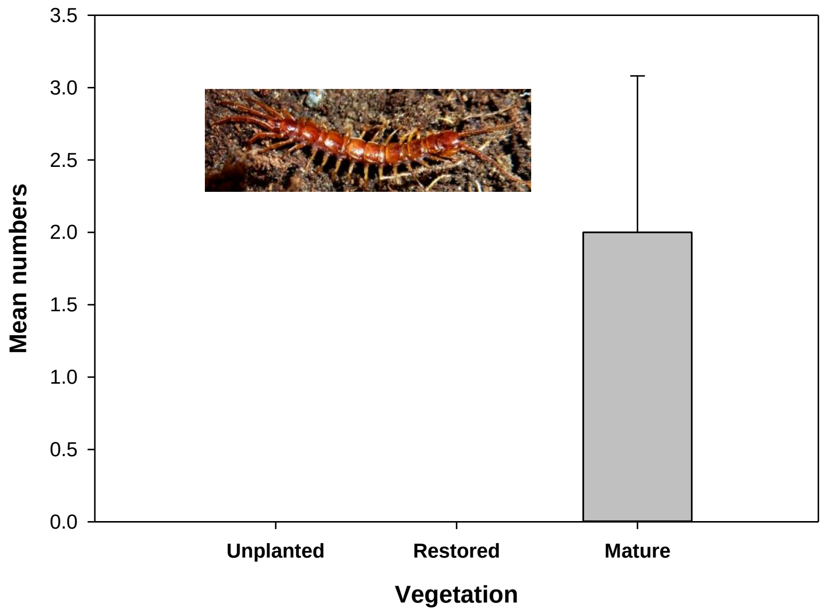
Figure 23: Beetle (excluding Staphylinidae) numbers in leaf litter at three vegetation types (mean ± S.E.)



Centipedes

Centipedes were only found in leaf litter collected from mature sites but in low numbers (Figure 24).

Figure 24: Centipede numbers in leaf litter from three vegetation types (mean ± S.E.)



4.03 Foam wraps

No lizards were present in the Foam Wraps but a variety of invertebrates were found at all sites. Cockroaches were the most consistent taxa found with Site 3 (the coastal forest), containing the most (Table 4).

Table 4: Fauna found in four Foam Wraps at each of the four mature sites

	Mature 1	Mature 2	Mature 3	Mature 4
Lizards				
Leaf-vein slugs	1			
Slaters	6			140
Amphipods				1
Millipedes	1	3		2
Centipedes	2	1		
Tree weta				
Cave weta			3	
Cockroach	1	2	27	8
Ants				10
Spiders	3	2	3	1

4.04 Lizard lodges

A variety of invertebrates were found in the lizard lodges but there were no statistically significant differences between mature, restored and unplanted sites (Table 5). No lizards were found. Slaters were most common in the mature forest sites. Slugs (exotic) were most common in the unplanted sites, and absent from the mature forest sites. Cave weta and harvestman were only found in mature sites.

Table 5: Invertebrates found in 24 Lizard Lodges at three vegetation types

	Mature	Restored	Unplanted
Cave weta	2		
Cockroach	2	4	
Spider	6	4	4
Harvestman	2		
Millipede	6		2
Amphipod	2	4	
Slater	62	4	6
Slug		10	24
Worm		2	

4.05 Weta motels

Weta motels contained a variety of invertebrates including immature Wellington tree weta (*Hemideina crassidens*), cave weta (*Talitropsis sedilli*) and a ground weta (Table 6). There was no statistically significant difference between mature, restored and unplanted sites.

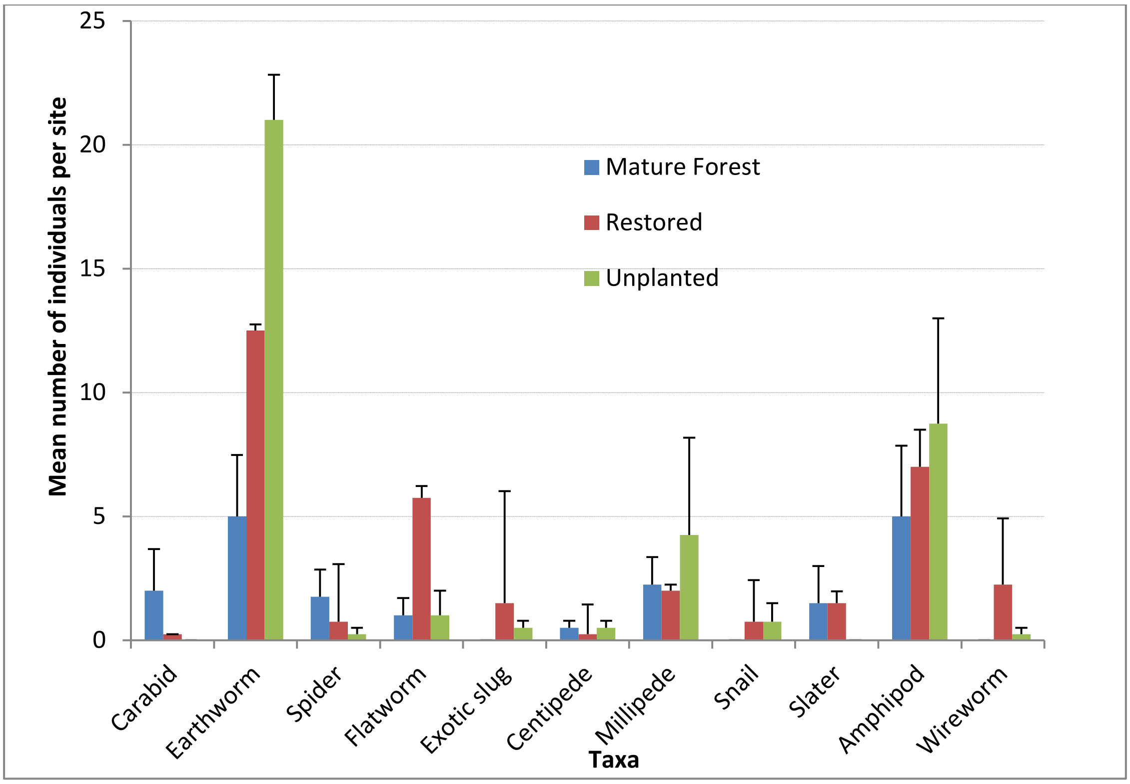
Table 6: Invertebrates found in 36 weta motels placed in three vegetation types

	Mature	Restored	Unplanted
Tree weta		2	
Cave weta	2		
Ground weta		2	
Cockroach	1		
Spiders	4	3	2
Moths	1		
Slaters		1	

4.06 Wooden discs

A variety of invertebrates were found under the wooden discs, but most of the results show little difference between the mature, restored, and unplanted sites (Figure 25). The exceptions were earthworms and carabid beetles. An average of 21.0 worms were found in each unplanted site compared with 12.5 in the restored sites and 5 in the mature forest sites. An average of 2.0 carabid beetles were found in each mature site compared with 0.25 in the restored sites and none in the unplanted sites.

Figure 25: Mean invertebrate numbers found under four wooden discs in the three vegetation types (standard error bars above)



4.07 Earthworm sampling

There was significantly less earthworms (mean total worm abundance) in the mature sites than in both restored (P=0.019) and unplanted sites (P=0.017) (Figure 26A). These differences are mainly due to exotic earthworms which were more abundant in unplanted and restored sites compared to mature sites (P=0.007 and P=0.021). Differences between restored and unplanted sites were not significant. Similar trends were observed for total biomass and biomass of exotic earthworms although these were not significant (Figure 26B).

The proportion of endemic versus exotic earthworms varied with the treatment both for abundance (P=0.031) and biomass (P=0.001). There was significantly higher proportions of endemics in mature sites than in restored (abundance: P=0.001, biomass: P=0.004) and unplanted sites (abundance: P=0.016, biomass: P=0.016) (Figure 27). Although the proportion of endemics in restored sites was intermediate, differences between restored and unplanted sites were not significant (Figure 27).

Figure 26: Mean earthworm abundance (A) and biomass (B) in the three vegetation types

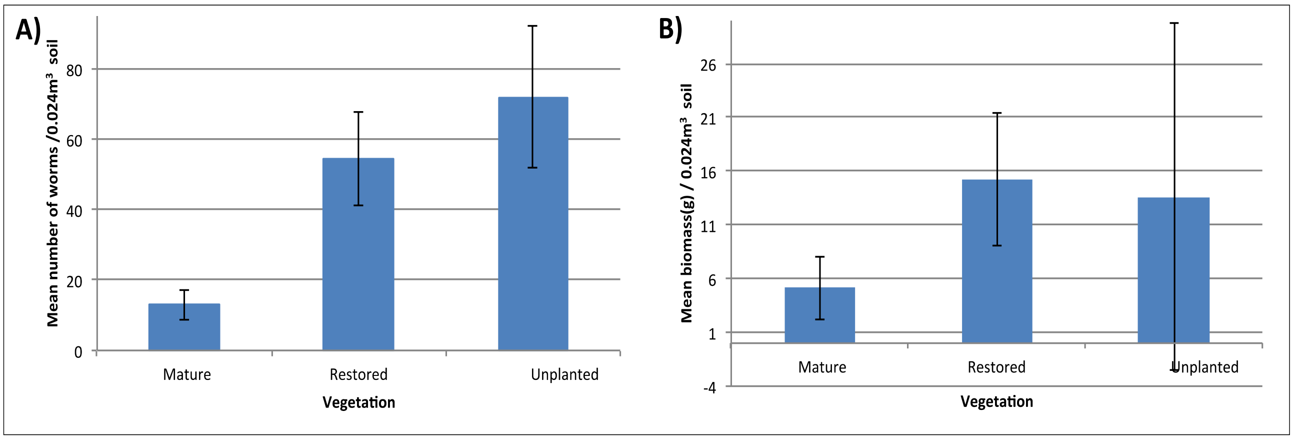
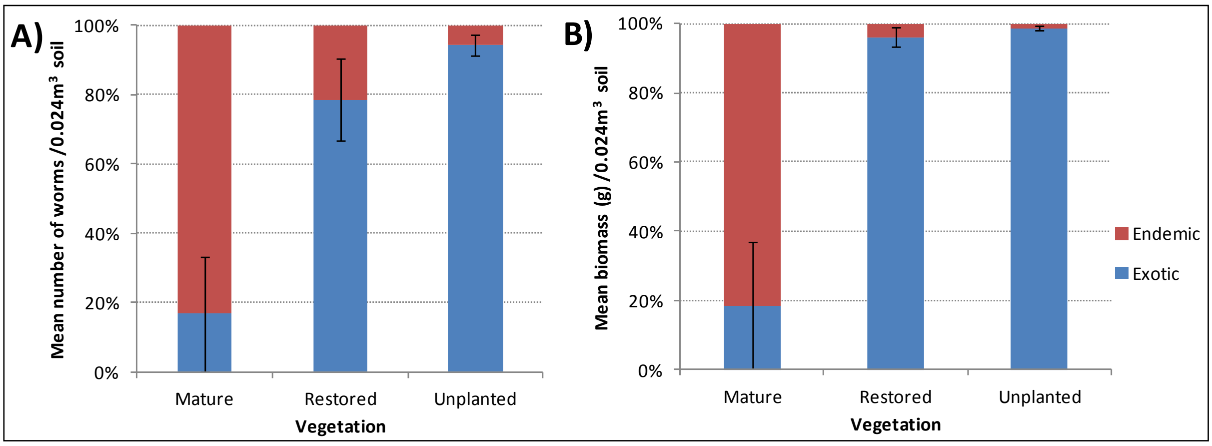


Figure 27: Proportion of endemic and exotic earthworm abundance (A) and biomass (B) in the three vegetation types



4.08 Moths

Completely different moth communities were collected from restored sites (R1 and R3) and mature sites (M1 and M3) over two nights trapping (Table 7).

Table 7: Moths caught in light traps in two restored and two mature sites

Moth species	Host species/Habitat	Sites sampled			
		R1	M1	R3	M3
Bactra noteraula	*Cyperus* & *Desmoschoenus* species			2	
Chloroclystis inductata	Flowers			1	
Cydia succedana	Gorse			12	
Epiphyas postvittana	Polyphagous			1	
Eudonia leptalea	Lichen, mosses			1	
Eudonia melanaegis	Lichen, mosses			1	
Eudonia minualis	Mosses	1			
Eudonia submarginalis	Grassland	1		5	
Orocrambus flexuosellus	Grassland	1			
Platyptilia repletis	?	1		2	
Udea flavidalis	Polyphagous on herbs	1			
Wiseana copularis	Grassland			1	
Wiseana umbraculata	Grassland			1	
Gellonia dejectaria	Polyphagous on trees and lianes				1
Leptocroca sp.	?				2
Oecophorid sp.	?				1
Opogona omoscopa	Decaying vegetation (exotic species)		1		
Schrankia costaestrigalis	Herbaceous and woody plants				1
Tingena sp.	Leaf litter				1
Xanthorhoe occulta	Leaves				1

<u>Flatworms</u>

Three species of flatworm were found by lifting logs and debris but have not been identified (Figure 28).

Figure 28: Three unidentified species of flatworms found

4.09 Aquatic Invertebrates

The number of species found at each site was very similar, although the total numbers caught was far greater in the 2nd Bridge sites in the restored area (Table 8). This is due to the large numbers of snails and ostracods collected in the samples. These sites were sandy-bottomed and aquatic weed infested which supported these taxa. However snails and ostracods have a low MCI score (4 and 3 respectively). The % EPT reflects this with considerably higher values with a mean of 40% for Scotsmans Creek (upper site), 47% for Nikau Reserve (below bridge) and 22% in restoration plant site (2nd Bridge).

Table 8: Aquatic Invertebrates collected from three locations

Species or family	Order	MCI[1] score	Scots Creek # 1	Scots Creek #2	Nikau Res. #1	Nikau Res. #2	2nd Bridge #1	2nd Bridge #2
Deleatidium	Ephemeroptera	8	20	15	11	16		
Coloburiscus	Ephemeroptera	9	8	1	2	1	1	
Archichauliodes	Megaloptera	7	1	1	1	2		
Austrosimulium	Diptera	3	1		1	2	1	
Culicidae	Diptera	3	1					
Paradixa	Diptera	4	1	1	2	2		3
Hemiptera	Hemiptera	5	3	2				
Hydraenidae	Coleoptera	5		1				
Olinga	Trichoptera	9		1	3	3		
Costachorema	Trichoptera	7		3	1	1		1
Oligochate worm		1			1	1		
Coleoptera (?)		5?			1			
Very small stony-cased caddis	Trichoptera	?						1
Unknown pupa 1		?					1	
Unknown pupa 2		?					1	
Potamopyrgus	Mollusca	4					106	146
Austrolestes	Odonata	6					3	6
Amphipod		5						3
Ostracod		3					200	50
Total individuals			**35**	**25**	**23**	**28**	**313**	**210**
Species richness			**7**	**8**	**9**	**8**	**7**	**7**
% EPT taxa[2]			**29%**	**50%**	**44%**	**50%**	**14%**	**29%**

[1]The Macroinvertebrate Community Index (Stark, 1993; Stark, 1998) scores aquatic invertebrates based on their tolerance to water quality. The most sensitive taxa are given an index of 10 and taxa that can survive in the poorest quality water are given an index of 1.

[2] The taxa Emphemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are very sensitive to pollution and are expressed as a percentage of the total fauna to gives a measure of water quality. The higher the percentage, the better the water quality.

4.10 Freshwater fish

In the restored area at the second bridge we saw between 20 to 30 *Galaxias maculatus* (Figure 29) and an unidentified eel, either a longfin (*Anguilla dieffenbachii*) or shortfin (*A. australis*) (Figure 30a). In Scotsmans Creek at the crossing we caught a red-fin bully (*Gobiomorphus huttoni*) (Figure 30b).

Figure 29: Inanga (*Galaxias maculatus*)

Figure 30: (a) Eel (b) Red-fin bully

4.11 Birds

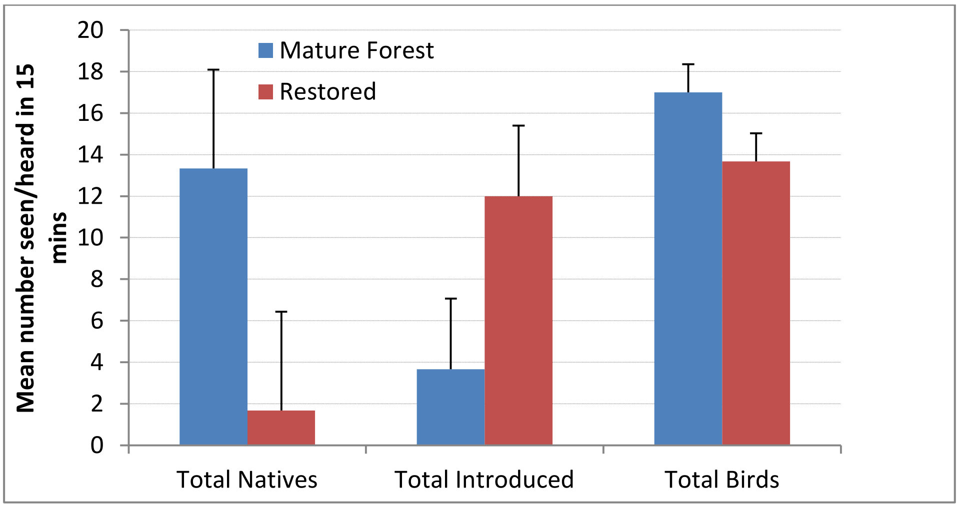
Bird species observed are listed in Table 9. Birds were 24% more numerous in the mature forest than in the restored areas. There were 8 times as many native birds in the mature forest than in the restored areas, and conversely, 3 times as many introduced birds in the restored areas compared with the mature forest sites (Figure 31). Differences between the mature and restored sites were statistically significant for both native (P=0.012) and introduced (P=0.023) birds (Figure 31).

Table 9: Bird species observed during and outside of five minute bird counts

	Mature sites	Restored sites
<u>Native</u>		
Bellbird	✓	
Fantail	✓	
Grey Warbler	✓	
Kereru		✓
Shining Cuckoo	✓	
Silvereye	✓	✓
Spur-winged Plover	✓	
Tui	✓	
Weka	✓	
Red-billed Gull		✓
<u>Introduced</u>		
Blackbird	✓	
Chaffinch	✓	✓
Goldfinch		✓
Redpoll		✓
Skylark	✓	✓

Other birds observed outside of the 5 minute bird count include: Australian harrier hawk, Black-backed Gull, Brown Creeper, Caspian Tern, Morepork, Pukeko, domestic geese and shag

Figure 31: Comparison of birds recorded in five minute bird counts at mature and restored sites



4.12 Bats

No bats were detected from the limited survey.

4.13 Restoration plantings

Using the maximum width and minimum width measurements to calculate the area of an ellipse to estimate canopy cover was not very meaningful for very small recently planted trees, but it will be a more useful indicator as they develop. Site R1 has the largest canopy area (Figure 32) and the largest canopy area per plant (Figure 33). The relatively large canopy area in R5 is the result of dense planting.

Figure 32: Canopy area in seven 10m x 10m plant plots

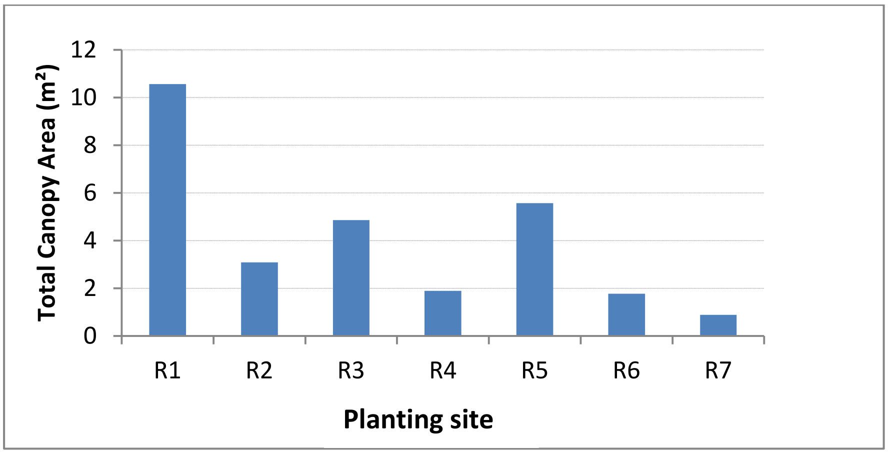
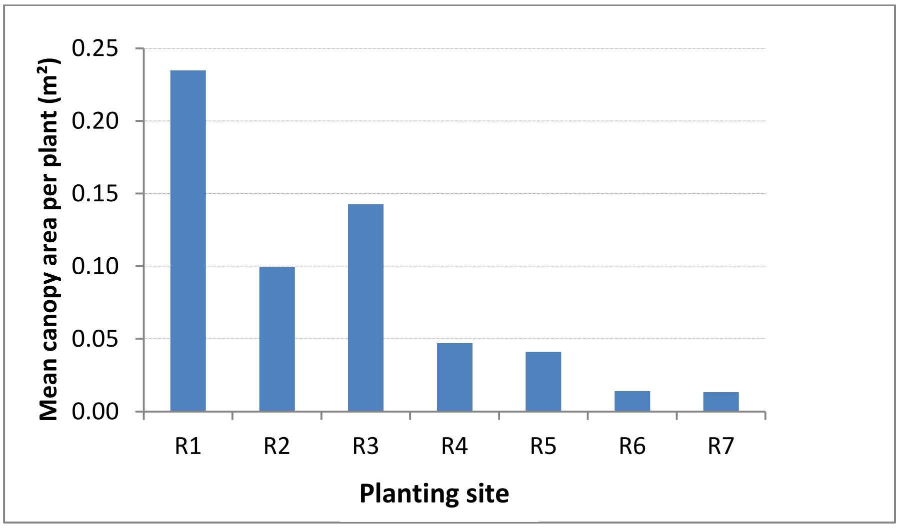


Figure 33: Canopy area per individual plant in seven 10m x 10m plots



4.14 Soil analysis

The mature forest stands combined had significantly more organic carbon (but also more nitrogen) that is reflected in higher C/N ratios (Table 10). There appears to be decreased acidity (nearing a full pH unit, or 10 x lower H^+ ion concentration) in the unplanted grassland, restoration plots and disturbed mature bush. The high C/N ratio apparent in the mature forest is functionally significant; it would indicate low rates of decomposition and slow release of mobile N. Median concentration of N in typical NZ pasture soils are about 0.5%. Variability of soil nitrogen did not vary substantially from this, nor between the different vegetation types (Figure 34). Plot M3 was close to the shore and contained a high proportion of gravel extracted prior to the analysis which may have elevated N in the analysis. Carbon concentrations were higher in the mature forest soils (Figure 35), and above a mean value of 6.25%C recorded in pasture soils across NZ.

Table 10: Organic matter, major nutrients and pH of soils with differing vegetation and management history.

SITES	LOI%	%C	%N	C/N Ratio	Total P (mg kg^{-1})	Total K (mg kg^{-1})	pH
Mature stands (M1-M4)	18.96	9.79	0.618	16.2	871.4	1,864	4.80
Nikau Scenic Reserve (M1 & M2)	13.04	6.98	0.394	17.7	333.8	658	4.19
Restoration Plantings (R1-R4)	12.72	6.66	0.570	11.7	833.0	1,226	5.01
Unplanted grassland (U1-U4)	10.06	4.64	0.401	11.4	735.4	989	4.89

Figure 34: Comparison of soil nitrogen in the different types of mature forest plots, restoration plots and unplanted grassland

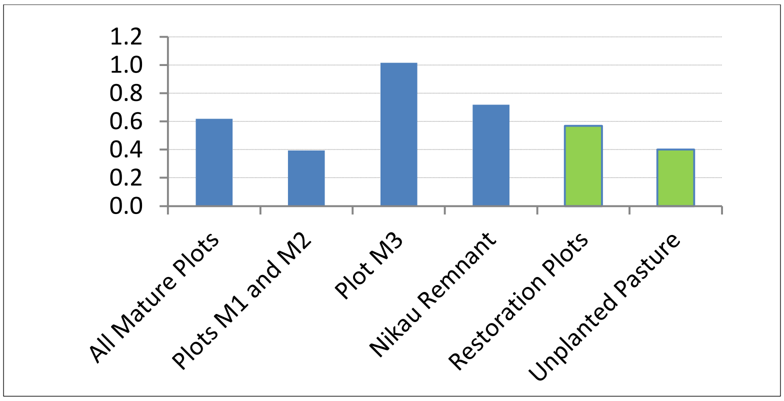
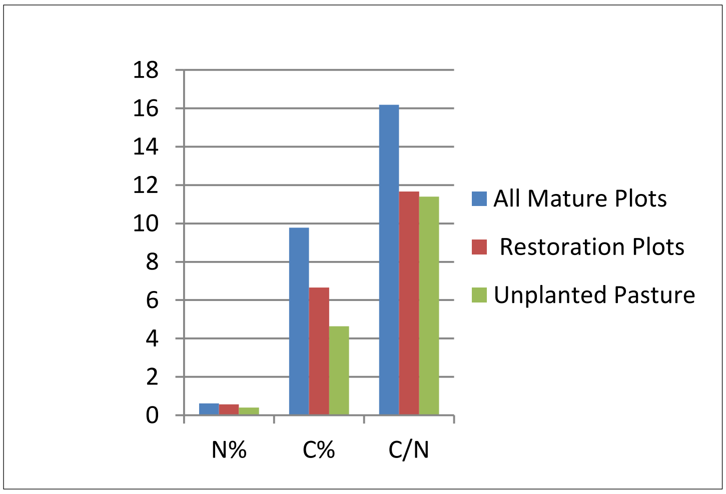


Figure 35: Comparison of mean values of carbon, nitrogen and C:N ratios under the three types of vegetation



There was little variability between the replicates samples in the upper part of the Nikau Scenic Reserve (Figure 36) and different parts of the mature remnant forest stand (Figure 37), providing some confidence about the reliability of the limited amount of data collected in this study. Soil concentrations of phosphorus were significantly lower in the Nikau Scenic Reserve (Figure 38).

Figure 36: Replicated samples in Nikau Scenic Reserve mature forest (M2) in three parallel sampling rows, 1 m apart

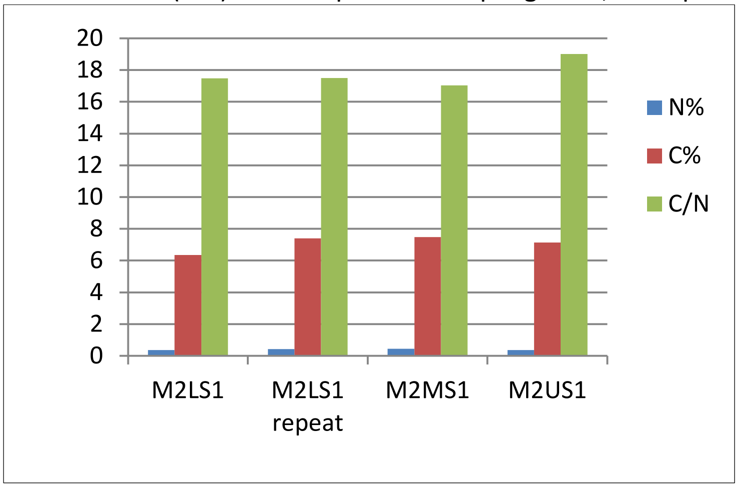


Figure 37: Carbon and nitrogen at five sampling sites within the mature remnant stand (M4)

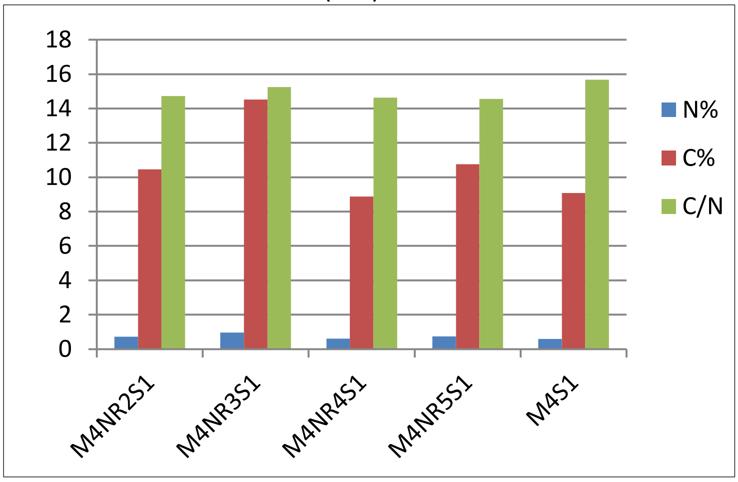
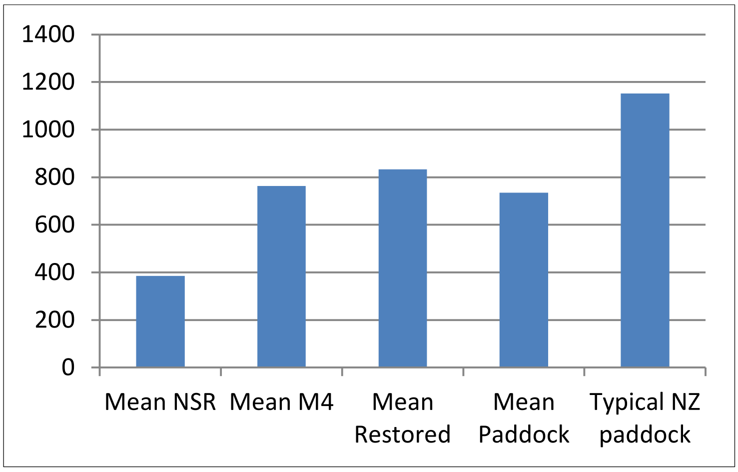


Figure 38: Total phosphorus (mg/kg) in the Nikau Scenic Reserve (NSR) soils compared with other sampling sites and typical values for New Zealand paddocks



Trace element profiles (Table 11) show that the reserve has lower Fe, Mg , Ni and S. Lower concentrations of Al and S coupled with similar Ca concentrations appear to contradict the fact that pH is lower in the reserve soils. Median and mean boron concentration in New Zealand pasture soils have been recorded as 4.5 and 5.2 mg kg^{-1} respectively; thus, B deficiency seems likely, except in the remnant and near-coast mature stand soils (Figure 40). Soil concentration of zinc (Zn) in the mature forest stands appeared significantly higher than the normal range of about 65 mg kg^{-1} reported for New Zealand soils, but this was largely due to a high value in the stony sampling area closest to the shoreline (Figure 41). Low lithium in the reserve soils, alongside a NZ pasture mean of 23.5 mg kg^{-1}, is an interesting and unusual feature but may be an anomaly with such a small sample size. Lower Fe, K, Mg, Ni and S in the Nikau Reserve soils is identified in the analysis and this is deserving of further study in the context of the desirable restoration.

Table 11: Trace element profiles of soils at Punakaiki, highlighting potentially significant variables that separate the habitats

Sites	Al	As	B	Ca	Cr	Cu	Fe	K
Mature Stands Combined	17,135 ± 5,419	4.8 ±1.53	9.0 ±2.83	6,201 ±1,961	28.1 ±8.90	6.9 ±2.18	16,804 ±5314	1,864 ±590
Nikau Scenic Reserve	7,898 ±621	1.9 ±0.24	2.3 ±0.3	5,224 ±410	20.3 ±2.36	1.5 ±0.27	8,921 ±665	658 ±86.9
Restoration Planting	13,110 ±1,694	3.2 ± 0.4	4.2 ± 1.1	6,617 ± 679	23.4 ± 1.4	4.5 ± 1.2	16,404 ± 909	1,226 ± 253
Unplanted Paddock	12,333 ± 728	2.9 ± 0.1	2.8 ± 0.5	7,293 ± 494	29.3 ± 3.7	3.4 ± 0.9	15,212 ± 1,037	989 ± 187
NZ Pasture Soil MEANS	26,970	5.9	5.2	6,922	40.0	16.6	26,410	3,680

Sites	Li	Mg	Mn	Na	Ni	Pb	S	Zn
Mature Stands Combined	23.1 ±7.32	1,224 ±387.0	802 ±253.5	298 ±94.3	10.9 ±3.44	13.1 ±4.14	693 ±219.3	114.4 ±36.16
Nikau Scenic Reserve	3.2 ±0.24	648 ±41.0	1,024 ±75.6	74.9 ±7.84	0.92 ±0.09	8.3 ±0.39	373 ±52.8	49.1 ±1.69
Restoration Planting	15.3 ± 3.5	1347 ± 110	986 ± 144	93.8 ± 27.1	6.2 ± 1.7	12.9 ± 1.5	612 ± 207	62.8 ± 11.6
Unplanted Paddock	13.6 ± 1.3	1,283 ± 87.5	1,017 ± 94.2	79.7 ± 20.2	5.4 ± 0.6	11.8 ± 1.6	508 ± 188	65.6 ± 8.3
NZ Pasture Soil MEANS	23.4	1,496	444	270	22.3	12.2	635	65.0

Figure 39: Total phosphorus (mg/kg) in the Nikau Scenic Reserve (NSR) soils compared with other sampling sites and typical values for NZ paddocks

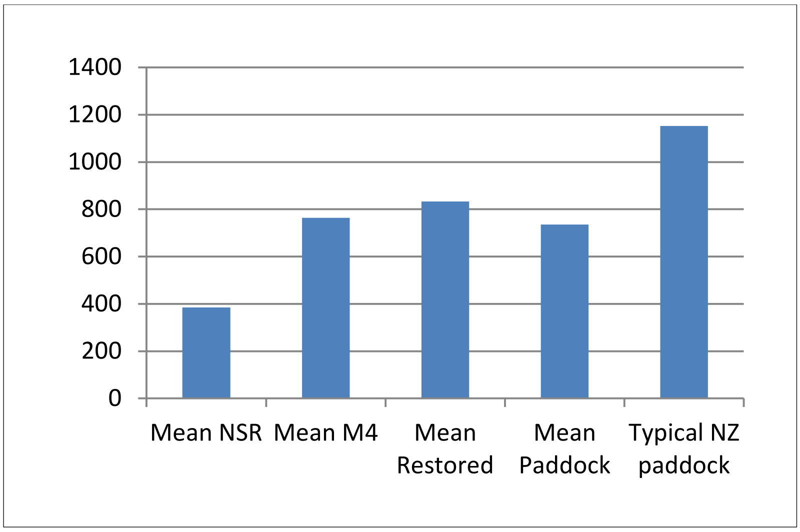


Figure 40: Boron (mg/kg) in the mature forest soils
(standard errors shown for the replicated sampling plots)

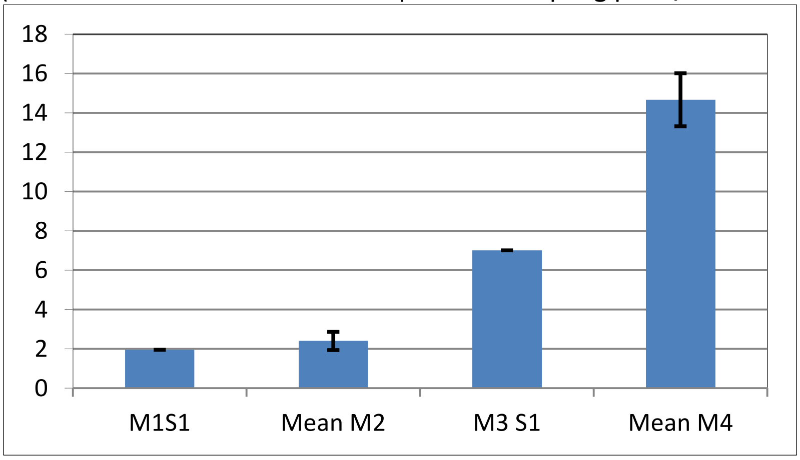
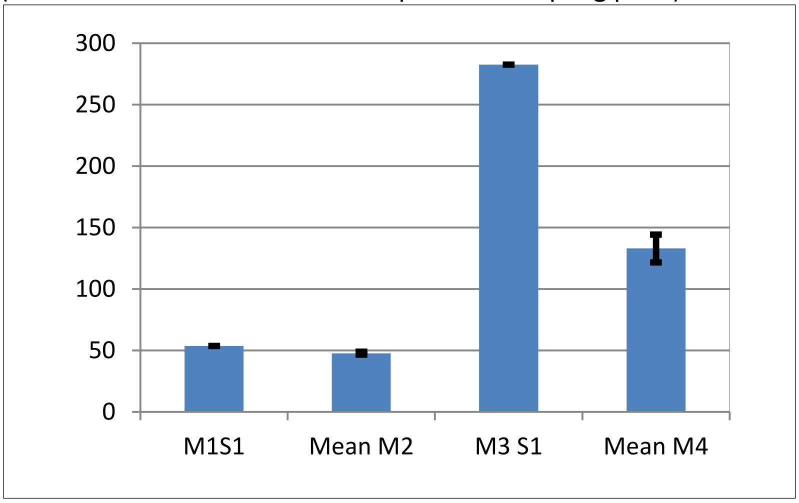


Figure 41: Zinc (mg/kg) in the mature forest soils
(standard errors shown for the replicated sampling plots)



5. DISCUSSION

This survey aimed to provide a broad and relatively brief ecological evaluation of the site rather than a detailed study. Our focus was to identify points of interest that could be explored further. In particular we were keen to work with Rio Tinto to begin identifying key biodiversity features of the site that may provide reliable indicators of a successful restoration.

The main part of this survey was executed in a design with three “treatments”, a gradient ranging from grassland, recent restoration plantings, to mature forest. Four replicates were used so results could be statistically analysed to show differences between the “treatments”. Other parts of the data were collected outside of this design, to provide a fuller picture of what is actually present in the various habitats. Much of the data collected will be more informative when the monitoring is repeated and the results compared over time.

Transects

We had low expectations of being able to identify differences between restored and unplanted sites, as these are both predominantly grassland habitats, but we did expect to see differences with the mature forest stands in the Nikau Scenic Reserve and remnant stands of more mature vegetation at the site.

The invertebrate monitoring devices we installed have been left in place for future use: i.e. weta motels, lizard lodges, wooden discs, foam wraps. We observed and recorded data from these devices only six weeks after installing them which is not optimal. They are likely to provide more useful data after longer time periods. For example tree weta and lizards, if present, may take four months or more to find and inhabit the artificial refuges we have provided for them. No lizards were found on previous surveys (Don, 1986) however we would expect there to be some common skinks present although in low numbers given the presence of weka.

Invertebrates from pitfall traps

There were 84 pitfall traps and this is the most thorough data set collected. They were set for the standard four weeks over the middle of summer which is ideal for invertebrates. We trialled the use of Marley plastic downpipe joining sockets (RS80) for lining the pitfall holes as we were concerned that the usual metal liners would rust quickly in the sea air. Some of them had lifted a little above the ground level, which could reduce the efficiency of the trap. This may have been the result of using a foot to push the tube down the last cm or so, suggesting it is important to dig all the holes to the entire depth required with the soil corer and don’t force the tube into the soil at all. Also some of the plastic cups had been pushed up and did not sink down again. This would also have disrupted the trapping function. We imagine the cups were pushed up by ground water in wet periods, and the lip inside the plastic tube prevented it slipping down again. A tube with the lip inside removed would be preferable. The pitfall trap roofs and tubes have been left in the ground and can easily be reset again at any time for future monitoring. Regardless of minor problems we collected a lot of interesting specimens and many taxa showed interesting trends. The giant springtail *Holacanthella ?paucispinosa* was a significant find given this genus of springtail is highly sensitive to human disturbance and their rigid habitat requirements makes the protection of their habitat paramount

Steans et al. (2007). It has previously been suggested by Steans et al. (2007) that this springtail genus could be used as an indicator for measuring forest health in forest restoration programmes.

Ants, ground beetles and a dung beetle (*Saphobious* sp.) were taxa which increased in numbers from unplanted to mature. Perhaps the most interesting results were the dung beetles which are found in mature sites at a mean of over 80 (Figure 16). Only four specimens were found outside of the mature sites (in restoration site 3A). The Mature Site 4 had the largest numbers which was interesting given it has only been closed from cattle grazing within the last few years (unlike the other mature sites). Whether remnant cow dung or the site's higher soil moisture affected the *Saphobious* numbers is hard to know at present with only one year's sampling.

Ground beetle numbers in the pitfall traps were higher in mature sites than in other vegetation types. This was mirrored by ground beetles under wooden discs which supports the trend and indicates these beetles is worth further study. Reay and Norton (1999) have used ground beetles to assess restoration success in the Port Hills of Christchurch. They found beetle richness increased from grassland to mature forest.

Ants have also been used as indicators of successful restoration of mine sites in Australia (Anderson et al. 2003). Australian ant communities have been implicated in bush regeneration through seed dispersal (Grimbacher and Hughes, 2002), however the ants in New Zealand are not as diverse and may not have the same ecological functions and interactions as the Australian species. Further research is needed to determine what species are present at Punakaiki and their ecological roles.

Earthworm numbers (Figure 12) and wasps (Figure 15) are two taxa that showed a downward trend in numbers from unplanted to mature sites in pitfall traps. Earthworm numbers under wooden discs (Figure 25) and earthworm digs (Figure 26A) both had similar downward trends, indicating earthworms are a reliable measure of changes. The worms under discs were not identified as endemic or exotic, however the worms dug from hole does identify endemic and exotic worms and shows that the high numbers of worms in the restored and unplanted sites are predominantly exotic, which strongly suggests that this would be the case for the worms found under the wooden discs also.

The proportion of endemic earthworms was very high in mature sites, intermediate in restored sites and very low in unplanted sites. Only a few years after restoration, the proportion of endemic earthworms seems to have increased already compared to unplanted sites, which could indicate a rapid response of earthworms to restoration efforts. The proportion endemic earthworms could be an early indicator of restoration success.

Centipedes under wooden discs (Figure 24) did not support the pitfall results trend and the numbers were too low to be a reliable indicator.

Invertebrates from leaf litter

Many of the leaf litter invertebrates gave the most significant differences between the mature sites and restored and unplanted sites. Spotted earthworms, snails, ants, weevils and beetles (excluding Staphylinidae) were the taxa worthy of future research. Mites also appear greater diversity in mature sites and may warrant further analysis. Some weevils would have been expected in the grassland as pasture pest species like white-fringed weevils, *Sitona* weevils and Argentine stem weevils are often commonly found. More data is needed to confirm these results.

Soil analysis

Conversion of the original forest to pasture led to significantly reduced soil acidity, halved soil carbon concentrations and a doubling of soil phosphorus. Lower Fe, K, Mg, Ni and S in the Nikau Reserve soils is identified in the analysis and, together with Zn and B, concentrations of some of these elements may be critical features of a successful restoration.

Malaise traps

Malaise traps were set in only two of the mature sites but collected a large number of invertebrate species yet to be identified. Malaise traps catch a large number of flying insects including beetles, flies and wasps which takes more time to identify than we had available. With more funding and labour this method could allow us to build a large inventory of invertebrates present in restored and mature areas.

Moths

The moths caught in the restored sites (R1 and R3) were mostly grassland and a species associated with gorse (the gorse pod moth - *Cydia succedana*). Moth trapping was only done on two nights at paired mature and restored sites. This was limited by the need to wait for the petrels to depart and unfortunately the weather was not suitable at that time. The limited collection of moths did however show different species present in the mature sites compared with the restored sites (dominated by exotic grassland and gorse). Future moth surveys are recommended but this requires further specialist support for species identification.

Freshwater invertebrates & fish

The aquatic invertebrate data shows a clear distinction between the two parts of Scotsmans Creek and the creek in the restoration planting area. It was difficult to compare the aquatic fauna (freshwater fish and invertebrates) between mature and restored sites as the substrate differed – Scotsmans Creek was a stony base while the creek at the second bridge in the restored area was sandy/muddy, inundated with aquatic weeds and overhanging exotic grasses. Nevertheless the latter yielded large numbers of galaxiids and an eel. Planting around this area with appropriate riparian species would help reduce the exotic grasses and weeds from encroaching on the waterway and reduce silting. Two dragonfly and two damselfly species were abundant and with planting could provide great opportunities for education and advocacy purposes in the future. A riparian planted area could be included in future plans for a public walkway giving people opportunities to observe flora and fauna in a different habitats than are currently being planted. Continued monitoring of fauna within a restored riparian strip could also be undertaken. Indicators could include those used by Stark (1993 and 1998) for water quality or others thanks measure restoration success (Parkyn, 2010).

Birds

In spite of our small sample size our results do show significant differences between mature forest and restored areas. The forest areas have more birds in total and significantly more native birds. In the restored areas in contrast, more introduced birds were observed. This baseline data would be a useful indicator to compare over time.

We observed 26 bird species which is less than half the number Don (1986) listed for the entire Barrytown flat area (55). The only species we observed which was not previously listed is the (wild) domestic geese seen wandering about near the wetland. Our findings in the Nikau Scenic Reserve and the other forest plots were similar to what Don (1986) found although tomtits are the most striking omission in from our list. South Island robins, shining cuckoos and moreporks are known from the wider Barrytown flats area but not in the Nikau Reserve (Don, 1986). Although we did not observe any robins, we did hear moreporks and shining cuckoos from the reserve. Our survey was limited by the time available and skill levels of observers. Because of this it is likely there are also other bird species present but they were not observed in our survey. Some unknown bird calls were heard but that data was omitted from analysis. Ideally bird counts should be repeated 3 - 4 times a year on the same sites to account for seasonal variability (Laura Molles, pers. com. 12/12/2011).

Plants

The climate at Punakaiki is temperate and wet, with a high annual rainfall and frequent rainfall all of which is conducive to establishment of both plantings and natural revegetation. Because many native tree species are bird pollinated and/or have bird dispersed seeds (Kelly et al. 2010), the success of natural vegetation depends on having sufficient appropriate bird populations, native seed source close by, and a conducive climate. All of these factors exist at PCRP. Another advantage of the abundant and well distributed rainfall is that trees can be planted all year round, which is not possible in many other parts of the country without reliable irrigation.

A high percentage of canopy closure within five years is a desirable outcome for revegetation projects. Stace et al. (2003) studied tree species used for catchment protection in the Bay of Plenty. Their list of species with high percentage cover includes: *Pittosporum colensoi, Dodonaea viscosa, Pittosporum tenuifolium, Phormium tenax, Coprosma repens, Leptospermum scoparium, Pittosporum eugenioides and Kunzea ericoides.* These trees planted at 2m spacings created 90% cover in 4.5 years. Stace et al. (2003) also note the importance of maintaining complete control of invasive weed species during the establishment phase of revegetation planting. Once the canopy cover is established, the weeds are much less of a threat.

The plant plots established within the 12 plot “design” (R1, R2, R3, and R4) will not give data about survival of species, as records were not kept of numbers or species planted, and some plants have disappeared already. They can however still provide data about growth rates of the species currently in the plots, the rate of canopy closure, and the arrival of restoration indicators such as coarse woody debris (Grove, 2002) in the future.

Plots R5, R6, and R7 are in a recently planted area and all the trees are still in their plastic sleeves. Very few had died at the time of monitoring, and those few could still be identified. Consequently these plots if monitored over time will give information about species survival as well as growth rates and rate of canopy closure.

The canopy area results are a combination of the “footprint” of the plant and the planting density. Planting densities were not consistent at time of planting, and are even less consistent now after some plants have died so comparison between plots is not always meaningful. For this reason I have included the canopy area per plant graph (Figure 32) which gives a more direct comparison. Plot R1 shows by far the highest canopy area and also the highest canopy area per plant. These results are as expected, where R1, one of the earliest planted areas (Aug, Sept 2009), has some of the biggest and most established of the restoration plants. This plot has the advantage of being a step ahead in the recovery process i.e. more canopy closure, so could also be expected to show other signs of ecological improvement earlier than the other plots. The high canopy area for plot R5 is the result of very high planting density. The canopy area per plant consequently is not high*.

There are many variables in the planting practices used in the restoration planting, which make it difficult to make direct comparisons between different areas or different species such as pre-planting preparation/spraying; time of year planted; planting density; planting competency by volunteers; species planted; age/size of seedlings when planted; size of roots, deep or shallow pot/bag; weather events after planting (e.g. heavy frost, drought, storm); maintenance/release of trees; damage by herbivores. Site specific factors are also very variable: soil type; drainage; prevalent weeds; shelter/microclimate. These aspects are not the focus of the present report.

6. CONCLUSIONS

The present study has found large differences in soils, invertebrates and bird fauna along the vegetation gradient from unplanted grasslands through restoration plantings to mature forests. There is a huge potential to quantify and qualify biodiversity gains from the results as a way of defining future restoration “success”.

*Note: The area of an ellipse measurements of very young trees do not give an accurate portrayal of the “footprint” of the trees in the way they do when the tree is older and bushier as a newly planted tree does not effectively create any ground cover or canopy cover.

7. RECOMMENDATIONS

A proposal relating to future research is provided separately. The following recommendations apply to the restoration activities and continued monitoring at the site.

Ecological monitoring

- Continued monitoring at regular intervals to document changes compared to baseline data.
- Malaise traps in restored areas.
- More bird counts are recommended including at other times of the year. It may be possible to utilise local people, maybe ornithological society.
- Plant plots could also be set up in mature forest to create reference data for restoration plantings (*see* Kanowski and Catteral, 2007).
- Restoring pH, carbon, phosphate and potentially critical trace elements concentrations may be critical determinants of ecosystems function in mature sandplain forest soils and vital to a successful restoration. This requires further investigation.
- Replant into gaps in existing plantings to create more continuous canopy cover, and also to maximise benefit of the weed control work done in those areas. Also plant to link existing remnants as much as possible to create wildlife corridors (Tucker and Simmons, 2009).
- Leave an area unmanaged to cover itself in gorse etc and revegetate “naturally”. It would be very interesting to compare this minimum intervention approach with the restoration planting approach.

Conservation Volunteers

- Lizard lodges and wooden discs need grass trimmed from time to time to provide warmth and sunlight.
- Maintain markers for plots and devices – some bamboo canes and flagging tape may need to be replaced.
- Plant tags on plant plots will probably need to be replaced within 2 or 3 years – Recommend using aluminium plant tags in future.
- Wooden discs can last up to five years in some conditions but may require replacement after 1-3 years in damper conditions.
- Leave unplanted plots unplanted at least within the corner markers. An even bigger area is desirable. Weed control can be carried out within these plots if necessary.
- Do more plant plots in new areas as they are planted – Use aluminium plant tags.
- Keep records of tree numbers and species planted to help to access mortality.
- Could also keep records of pre-planting preparation/spraying; time of year planted; planting density; planting competency by volunteers; species planted; age/size of seedlings when planted; size of roots – has it been raised in a deep or shallow container; weather events after planting (e.g. heavy frost, drought, storm); maintenance/release of trees; damage by herbivores; Also site specific factors are very variable: soil type; drainage; prevalent weeds; shelter/microclimate.
- Calculate canopy areas for different species and compare. This could only be done in a site by site basis where all plants have been planted at roughly the same time (not in planted later). The trees probably need to be three or more years older to allow sufficient growth to calculate reliable canopy ‘foot prints’ for each species. This would help to identify the best and fastest growing species for the various ground conditions found there.
- Biodiversity centre and/or Interpretation panels along walkway would be added value.

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Appendix: Invertebrate species list

Common name	Family/Genus / Species	Location collected	Date	Rarity/ No. found	Native/ Exotic
Springtail	*Holacanthella ?brevispinosa* (or *paucispinosa*)	Pitfall trap in Mature 2B (Nikau Scenic Reserve)	2011/12	single	N
Earthworm	Small, spotted, corn cob-like	Leaf litter in mature sites	2011/12	common	N
	Dark endemic earthworm	Soils, pitfalls, under discs		common	N
	Pink exotic earthworm	Soils, pitfalls, under discs		common	E
Flatworm	Orange	Under iron near U1			N
	Light brown	Under iron near U1			N
	Dark brown	Under iron near U1			N
Leaf-vein slug	Athoracophoridae	Under foam rap		pair	N
Ground beetles	"*Anchomenus*" sp.	Under logs, wooden discs in mature 4 (damp)		common	N
	Cicindela ?parryi	Pitfall in R2A	-11/1/12	single	N
	Neoferonia integra	Under logs, wooden discs in mature sites		common	N
	Nesamblyops oreobius			Single	N
Snails	*Allodiscus punakaiki*	Litter M1	2/12/11		N
	Cavellia reeftonensi	Pitfall M1A	-11/1/12		N
	Cytora pannosa	Pitfall M1A	-11/1/12		N
	Georissa purchasi	Litter M4	30/12/11		N
	Oxychilus sp	Grassland sites (U's & R's)	12/2011	common	E
	Phrixgnathus celia	Pitfall M2E	-11/1/12		N
	Potamopyrgus	Aquatic sampling	11/1/12	common	N
Mayflies	*Coloburiscus* sp.	Aquatic sampling	11/1/12	common	N
	Deleatidium sp.	Aquatic sampling	11/1/12		N
Dobsonflies	*Archichauliodes* sp.	Aquatic sampling	11/1/12		N
Caddisflies	*Costachorema* sp.	Aquatic sampling	11/1/12		N
	Olinga sp.	Aquatic sampling	11/1/12		N
Moths	*Bactra noteraula*	Light trap R3	12/1/12		N
	Chloroclystis inductata	Light trap R3	12/1/12		N
	Cydia succedana	Light trap R3	12/1/12	common	E
	Epiphyas postvittana	Light trap R3	12/1/12	common	N
	Eudonia leptalea	Light trap R3	12/1/12		N
	Eudonia melanaegis	Light trap R3	12/1/12		N
	Eudonia minualis	Light trap R1	10/1/12		N
	Eudonia submarginalis	Light trap R1 & R3	10&12/1		N
	Gellonia dejectaria	Light trap M3	12/1/12		N
	Leptocroca sp.	Light trap M3	12/1/12		N
	Nyctemera annulata	Feeding on ragwort	12/1/12	common	N
	Oecophorid sp.	Light trap M3	12/1/12		N
	Opogona omoscopa	Light trap M1	10/1/12		E
	Orocrambus flexuosellus	Light trap R1	10/1/12		N
	Schrankia costaestrigalis	Light trap M3	12/1/12		N
	Tingena sp.	Light trap M3	12/1/12		N
	Platyptilia repletis	Light trap R1 & R3	10&12/1		N
	Udea flavidalis	Light trap R1	10/1/12		N
	Wiseana copularis	Light trap R3	12/1/12		N
	Wiseana umbraculata	Light trap R3	12/1/12		N
	Xanthorhoe occulta	Light trap M3	12/1/12		N
Water beetle	Hydraenidae	Aquatic sampling	11/1/12		N
Manuka Chafer	*Pyronota* sp.	R3		Single	N
Dung beetle	*Saphobious*	Mature sites esp. M4 pitfall	-11/1/12	common	N

Weevils	*Adstantes rudis*	Malaise trap in Mature 1	-12/1/12		N
	Catoptes sp. nr. *coronata*	Malaise trap in Mature 1	-12/1/12	Single	N
	Liromus pardulis	Malaise trap in Mature 1	-12/1/12		N
	Psephelax sulcatus	Malaise trap in Mature 3	-12/1/12	Single	N
	Scolopterus tetracanthus	Malaise trap in Mature 1	-12/1/12	Single	N
	?Stronyylopterus hyloboides	Malaise trap in Mature 3	-12/1/12	Single	N
	Synaculles indet. Sp.	Malaise trap in Mature 1	-12/1/12		N
Flower longhorn	*Zorion ?minutum*	Malaise trap in Mature 1	-12/1/12		N
Stag beetle	*Geodorcus auriculatus*	Soil in Mature 2		Single	N
Dragon flies	*Procordulia smithii*	Swept near 2nd bridge	11/1/12	common	N
	Aeshna brevistyla	Swept near 2nd bridge	11/1/12	common	N
Blue damselfly	*Austrolestes colensonis*	Swept near 2nd bridge	11/1/12		N
Red damselfly	*Xanthocnemis zealandica*	Swept near 2nd bridge	11/1/12		N
Ants	Species 1	Pitfall traps	-11/1/12		?
	Species 2	Pitfall traps	-11/1/12		?
	Species 3	Pitfall traps	-11/1/12		?
Stick insect	*Acanthoxyla* sp.	Mature 3	12/1/12		N
Spittle bugs	Cercopidae	Grassland (U1)			N
Nursery web spider	*Dolomedes minor*	Grassland, gorse, open sites	-11/1/12	common	N
	Anoteropsis hilaris	Open grassland sites	-11/1/12	common	N
	Arachnura feredayi				E
	Orsinome lagenifera	Under Scotsmans Bridge	11/1/12		N
	Meta rufolineata	Under Scotsmans Bridge	11/1/12		?
	Haplinis sp.				?
	Sidymella sp.	Pitfall traps	-11/1/12		N
Harvestman	Black long legged	Pitfall traps	-11/1/12		N
	Short legged brown	Pitfall traps	-11/1/12		N
Mite-like harvestman	Cyphophthalmi *Aoraki denticulata*	M1 leaf litter	2/12/11		N
Velvet Mite	Trombidiidae	Leaf litter		common	N
Mite	Uropodid mesostigmata	Leaf litter			N
Well. tree weta	*Hemideina crassidens*	Weta motels (R1)		four	N
Cave weta	*Talitropsis sediloti*				N
Ground weta	Unidentified sp.	Malaise trap (1 & 3)	-12/1/12	common	N
Cockroach	Unidentified sp.	Foam wraps		common	N
Spider wasps	*Priocnemis* sp.	Malaise trap in Mature 1	-12/1/12		N
Spider egg para	*Baus* sp.	Pitfall traps	-11/1/12		N
Robber fly	Unidentified sp.	Caught mating on flower		common	N
Phoridae	Species 1	Pitfall traps	-11/1/12	common	N
	Species 2	Pitfall traps	-11/1/12	common	N
Black fly/Sand fly	*Austrosimulium* sp.	Aquatic sampling	11/1/12	common	N
Hoverfly/Syrphid	*Allograpta* sp.	Malaise trap	-12/1/12	few	N
Chironomidae	*Paradixa* sp.	Aquatic sampling	11/1/12		N