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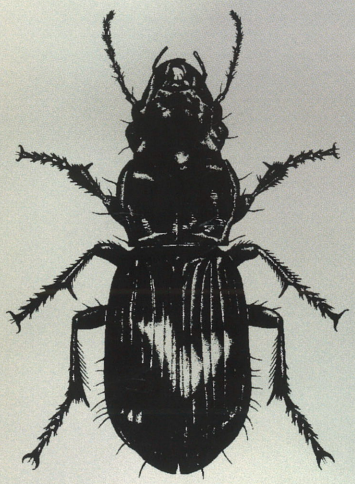

Lincoln University Wildlife Management Report No. 56

Department of Ecology
Faculty of Agriculture and Life Sciences

New Zealand's specialist land-based university

Lincoln University
Te Whare Wānaka o Aoraki
CHRISTCHURCH·NEW ZEALAND

ISSN: 1177-6242 (Print)
ISSN: 1179-7738 (Online)
ISBN: 978-0-86476-395-2 (Print)
ISBN: 978-0-86476-396-9 (Online)

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Prepared for:

Winstone Aggregates
May 2015

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Abstract

In this study we surveyed Winstone Aggregates Hunua Quarry restoration plantings for invertebrates. We wanted to measure the restoration success and used an unplanted control site and a mature forest site in the same area as a comparison. Using different entomological surveying techniques we found that ground beetle and centipede numbers increased from the control site through to the mature forest. Tree weta was well represented in the restored area, while ants, earthworms and rove beetles resulted in a downwards trend from the mature area to the control site. Five native species of snail were found only in the mature forest. Previous studies such as Bowie et al. (2012) Punakaiki restoration project, found similar trends. Both this study and the Punakaiki project are baseline studies. Further research is proposed for the future.

Introduction

Winstone Aggregates is New Zealand's leading provider of aggregates (Fletcher Building, 2015). In 1955 the company brought Hunua Quarry, one of the largest quarries in Auckland (Titchall, 2010), located in the Hunua Ranges near Papakura, South Auckland. The quarry is approximately 250ha in size and extracts greywacke rock as its main resource. In 1958 they also acquired the neighbouring land called Symonds Hill for future extraction (Winstone Aggregates, 2011).

The Hunua Ranges are a series of sharp slanted ranges (up to 688m high) formed from blocks of uplifted greywacke. A considerable amount of the area is a regional park as they are covered with dense forest, large valleys and are home to the Hunua Falls. The area is one of Auckland's major water catchments as some of valleys have been dammed. They are located north of the highway between Miranda and Mangatawhiri (McClude, 2012) and approximately 25 miles south-east of Auckland city (Te Ara, 1996 -2009).

The climate on this part of Auckland is humid and mild with few extremes of weather. The higher elevation of the Hunua Ranges causes a 50% higher mean rainfall between 1,400 – 2,000mm annually and a 2-4 °C lower mean annual temperature at 12 °C than that of lower lying areas of Auckland. The area also receives a lower mean annual of sunshine hours between 1,900- 1,950 (Chappell, 2013).

For Winstone Aggregate's work to comply with New Zealand legislation, any unavoidable damage on the environment caused by their activities needs to be ecologically compensated for (Parliamentary Counsel Office, 2009). Ecological restoration is one of the main actions taken when trying to compensate or repair environmental damage (Cooke & Suski, 2008). This is the action the company has proceeded with and they have been achieving this by increasing the environmental values of other areas within the same location site.

As described by the Hunua Protected Natural Areas survey programme, the original vegetation of the area once supported a mixed forest. However due to deforestation pre-European times and post-European times, the present vegetation has been modified consisting of exotic vegetation (weeds and pasture grasses) and regenerating indigenous forest at various stages in growth (Lindsay et al. 2009). These changes within the forest

before mining, have given Winstone Aggregates the opportunity to try and create a prospering forest with a thriving ecosystem from what used to be bare soil.

A mitigation plan proposed by Winstone Aggregates outlines the goals and objectives of how their compensation programme will work. It is a framework for the various management plans they have including a Vegetation Management Plan (Tokin and Taylor LTD, 2010). This states the methods for monitoring and reporting their progress.

The goals and objectives for the Vegetation Management Plan are to create an ecological gain for forest-dwelling biota and plant populations by revegetating 39.9 ha of indigenous forest and by better management of the existing forest. Winstone Aggregates has a plant nursery on site to assist with this (Tokin and Taylor LTD, 2010).

The purpose of this study is to collect data using a range of entomological collection techniques (pitfall traps, leaf litter extraction, weta motels and wooden discs) in order to evaluate the re-establishment of invertebrate biodiversity in the restoration plantations. The mature and unplanted control forest sites were observed as a method of comparing and assessing the ecological trajectory of the restored areas. This will allow for an insight into the restoration success and will be useful data for further assessment in the future.

Studies have been previously done at the Hunua Quarry. One of the more recent studies was an offsetting pilot project comparison report prepared for the Department of Conservation (Lloyd et.al. 2012). Their study focused on the aquatic fauna, birds, pest animals and geckos. This study is focused solely on invertebrates (mainly terrestrial).

Methodology

Three types of vegetation status, unplanted (exotic grassland), restored (planted in 2011) and mature forest were identified in the Winstone Aggregates Quarry in the Hunua Range. The unplanted area was used as the control site. Four replicates of each vegetation type were then selected for monitoring. Each plot consisted of one transect line that consisted of four sub-replicates of each of the surveying methods used to reduce variability of the data. The surveying methods used was wooden discs, pitfall traps and weta motels. This gave a total of twelve transect lines, 48 wooden discs, 48 pitfall traps and 48 artificial weta motels. The lines were positioned facing north to reduce factors such as edge effects, slope, orientation and aspect unduly influencing the results (Figure 1).

Weta Motels

A weta motel is an artificial refuge for weta and other invertebrates (Bowie et al. 2014). They are constructed from untreated wood, have a slopping roof generally made from plastic and have a small entrance hole at the base preventing any predators from entering. This design is known as the ‘pencil box’ and can be made in larger or smaller form. The motels used in Hunua were the smaller size with dimensions of 50 x 50 x 210mm long (Bowie et al. 2014). These were placed with lacing wire on either stakes or trees depending on the terrain of the area and whether there was a suitable tree available for the motel to be positioned. The motels were placed out on the 19th of November 2014 and were assessed for occupation on the 18th of December 2014 and the 19th of January 2015. Where

invertebrate species could not be identified *in situ* they were collected for identification later. The weta motels remain at the sites for possible future surveying.

Pitfall Traps

The pitfall traps were placed together in the same area as the motels but in the ground. Pitfall traps are used to capture ground-dwelling invertebrates (Work, et al. 2002). This was done by using a soil corer to cut a hole into the ground enabling a plastic cup to be able to be placed at the same level as the top soil. Square roofs made of coreflute were put over the capture cups (69 mm dia.) and were held down by lacing wire leaving a gap of about 1.5 cm to prevent rain and any undesirable debris from falling in whilst also allowing larger invertebrates to be able to enter the pitfall trap. In the afternoon on the 19th of November 2014 approximately 100ml of Monopropylene Glycol (antifreeze) was placed into each pitfall cup as a preservative. The pitfall traps were retrieved to be analysed on the 18th of December 2014. Their roofs and cup holes remain for future surveying purposes. Sticks were put inside the pitfall holes allowing any invertebrates that fall in to be able to get out during the off-surveying period.

Wooden Discs

Between each set of weta motels and pitfall traps there was a 10 m gap. In the middle of this, an area on the ground was cleared to reveal bare soil for each wooden disc to be placed avoiding any gaps between soil and disc. The first wooden disc of the four was placed outside the starting weta motel in the transect line to allow for the total of four discs at each site to be placed. Two of the wooden discs at each site were made from a *Cupressus lusitanica* (white cedar) tree whilst the other two were *Vitex lucens* (Puriri) and pine. These were placed in a random order at each location. The pine was originally cut in log form in the summer of 2013-2014 and was cut into discs a couple of days before use. The cedar and puriri had been cut for a year in log form with a week to dry in disc form. The discs were of similar size ranging from 400mm and 600mm in diameter. The discs were placed on the 18th of November 2014 and were assessed for habitation on the 17th of December 2014 and the 19th of January 2015. The wooden discs remain at the sites for possible future surveying.

Leaf Litter Samples

Leaf litter samples about the size of an A4 paper (210 mm x 297 mm) were taken from each site. This was then put through a Berlese extractor with 40Watt bulb. The preservative was 70% alcohol and the samples were left in the Berlese funnel for one week before retrieving for analysis.

Analysis

All of the data collected from the leaf litter samples and the pitfall traps was analysed under a microscope and counted in the laboratory at Lincoln University, Christchurch, New Zealand. In order to measure the diversity of the invertebrates found, the mites and beetles were identified under the recognisable taxable unit (RTU) counting method. Each individual that looked morphologically different was given an RTU number and had a photo taken as a reference. This method is useful when studying invertebrates as there is a high number of these organisms and the low number of records on them (Oliver, 1993). The insects found in

the leaf litter samples were also counted under this system. The other insects where counted and identified into their main order groups. The beetles found were analysed and identified where possible after being initially counted as RTUs. Statistical graphs were then constructed from this data in order to show any significance and/or ecological trajectory found between the mature, restored and control sites.

Figure 1: Aerial view showing the location of the Control, Restored and Mature sites at the Winstone Aggregates Hunua Quarry.

Results

Weta Motels

The mean abundance 0.38 therids/motel was found on the 17/12/14 for the control site. They did not occupy the restored or mature site motels at this time. On the 19/01/15 the mean increased to 0.44 therids/motel for the control, 0.06 therids/motel for the restored and 0.38 therids/motel for the mature sites (Figure 2).

On the 17/12/14 tree weta was found at the restored sites with a mean of 0.69 tree weta/motel but did not occupy any of the motels in the control and mature sites. When assessed on the 19/01/15 this increased to 1.00 tree weta/motel in the restored area and 0.19 tree weta/motel in the mature site (Figure 3)

One cave weta was observed in the mature area on both dates of assessment. At each vegetation type during the first date of observation, one ant colony was found. The mature

site's ant colony was absent on the second date of assessment. Other unknown spiders were present in the control sites on both occasions but were not present in the other sites.

Pitfall Traps

Centipedes

A mean of 10.19 centipedes/ trap was found in the mature forest site. This decreased to 6.91 and 4.5 centipedes/ trap in the restored and control sites respectively (Figure 4).

Spiders

Spider numbers observed in the pitfall traps were the same for the restored and mature sites with a mean of 5.31 spiders/trap. This was significantly lower in the control area with a mean dropping to 0.75 spiders/trap (Figure 5). Two *Uliodon* species were found in mature and restored sites. One species was thought to be *U. albopunctatus* while the second species was a new species of *Uliodon* (see Appendix).

Ants

A range of different ant species were found in the pitfall traps. The mean abundance of these was significantly higher in the control site with a mean of 44.19 ants/trap compared to that of the mature site with a mean of 5.50 ants/trap (Figure 6).

Earthworms

A higher mean abundance earthworm species were found in the control site with 2.50 worms/trap dropping to 2.13 worms/trap in the restored and 0.13 in the mature (Figure 7).

Beetles

Eleven species of weevils were found across all of the sites but only in low numbers; three were identified as *Mandalotus miricollis*, *Phrynixus* sp. and *Scelodolihus* sp.

Eight species of carabid (ground) beetles were found in the pitfall traps across the three vegetation types. The mature site had the highest mean of 1.48 carabid/trap decreasing to 1.11 carabid and 1.02 carabid/trap in the restored and control sites (Figure 8). The carabid beetle *Holcaspis mucronata* (RTU 18) was not found in the control area however just three individuals were found in the restored area and only a small number were present in the mature site with a mean of 1.06 *H. mucronata*/ trap (Figure 9).

Staphylinidae (rove) beetles were found throughout all sites. There were five species found with the highest mean abundance observed in the control area (Figure 10). Beetle RTU 5 had a high abundance in the control site with a mean of 9.56 beetle RTU 5/ trap but was poorly represented in the restored area and was not present in the mature site (Figure 11).

Snails

The abundance of the common garden snail (*Helix aspersa*) was significantly higher in the control sites with a mean of 7.19 snails/trap. In comparison the mature and restored sites had mean abundance <0.5 snails/trap (Figure 12).

The cellar snail (*Oxychilus alliarius*) was not present in the mature sites but was found in low numbers in the restored and high numbers in the unplanted control sites. *Cohlopoca buccinella* was found only at the unplanted control sites. Both of these snail species are exotic (Figure 13).

In the mature forest, five other native snail species were found. They were only observed at this vegetation type. These were *Thalassohelix ziczag*, *Laoma marino, Phrixgnathus* sp., *Allodiscus dimorphus* and *Cavellia buccinella* (Figure 14).

Wooden Discs

17/12/2014

A wide variety of invertebrates were found under wooden discs on the 17/12/14. Each vegetation grade had worms, ants, isopods (slaters), millipedes, slugs and snails residing under the discs. The mature forest site had the lowest number of species found under the wooden discs but was the only site with an *Uliodon* spider. The control sites had a significantly larger numbers of slaters, but differed from the restored and mature sites by the findings of one *Stethaspis longicornis* (Mumu chafer) beetle, one wireworm and one species of carabid.

A high abundance of *Limax maximus* (tiger slug) in the restoration sites.

19/01/2015

There was a slight variation of organisms found at each site on the second assessment (19/01/15). New occupants were observed whilst there was an absence of some of the original species found.

There were a large number of exotic snails (*Oxychilus alliarius* and *Cohlopoca buccinell)* found in the control site with a mean of 3.2 exotic snails/disc. No snails were present in the mature site and the tiger slug species was only present in the restored sites.

Carabid beetles were found across all sites compared to only one being observed in the control on the first date of assessment. The restored site obtained the highest mean of 0.75 carabid/disc (Figure 15).

A large centipede was found in both the restored and mature sites compared to only one being found in the restored area on the first date of observation. The mature site contained the highest abundance of with a mean of 1.38 millipedes/disc (Figure 16).

Some new species were observed but only in low numbers. A small mean of 0.06 Scarabaeidae (scarab beetles)/disc and a mean of 0.06 Elaterids (click beetles)/disc were found in the restored area but were not observed in the other sites. Cockroaches resided in the control site with a mean of 0.25 cockroaches and 0.13 cockroaches/ disc in the restored site. Whilst three weevils were found only in the control area giving a low mean of 0.19 weevils/disc.

Leaf Litter Samples

Insects

The total mean abundance of insect species diversity found in the mature site was almost double that of the control site. The mature had a mean of 18.0 species diversity/ leaf litter sample dropping to 10.8 species diversity/ leaf litter sample in the restored and 9.8 species diversity/ leaf litter sample in the control site (Figure 17).

Mites

The total mean abundance of mite species diversity showed a similar trend with a mean of 19.5 mite species/leaf litter sample for the mature site decreasing to 14.8 mite species/leaf litter sample in the restored and 11.5 mite species/leaf litter sample in the control (Figure 18).

There was a large abundance of the mite species RTU 26 found in the mature site which had a mean of 24.5 RTU 26/ leaf litter sample decreasing to 13.25 RTU 26/ leaf litter sample and 0.25 RTU 26/ leaf litter sample in the restored and control sites (Figure 19).

A mean of 17.0 RTU 2/ leaf litter sample was found in the control site. This dropped to just over half in the restored and then decreased significantly to 2.75 RTU2/leaf litter sample in the mature forest (Figure 20).

Mite RTU 22 was represented by only one mite in the control site whereas the mature forest had a mean abundance of 8.0 RTU 22/ leaf litter sample (figure 21).

Collembola

The abundance of Collembola (springtails) species diversity found throughout all sites was very similar. The restored site held the highest species richness with a mean of 4.8 Collembola/ leaf litter sample (Figure 22).

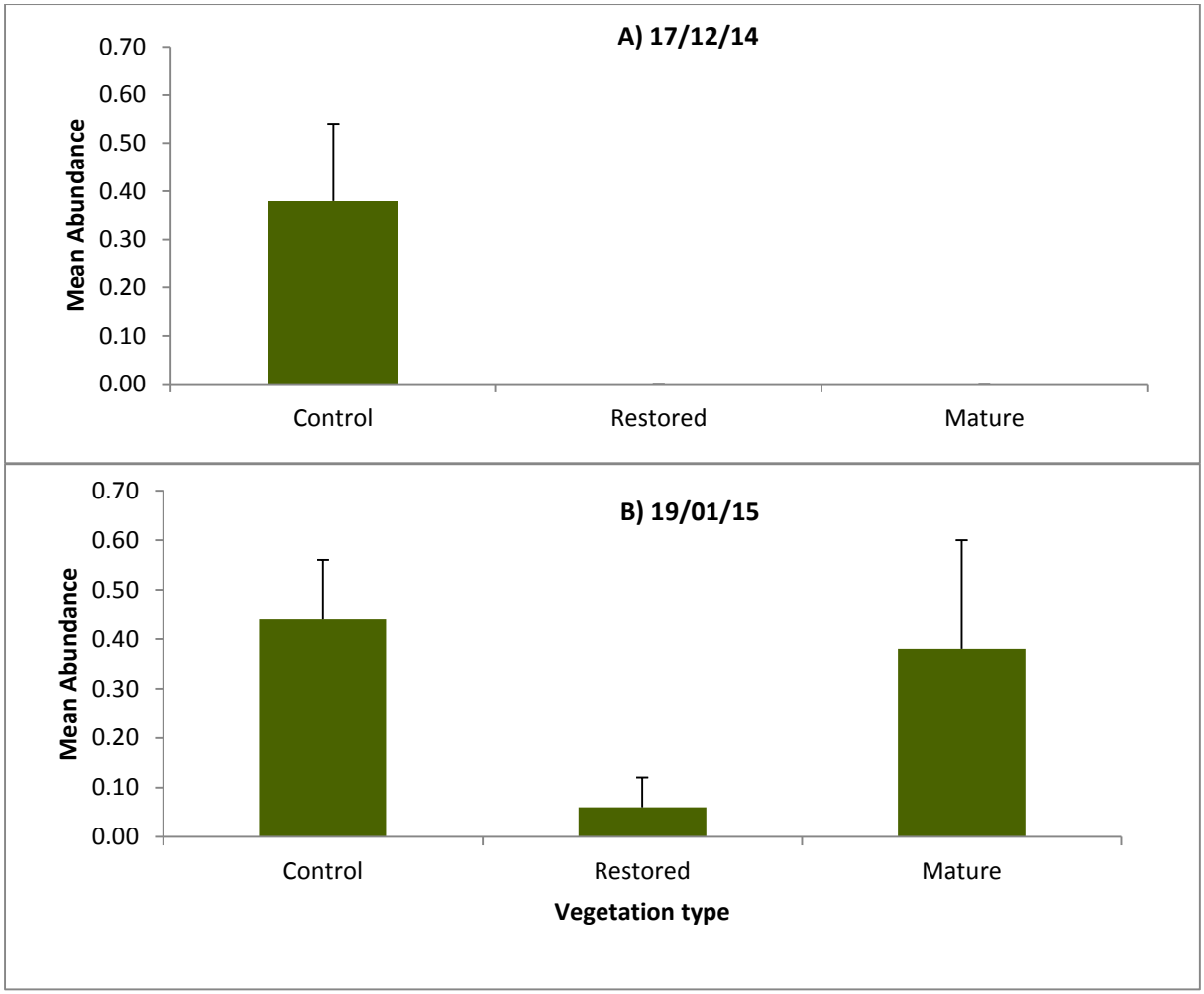

Figure 2: Mean Theridiidae abundance found in weta motels over two dates A) 17/12/14 and B) 19/01/15 across three vegetation types.

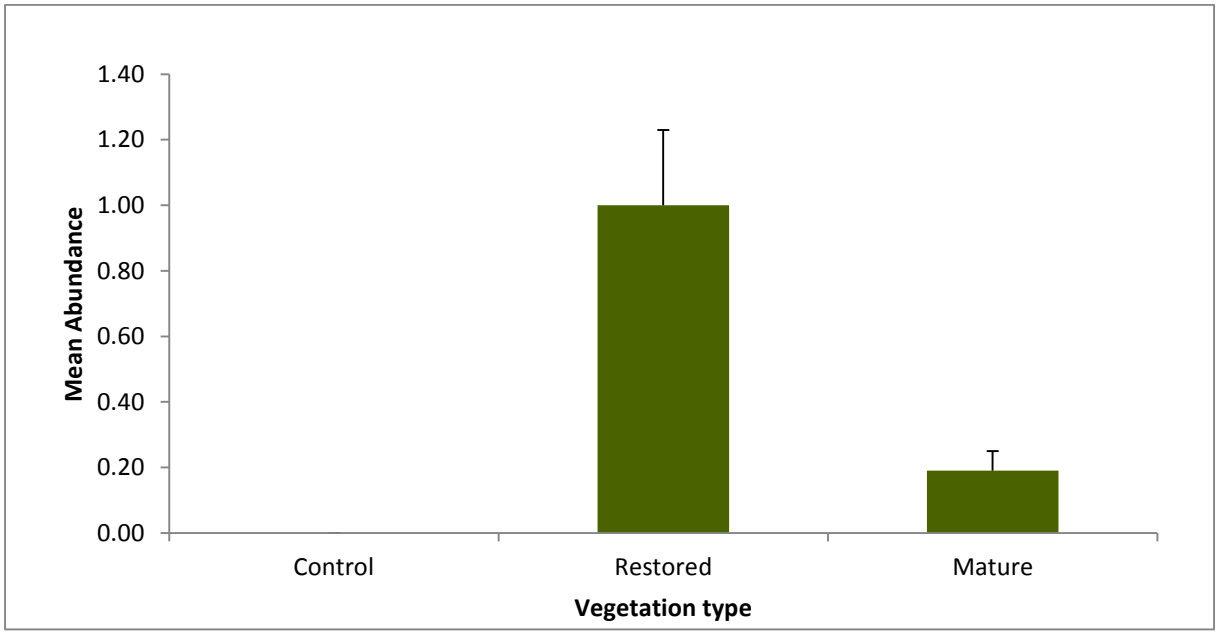

Figure 3: Mean tree weta abundance in weta motels across three vegetation types.

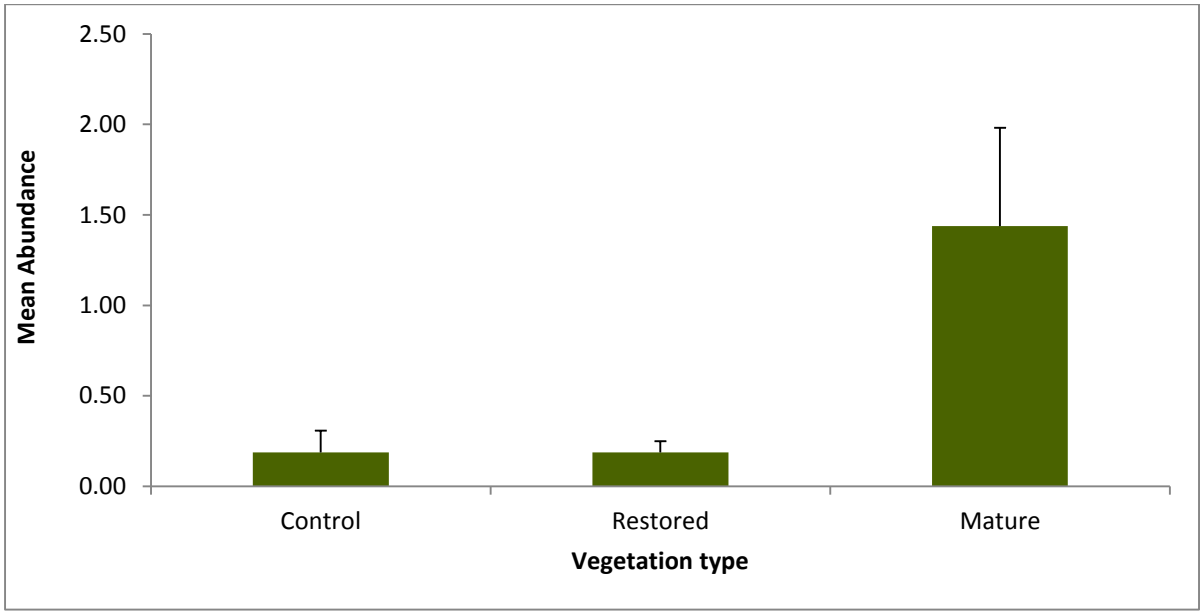

Figure 4: The mean abundance of centipedes found in pitfall traps across three vegetation types

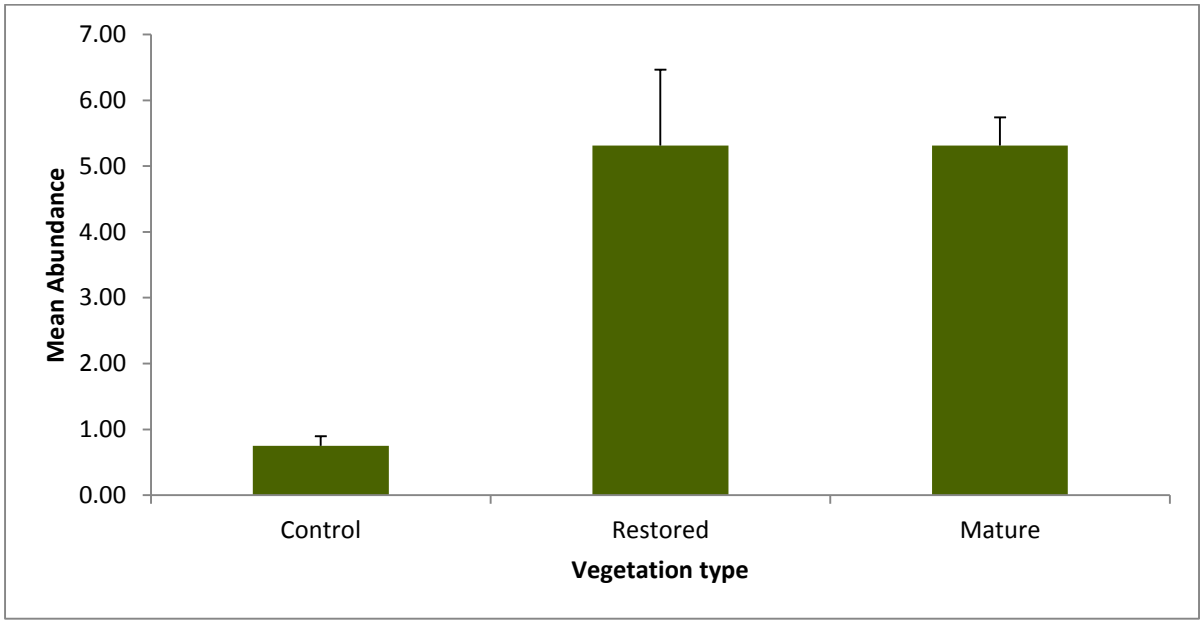

Figure 5: The mean abundance of spiders found in pitfall traps across three vegetation types.

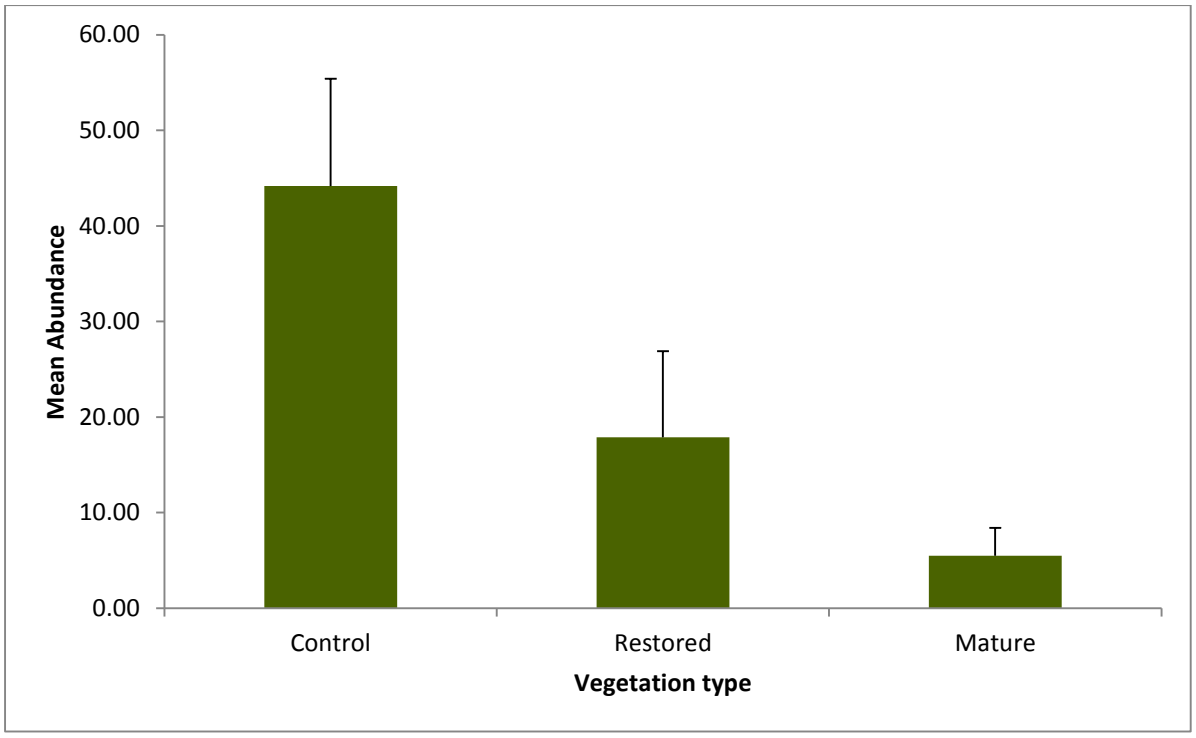

Figure 6: The mean abundance of ants found in pitfall traps across three vegetation types.

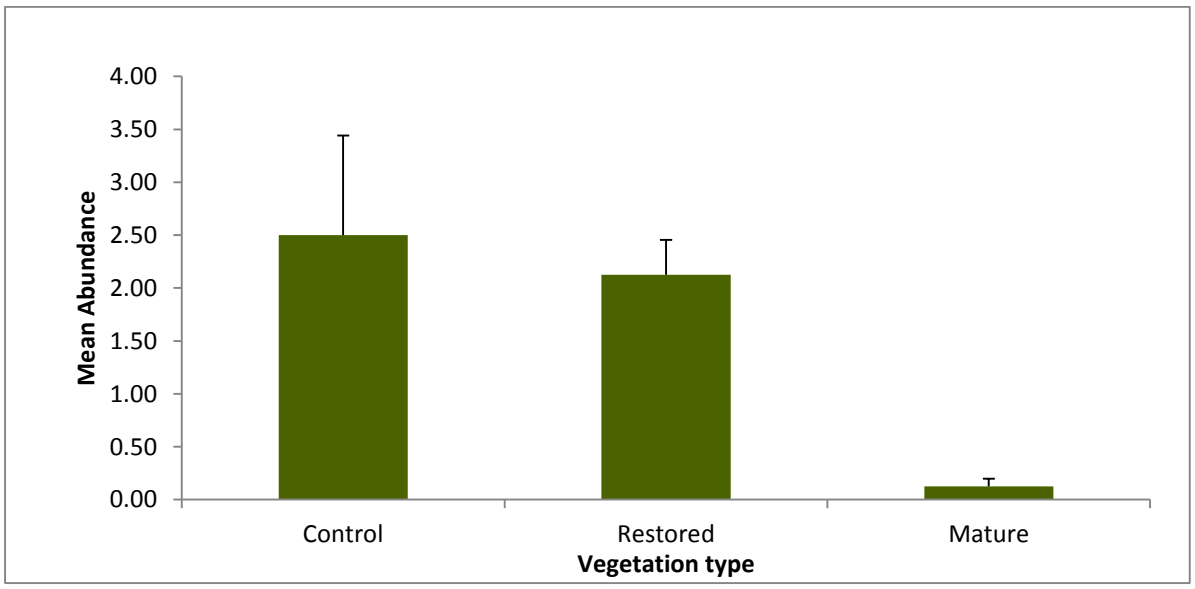

Figure 7: The mean abundance of worms found in pitfall traps across three vegetation types.

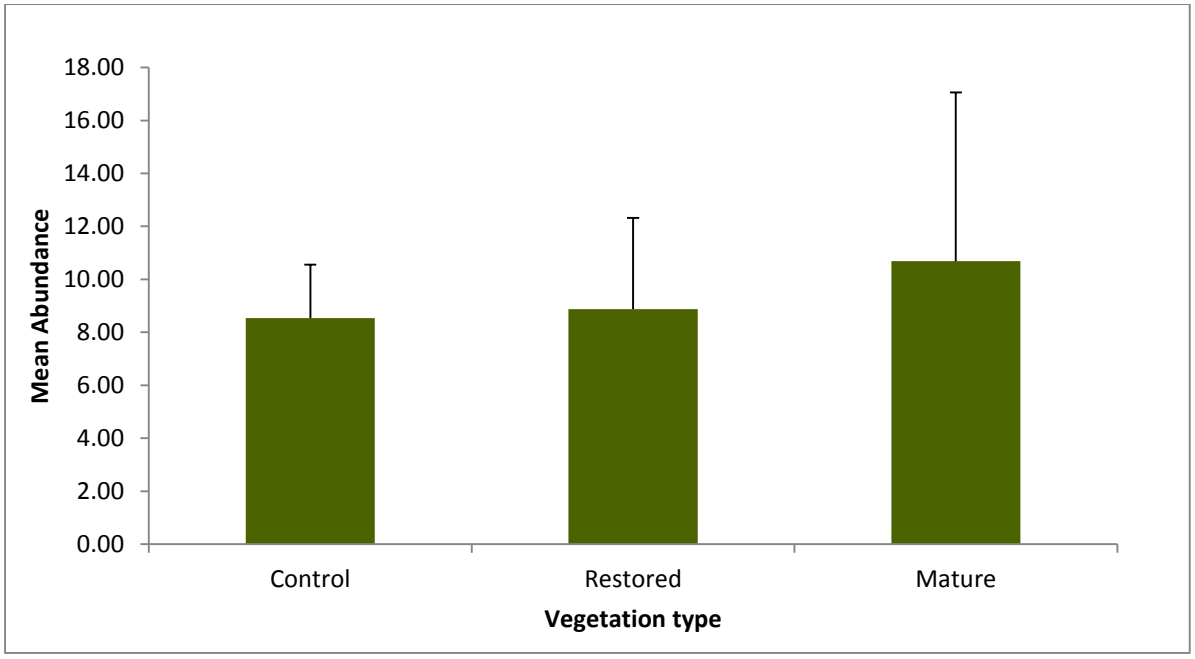

Figure 8: The mean abundance of carabid (ground) beetles found in pitfall traps across three vegetation types.

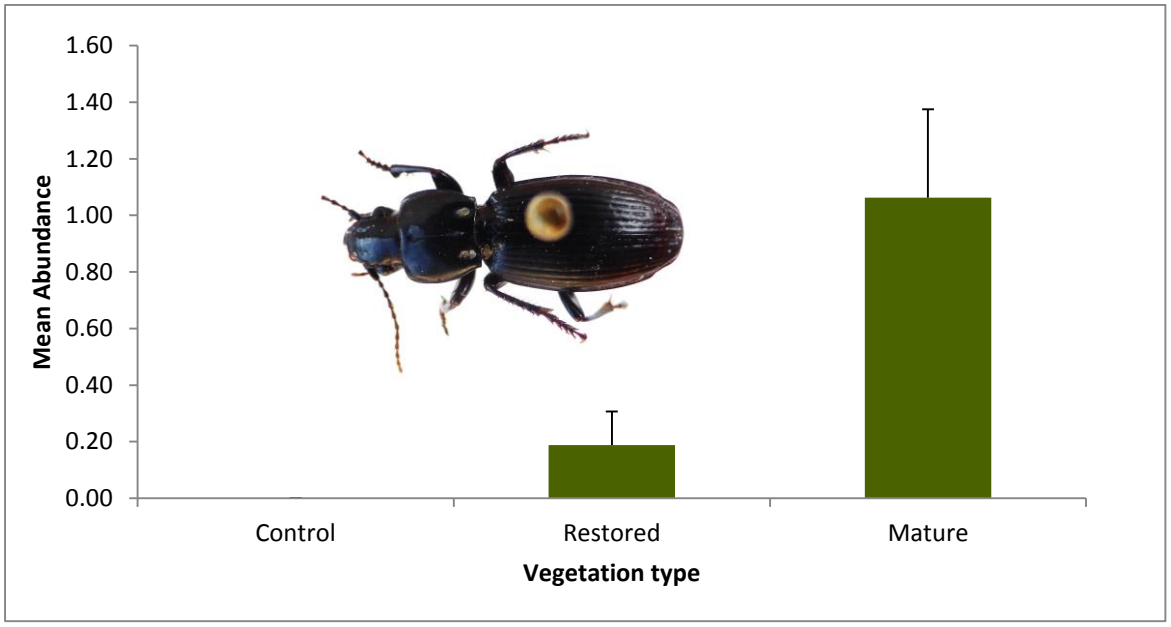

Figure 9: The mean abundance of beetle *Holcaspis mucronata* found in pitfall traps across three vegetation types.

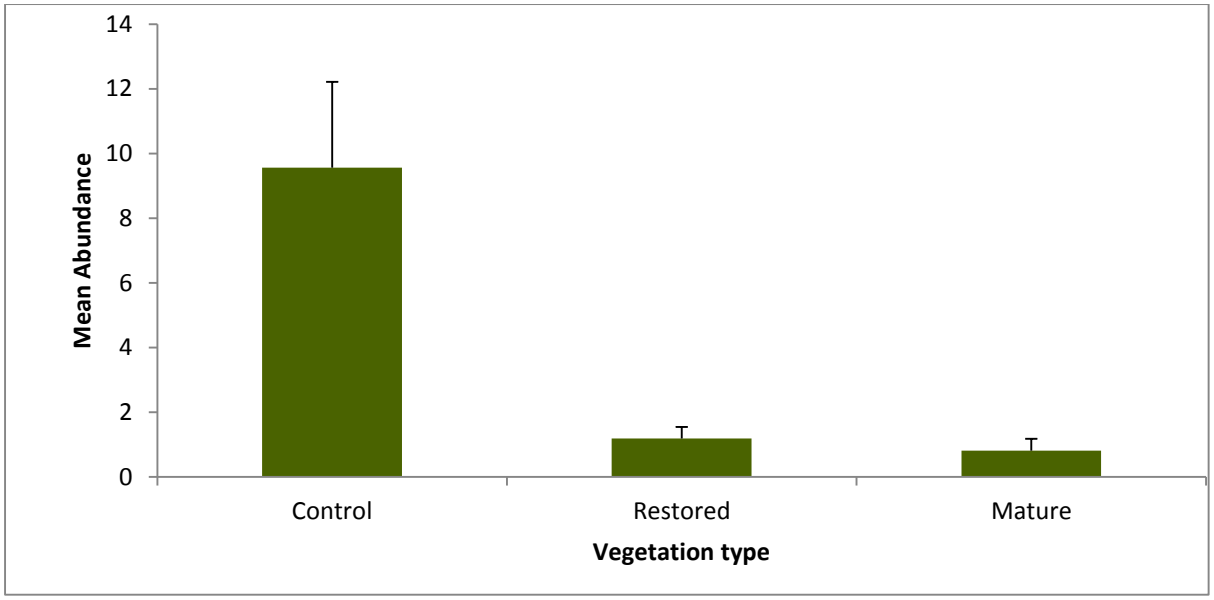

Figure 10: The mean abundance of Staphylinidae (rove) beetles found in pitfall traps across three vegetation types.

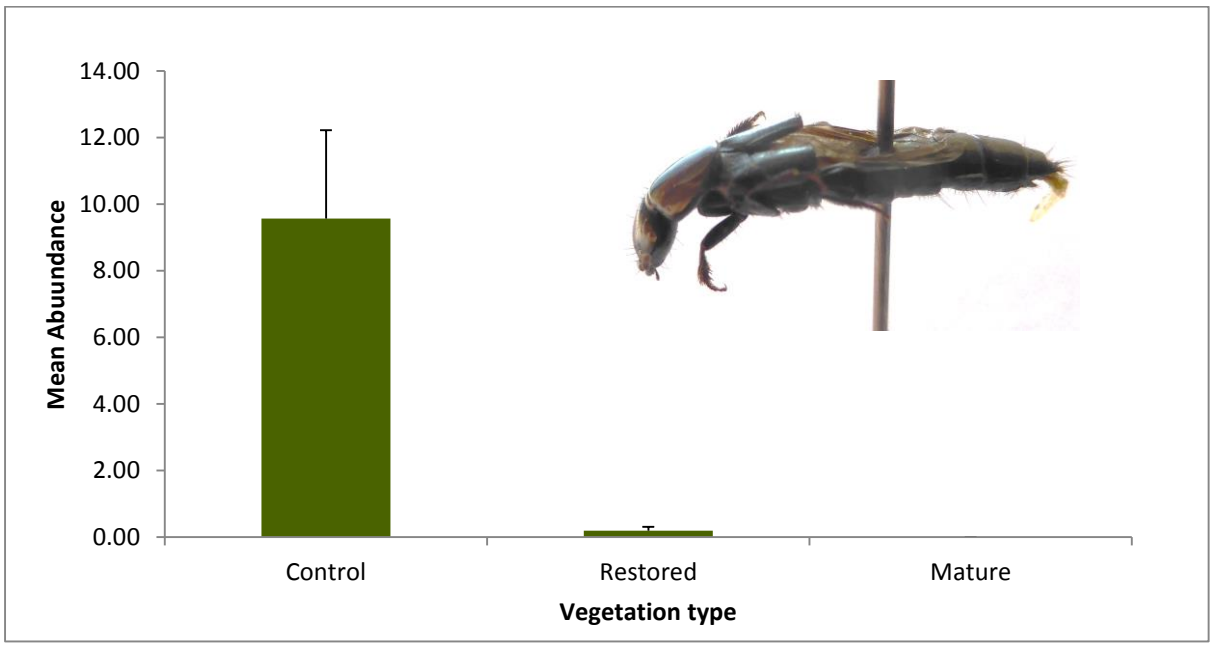

Figure 11: The mean abundance of Staphylinidae (RTU 5) found in pitfall traps across three vegetation types.

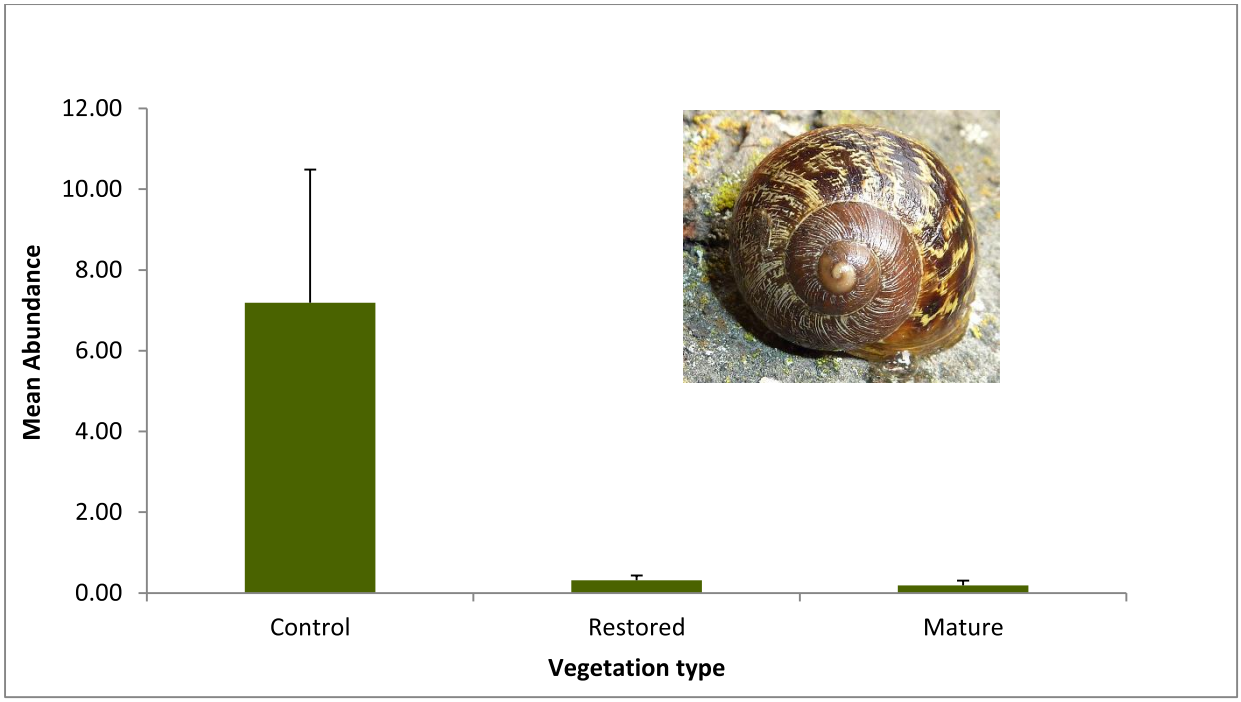

Figure 12: The mean abundance of garden snails (*Helix aspersa*) found in pitfall traps across three vegetation types.

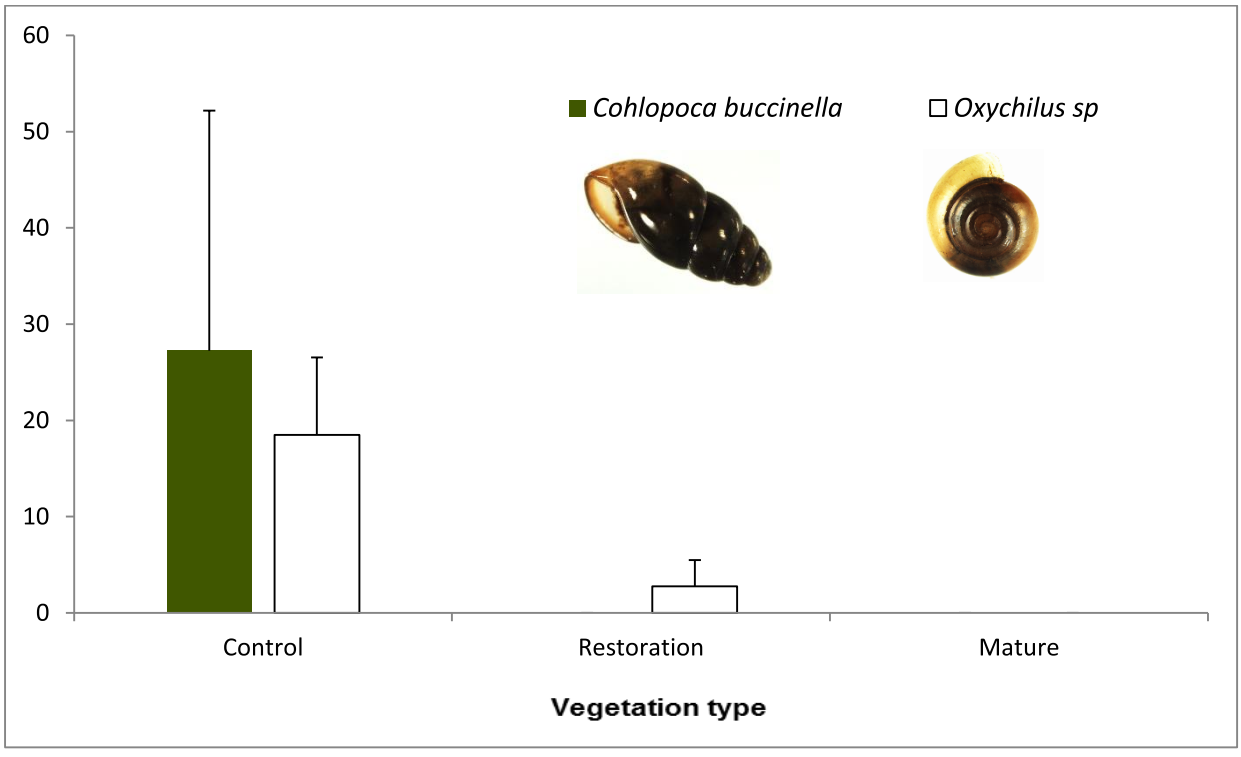

Figure 13: The mean abundance of two exotic snail species *Cohlopoca buccinella* and cellar snail (*Oxychilus* sp.) found in pitfall traps across three vegetation types.

Thalassohelix ziczag

Laoma marino

Phrixgnathus sp.

Allodiscus dimorphus

Cavellia buccinella

Figure 14: Native snail species found in pitfall traps at the mature site only.

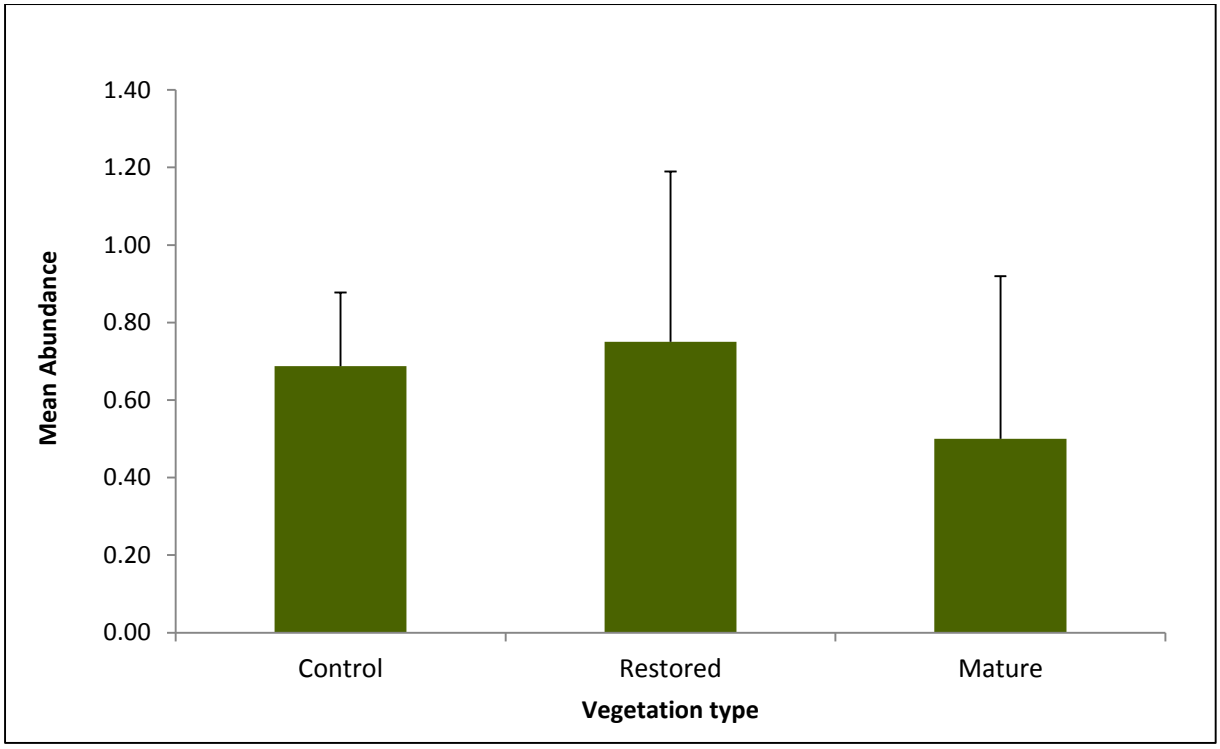

Figure 16: Mean abundance of carabid beetles found under the wooden discs across vegetation types.

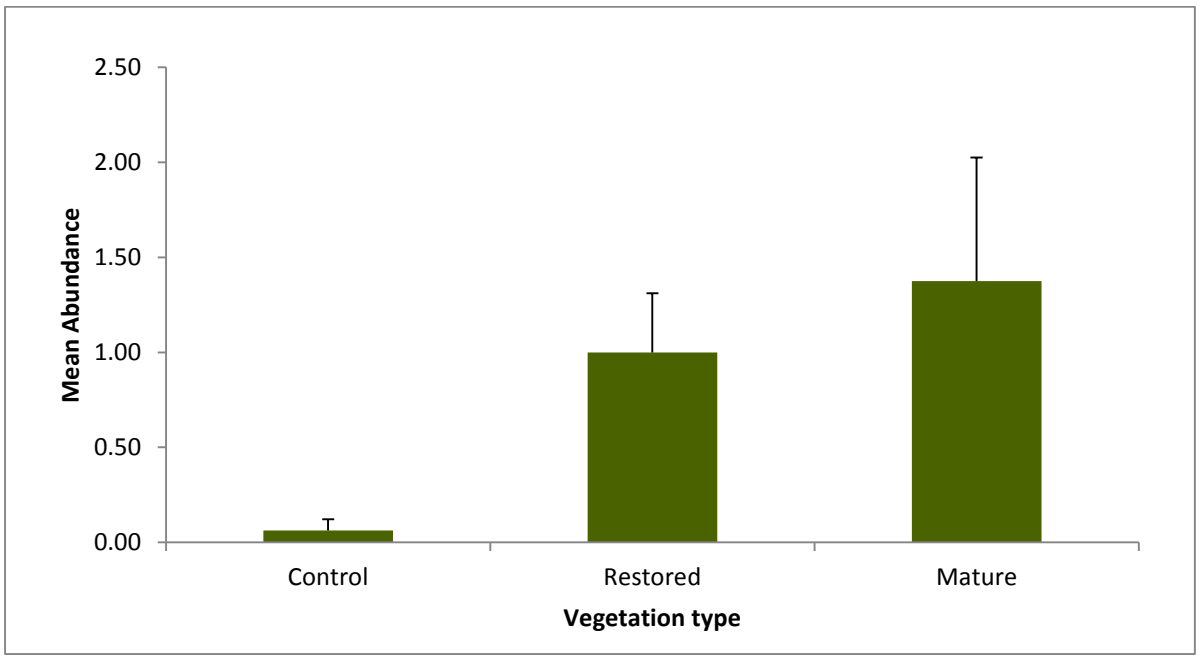

Figure 17: Mean abundance of millipedes found under the wooden discs across three vegetation types.

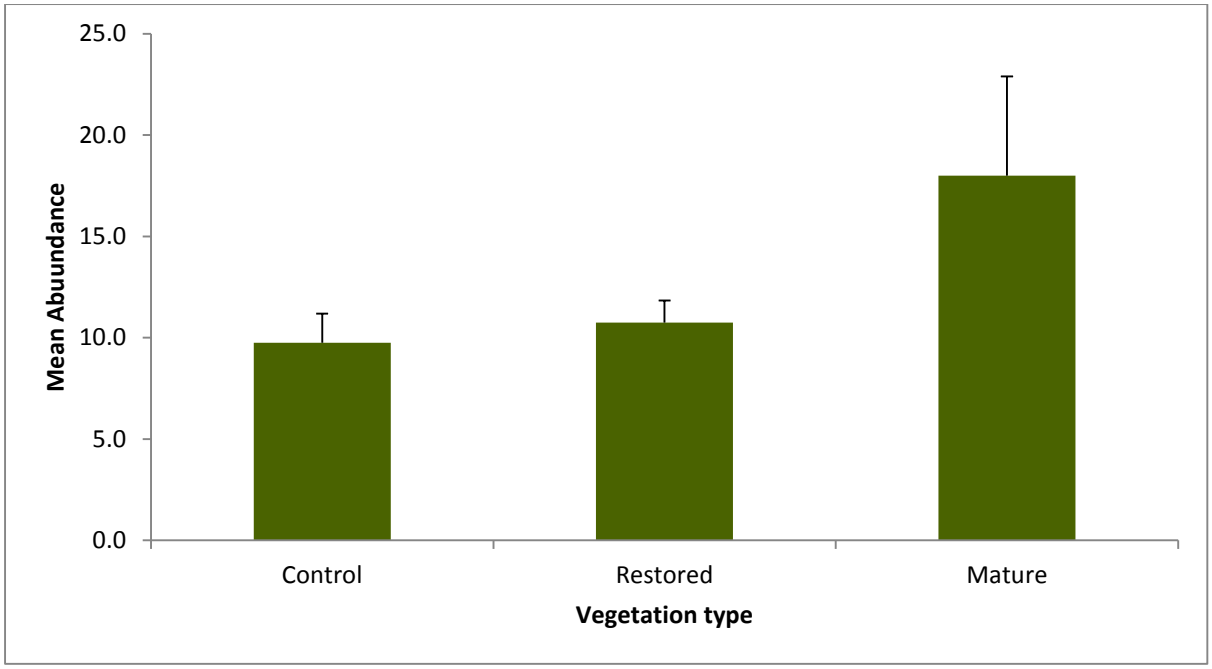

Figure 18: Mean abundance of insects found in the leaf litter samples from each site

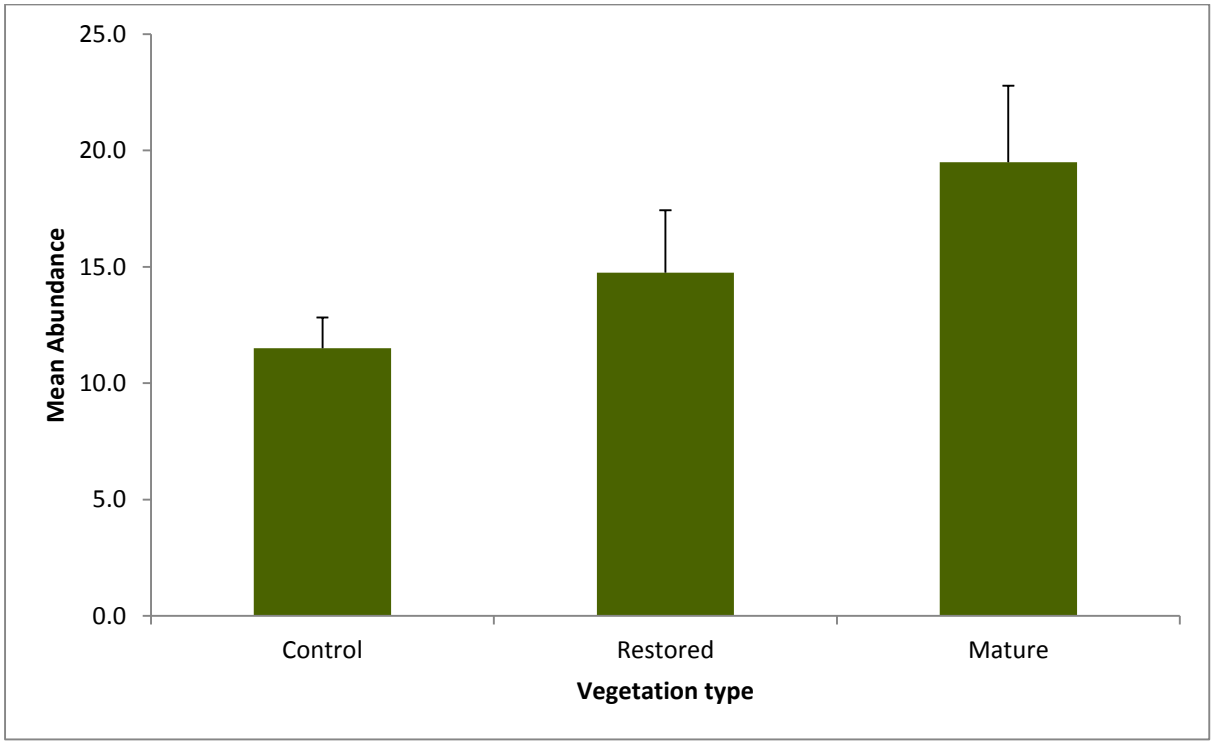

Figure 19: Mean abundance of mite species found in leaf litter samples from each site

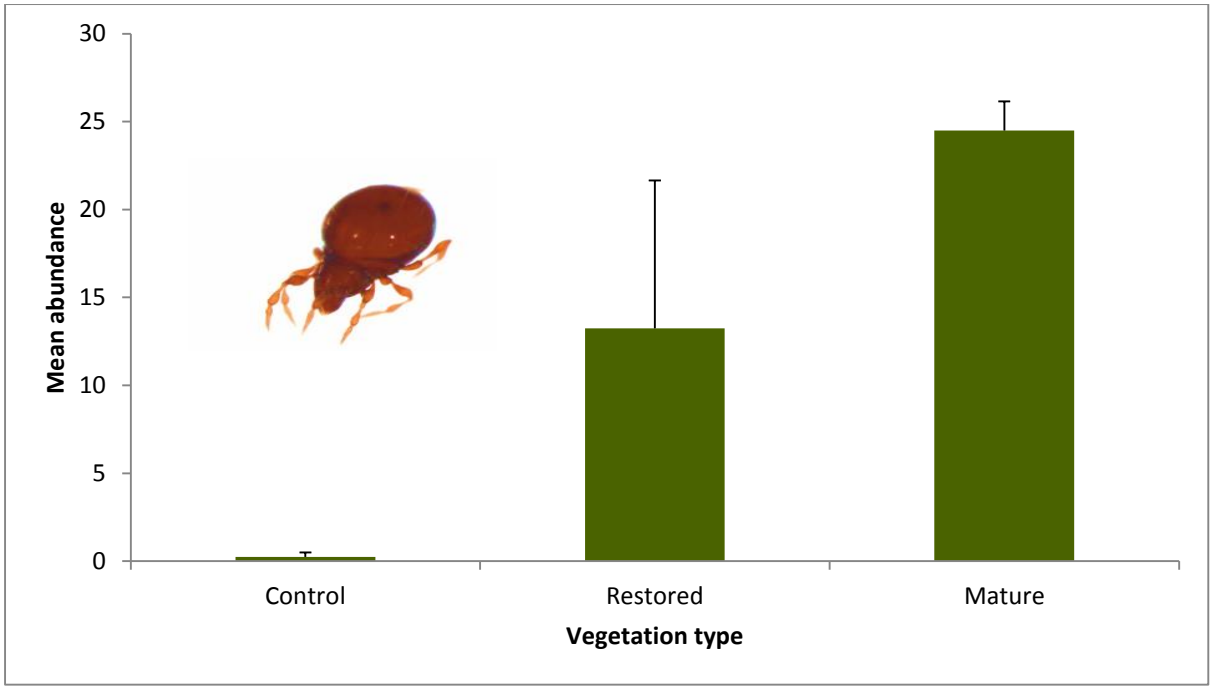

Figure 20: Mean abundance of mite RTU 26 found across three vegetation types

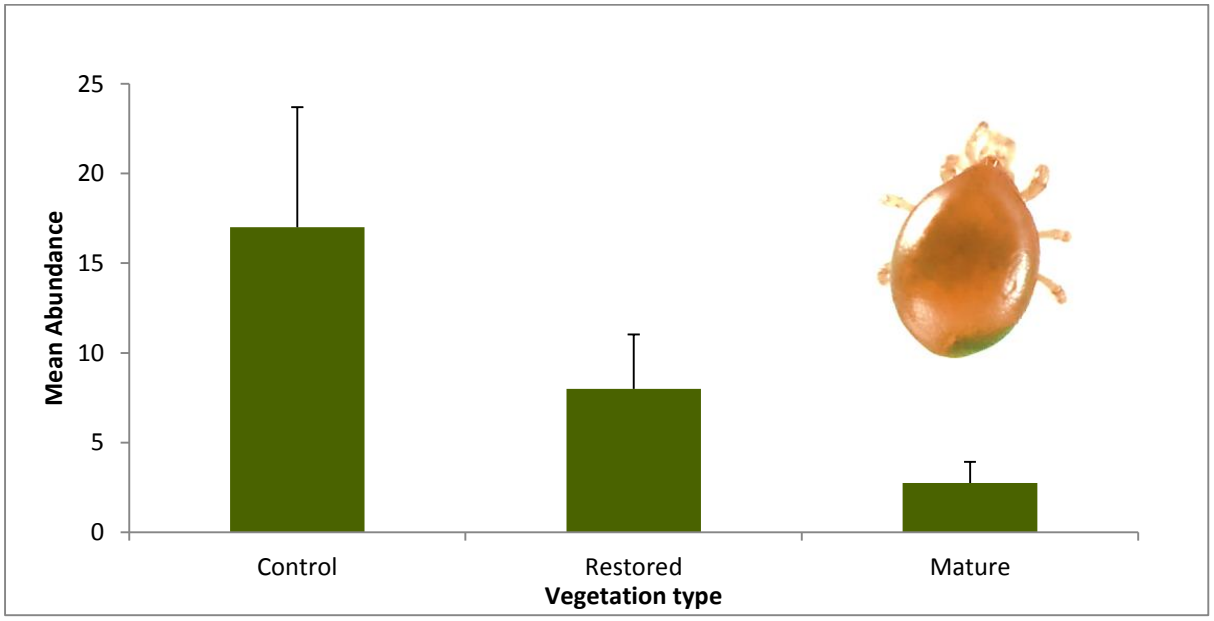

Figure 21: Mean abundance of mite RTU 2 found across three vegetation types.

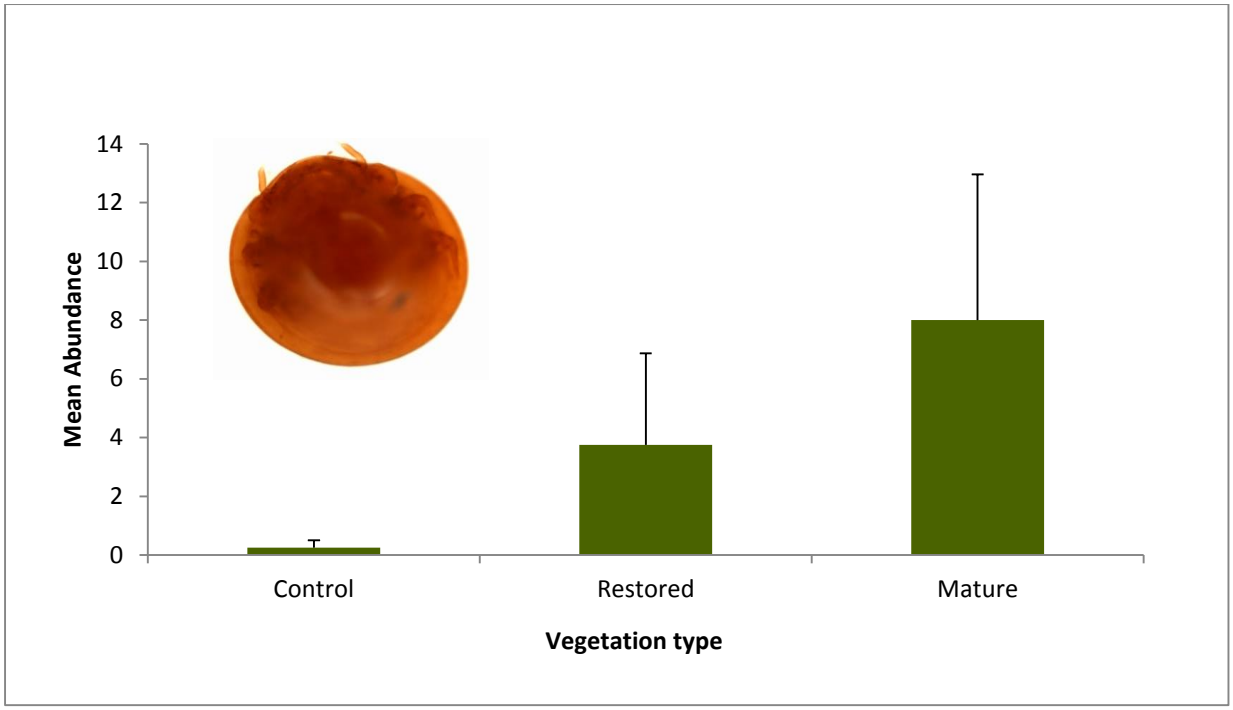

Figure 22: Mean abundance of mite RTU 22 found across all three vegetation types.

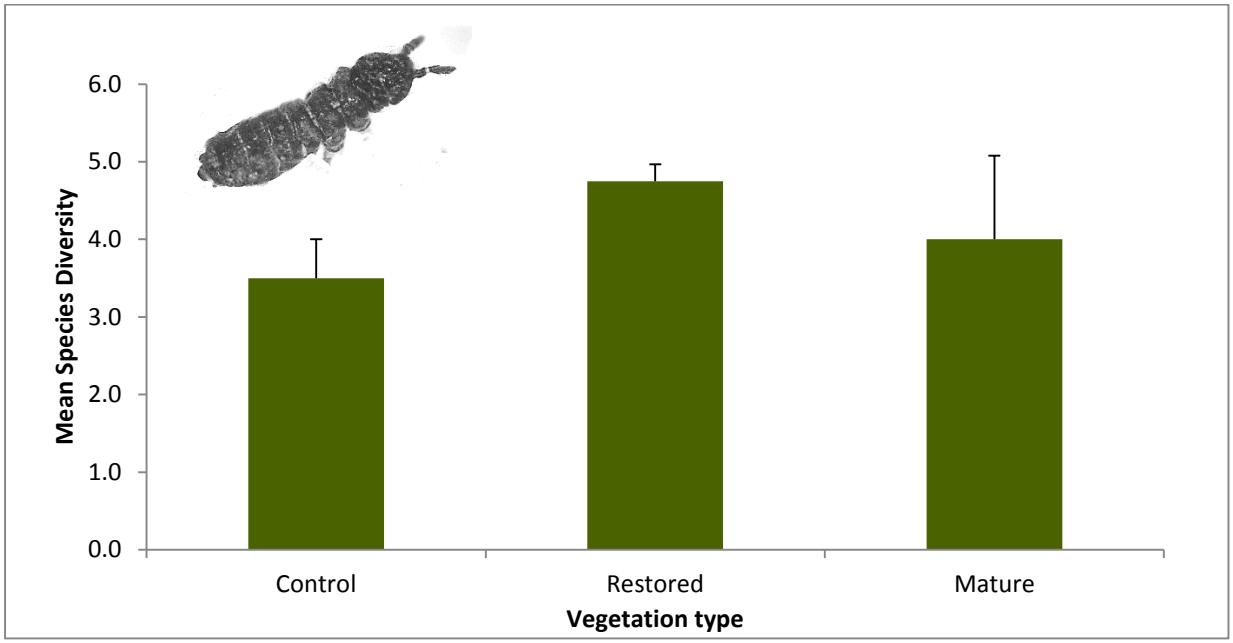

Figure 23: Mean springtails species diversity found in three vegetation types.

Discussion

This survey on Winstone Aggregate's Hunua Quarry site is a baseline study. It gives insight into the ecological restoration the company has accomplished and identifies key areas of interest that can be researched further.

Weta Motels

Therid spiders were observed mainly in the weta motels set in the control sites. This spider family is commonly found in motels (Hodge et al. 2007) and tends to construct their webs under some type of shelter (Shapiro 2014). Due to the control sites consisting of unplanted grassland the weta motels provide these spiders with an ideal place to live.

Tree weta was found in almost all of the motels in the restored site on the first date of observation. On the second date of observation 100% of the motels in the restored area inhabited tree weta. Tree weta prefer areas that are less dense with little canopy cover (Bowie et al. 2014). This is one possible reason as to why they were found only in the restored area. The complexity of the mature forest site in terms of natural refugia may be important in relation to the lower incidence of tree (Bowie et al. 2014). The habitat complexity of the mature forest may also be a factor influencing the amount of other invertebrates observed.

Pitfall Traps

There are a number of factors that can alter the quality and quantity of capture when using pitfall traps. This can consist of the behaviour of the organism including the availability of their food in the area and the weather involving temperature and climate (Hare 2012). The 12 transect lines consisting of 48 pitfall traps were set in the middle of summer for the duration of 4 weeks. Invertebrates are present all year round however they are more active in spring and summer (Johnson 2007). One pitfall trap, (mature site replicate 1), was full of rain water which may have washed a number of invertebrates out. The consequence of this would not have affected the study in a significant way due to the number of replicates and sub-replicates that were used for surveying.

The mature site found a total of 24 centipedes which were significantly higher than the three found in each of the control and restored sites. Centipedes provide an important ecosystem service- known as 'soil ecosystem engineers'. This means they help in processing the soil substrate and allow for water, oxygen and biogeochemical reactions to take place. This helps to regulate the soil (Colloff 2011). As the restoration plantation grows bigger and older, centipede numbers could be a good indicator of how successful the restoration planting has been.

The spiders observed had an equal amount found in both the mature and restored areas. The control site had the lowest abundance. Spiders can be useful when trying to restore an area given they are generalist predators they undertake an important role as pest control agents This means when the pests are eradicated or are low in numbers the spiders will feed on a substitute prey (Hajian-Forooshani et al. 2014). In this study we did not identify each species of spider captured due to a limited amount of time. This could be undertaken in

Future monitoring and may provide an insight as to why certain species are present in some areas but are absent in others.

Ground beetles showed an ecological trajectory that increased from the control site to the mature. Bowie et al. (2012) who assessed the restoration plantation in Punakaiki also found the ground beetles to have a higher abundance in the mature site compared to the control. The same trend was also observed by Reay & Norton (1999) in their assessment of restoration areas in the Christchurch Port Hills. This suggests that ground beetles could be of value for further study as they seem to be an important indicator for restoration success. The ground beetle *Holcaspis mucronata* was not present in the control site during this study. There was a small number found in the restored area and a larger number observed in the mature site. As claimed by Kuschel (1990), the majority of indigenous beetle species are incapable of living outside native bush due to having no tolerance or only a small level of tolerance of ecological changes. Foreign species on the other hand can generally live in both native and non-native habitats. This species may be unable to live well outside the native habitat and may explain why we found these results.

Ants, earthworms and staphylinidae (rove) beetles showed a downwards trend in numbers decreasing from the mature to the control site. In Australia ants have been a very useful indicator species for the restoration of mines and also for the quality of conservation areas (Peak et.al. 1996). Our study has found the opposite trend and this may be explained by the low number of ant species found in New Zealand. In Australia it was last recorded that there was 15,000 known species and subspecies of ants (CSIRO, 2015) whereas in New Zealand there is a little as 40 confirmed species (Landcare Research 2015).

Worm species abundance was much higher in the control site compared to the mature area. The worms were not identified as either exotic or native and this could explain why we got these results. As shown by previous studies (Bowie et al. 2012; Bowie et al. unpublished), the unplanted exotic grassland consists largely, if not completely of exotic earth worms whereas the restored area should be a mixture of both exotic and native earthworms. In the mature area the earthworms should consist of majority if not all of native worms (Springett et al. 1998). The higher abundance of earthworms in the unplanted area compared to the mature site could be related to soil moisture in the area. The abundance of oligochaete worms has a correlation with precipitation and is a valuable indicator of soil moisture (Hodkinson & Jackson, 2005). Earthworm analysis would be a beneficial point of study for future surveying.

Staphylinidae beetle individuals are known to represent almost one fifth of all beetle species in agricultural landscapes (Bowie et al. 2014; Bohac & Pospisil 1984). This could explain why there was a higher abundance of rove beetles found in the control grassland area. They are also common in managed forests and restored areas. In our study they were observed in the restored and mature sites but in lower mean numbers. These lower numbers could be explained by the fact that there is an enormous diversity of rove beetle species and the community diversity of the species varies in different types of forests (Bohac 1999).

The five native species of snail observed *Thalassohelix ziczag*, *Laoma marino, Phrixgnathus* sp., *Allodiscus dimorphus* and *Cavellia buccinella* were a significant find. These were only found in the mature forest and in conservation terms are of importance and could be good indicators of restoration success as the plantings get older.

Wooden Discs

During the first date of assessment pictures were taken of the underside of each wooden disc for observation. A limitation of this was the weather on the date of assessment as we encountered torrential rain whilst out in the field. This obscured much of the images taken however we were fortunate in having a second date of observation a month later providing us with more accurate results.

On both dates of observation the tiger slugs observed were found mainly in the restored area. These slugs are exotic to New Zealand and eat plant matter as well as other slugs and their eggs. They are only damaging to plants if found in large numbers. If found in low to moderate numbers they are seen as a valuable species due to their population regulation on the Spanish slugs *Arion vulgaris* as these are known to be a harmful slug species (Nordsieck n.d.). To ensure these slugs are beneficial to Winstone Aggregates restoration it may be worth surveying these slugs further for a better estimate on their population size.

The carabid beetles found under the discs had a highest abundance in the restored area. This does not support the trend seen in the pitfall trapping results.

Leaf Litter Samples

The mites were the most diverse taxa from this survey as there were as many as 69 individual RTUs counted. RTU 22 and RTU 26 were two mite species that could potentially be used as indicators of restoration trajectory towards mature forest. This mirrors monitoring work done at the Punakaiki restoration site where several mite species were isolated as potential indicators (Hahner & Bowie 2013). This is an area for further study.

Conclusion

This research explored the entomological trajectory of the restoration plantations at Winstone Aggregates Hunua Quarry. The mature forest and the unplanted grassland sites allowed for this comparison to be made. Large differences in invertebrate species diversity and abundance were observed across the three vegetation types. Result showed that some species displayed a downwards restoration trajectory whilst others showed an upwards trajectory in abundance from unplanted control to mature forest. It is probable to assume that the invertebrates showing a downwards trajectory are species of a lower ecological value and/or are exotic species. The species that resulted in an increasing trajectory illustrate the likelihood of the restoration success, but further research should be taken to confirm this over a second season.

Recommendations for further study

They are a number of opportunities to extend the research at Winstone Aggregates in the entomological and ecological field. Some recommendations for this are:

- Continued research using the same surveying methods to compare progress over time.
- The addition of the older mature forest close by to the present vegetation types as another area to include.
- Earthworm analysis in terms of their endemicity and abundance in the different vegetation types. We propose involving Stephane Boyer a colleague now in Auckland.
- Light trapping to assess herbivorous insects particularly moths. Comparisons using paired traps at restoration and mature sites in one night, and replicated over the four sites would be extremely valuable.
- Analysis of nutrients to ensure the restoration plantings are not limited by degraded soil. Comparisons with unplanted and mature site would also show soil nutrient trajectory.

Acknowledgements

The present study would not have been possible without the assistance, guidance and help of the following people and organisations. Our appreciation and thanks to:

- Mervyn Hood and Mark Marsh (Winstone Aggregates) – Access to the site, assistance on site, equipment, funding and support.
- Lincoln University – funding and equipment
- John Marris (Lincoln University) – Identification of beetles.
- Rowan Emberson (Lincoln University) – Identification of carabid beetles.
- Sam Brown (Lincoln University) - Identification of weevils.

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Appendix: Invertebrate species list

SPECIES	COMMON NAME	LOCATION
HYMENOPTERA	**Wasps, ants, bees**	
Sphecidae		
Pison spinolae Shuckard	Mason wasp	Mud nest of weta motel in Control 1 site with 3 parasitised spiders and wasp larva
Formicidae	**Ants**	
Amblyopone australis	Large native ant	Large ant photographed with eggs
Pachycondyla castanea	Native ant	M3
Tetramorium grassii	South African ant	1C4
COLEOPTERA	**Beetles**	
Lycidae		
Porrostoma rufipenne (Fabricus)		Under wooden disc in Control site 2
Silvanidae		
Brontopriscus pleuralis (Sharp)		Under wooden disc in Mature site 1
Carabidae	**Ground beetles**	
Ctenognathus bidens		Found in pitfall trap control 4/4
Ctenognathus lucifigus		Found in pitfall trap control 4/4
Ctenognathus cardiophorus		Found under disc in Mature 4/1
Rhytisternus miser		Found in pitfall trap control 4/4
Clivina vagans putzeys		Found in pitfall trap control 3/3
Lecanomerus atriceps (Macleay)		Found in pitfall trap control 1/1
Anomotarus ?illawarrae		Found in pitfall trap restored 2/1
Holcaspis mucronata (Brown)	(14 mm length)	Found in pitfall trap restored 2/1
Mecodema ?crenicolle		Found in pitfall trap restored 1/1
Melolonthidae		
Stethaspis longicornis Arrow	Mumu chafer	Hand collected in Restoration site 2
Scarabaeidae	**Chafers**	
Heteronychus arator (F.)		Found in pitfall trap control 4/4
Mitophyllus parrianus		Found in pitfall trap control 4/4
Odontria sp. indet.		Found in pitfall trap restored
Costelytra nr.*symmetrica*		Found in pitfall trap
Saprosites sp. indet.		Found in pitfall trap restored 2/4
Saphobius sp. indet.		Found in pitfall trap mature 4/2
Staphylinidae	**Rove beetles**	
RTU 5	(15 mm length)	Found mainly in Control sites
RTU 14		Found in pitfall trap
RTU 36		Found in pitfall trap
RTU 42		Found in pitfall trap
Silphotelus sp. Indet.		Found in pitfall trap restored 4/2
Elateridae	**Click beetles**	
Agrypnus variabilis		

Cerambycidae	**Long-horn beetles**	
? Ptinosoma		Found in pitfall trap restored 1/3
Curculionidae	**Weevils**	
Mandalotus miricollis (Brown)		Found in pitfall trap control 3/4
Phrynixus indet. sp		Found in pitfall trap restored 4/2
Scelodolihus indet. sp		Found in pitfall trap control 3/4
Latridiidae		
? Aridius costatus		Found in pitfall trap restored 2/2
-		
Melandryidae		
Hylobia sp.1 indet.		Found in pitfall trap restored 1/1
Hylobia sp.2 indet.		Found in pitfall trap restored 2/3
Hylobia sp.3 indet.		Found in pitfall trap restored 2/4
Leididiae		
Leiodidiae sp.1 indet		Found in pitfall trap restored 1/2
Leiodidiae sp.2 indet		Found in pitfall trap mature 3/4
?? Zeadolopus sp.3 indet		Found in pitfall trap mature 2/2
Lycidae	**Netwinged beetles**	
Porrostoma rufipenne	Redwinged Lycid	Wooden disc C2/4 - 19 Jan 2015
Nitidulidae		
? Epurea sp.indet.		Found in pitfall trap control 3/3
Cerylonidae		
Hypodacnella sp. Indet.		Found in pitfall trap mature 2/4
Zopheridae		
Syncalis sp. Indet.		Found in pitfall trap mature 4/1
Anthicidae		
Sapintus aucklandensis		Found in pitfall trap control 3/4
Sapintus pellucidipes		Found in pitfall trap mature 2/3
Hydrophilidae		
Hydrophilidae sp. indet.		Found in pitfall trap mature 1/2
Mycetophagidae		
indet. sp.		Found in pitfall trap mature 2/2
Coccinellidae		
indet. sp. 1		Found in pitfall trap mature 2/4
Corylophidae		
indet.sp.2		Found in pitfall trap restored 1/4
Lathridiidae		
Enicmus sp.		Pitfall trap in mature site 2/2
Pristoderus bakewelli	Ironclad beetle	Pitfall trap in restored site 1/3

DERMAPTERA		
Forficulidae	**Earwigs**	
Forficula ?auricularia		Pitfall trap restored ¼
HEMIPTERA	**True bugs**	
Cicadidae	Cicada	
Melampsalta ?suta		Reared as pupa under disc R4/2
Pentatomidae	**Shield bugs**	
Nezara viridula	Green vegetable bug	Grass control site 19 Nov 2014
THYSANOPTERA	**Thrips**	
Indet. species (RTU 5)		Found in leaf litter
MOLLUSCS	**Snails**	
Helix aspersa	Garden snail (exotic)	Control (grassland) sites
Thalassohelix ziczag		Found in pitfall trap mature sites
Laoma marina		Found in pitfall trap mature sites
Phrixgnathus sp		Found in pitfall trap mature sites
Allodiscus dimorphus		Found in pitfall trap mature sites
Cavellia buccinella		Found in pitfall trap mature sites
Oxychilus sp.	Cellar snail (exotic)	Found in pitfall trap control and restored sites
Cochlicopa buccinella	exotic	Found in pitfall trap control and restored sites
GASTROPODA	**Slugs**	
Athoracophoridae		
Athoracophorus rufovenosus	Leaf Vein Slug	On leaf in restored site
Limacidae		
Limax maximus	Tiger Slug	Restored sites
ARANEAE	**Spiders**	
Araneidae		
Eriophora pustulosa	Orbweb spider	Parasitised in mason wasp nest in weta motel
Cryptaranea subcompta		Parasitised in mason wasp nest in weta motel
Novaranea queribunda		Parasitised in mason wasp nest in weta motel
Hexathelidae		
Hexathele sp.	Trapdoor spider	Mature 4/3
Theridiidae		
Theridion zantholabio		weta motel M1/2
Zodariidae		
Forsterella faceta		Mature 3/2
Zoropsidae		
Uliodon ?albopunctatus		Mature or restored sites
Uliodon n. sp.	New species	Mature or restored sites

CHILIPODA	Centipedes	
Scolopendridae		
Cormocepahalus ?rubriceps		
DIPLOPODA	Millipedes	
Spirobollelidae		
Spirobollelus antipodarus	Grey/pink	Mainly mature sites
Dalodesmidae		
Icosidesmus sp.		

Photos of some of the fauna found at Hunua.

Millipede *Spirobollelus antipodarus*

Click Beetle *Agrypnus variabilis*

Millipede *Icosidesmus* sp.

Centipede *Cormocepahalus ?rubriceps*

Uliodon sp.

Orb web spider *Eriophora pustulosa*

Tiger slug *Limax maximus*

Southern michelin ant *Amblyopone australis*