The birds and the bees: identification of bird and invertebrate fauna providing ecosystem services following restoration plantings at the Lincoln University Dairy Farm

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Lincoln University Wildlife Management Report No. 63

Department of Ecology
Faculty of Agriculture and Life Sciences

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Abstract

This study monitored the birds and invertebrates in the native corner plantings, native corridors, and the pasture at Lincoln University Demonstration Dairy and compared their diversity and abundance in the three habitat types. A baseline study was previously completed in 2008/2009 and had assessed the presence of birds in the pasture just after the native planting. In late November and early December 2016 five-minute bird counts were completed in 20 pasture sites and the four native corner plantings. A range of entomological monitoring techniques were used in each site including pan traps, pitfall traps, wooden discs, and leaf litter extraction. A total of 22 species of birds were found, 11 native and 11 exotic species. There were three more bird species observed in 2016 compared to the 2008 study. A total of 74 invertebrate species were found. Native plantings had the highest abundance and richness of invertebrates followed by the corridors, then the pasture. A range of ecosystem services are provided by the birds and invertebrates that include predation and pollination. The plantings also provide shelter for stock, greater on-farm native plant diversity and enhance aesthetic appeal.

Keywords

Lincoln University, dairy farm, birds, invertebrates, monitoring, restoration, ecosystem services.

Table of Contents

1.0 Introduction

Since human settlement in Canterbury, there have been significant losses in indigenous biodiversity. This has primarily occurred through the loss and modification of habitat as a result of extensive deforestation, burning, drainage, settlement and development and the introduction of invasive pests. Now less than 1% of the original Canterbury Plains forest, woodland, grassland and wetland ecosystems remain.

The Lincoln University Demonstration Dairy Farm integrated approximately 6000 native plants into different sections on the farm in 2008 (SIDDDF, 2017). The main planting sites were the four corners and four fence-line corridors in the North block. A total of 39 native species were planted (Appendix 1).

In 2008 a baseline bird study was carried out on the farm just after the native plants were established. A goal of this current study is assess how the plantings have influenced the bird and invertebrate populations over this time and also to compare the bird and invertebrate diversity between the different habitat types.

Ecosystem services are defined as the profits and benefits humans receive from ecosystems (Dempsey and Robertson, 2012; Wratten, et al. 2013). There are four types of ecosystem services and they include: supporting (nutrient cycle and water), regulating (erosion prevention and water purification), provisioning (food production) and cultural (spiritual and aesthetics) (Wratten, et al. 2013; Maron, et al. 2017). Another goal of this study was to describe some of the ecosystem services provided by the birds and insects on the farm, particularly the native plantings.

2.0 Methods

2.1 Study site

The Lincoln University Demonstration Dairy Farm is approximately 2km from Lincoln and covers 186ha of land with 160.1ha of productive land (South Island Dairying Development Centre (SIDDC), 2017). The farm is divided into two main blocks: North and South with Ellesmere Junction Road running across the two main blocks. The average rainfall per year is 666mm and is further increased with another 450mm/year from irrigation to maintain the average evapo-transpiration rate of 870mm/year (SIDDC, 2017). The pasture consists of Ronsyn/Impact ryegrass (*Lolium perenne*), Aran sustain white clover (*Trifolium repens)* and a little area of Timothy (*Phleum pratense*) (SIDDC, 2017). In 2008, 6000 native plants were planted in 16 different sites around the farm (SIDDC, 2017). This study examined the four corner plantings in the North block and the four native fence-line corridors that split the pasture up in sections in the North block. Native species planted are shown in Appendix 1.

2.2 Birds

Twenty pasture sites were used with eleven sites in the North block and nine sites in the South block (Figure 1). A Garmin GPS 60 handset was used to record the coordinates (Table 1). Each site was approximately in the middle of each paddock. One minute 'settling down period' was used before monitoring commenced. The following observations were recorded during the one minute period: wind speed, precipitation, level of disturbance, temperature and any nests that were observed in the paddock. Five-minute bird counts were carried out whereby all the birds seen and heard within the boundary of each paddock fence line were recorded. This was repeated for all sites. On one of the days in site N3 and N4, only three-minute bird counts were carried out due to the danger of bulls being in the paddock. All 20 sites were monitored on the three mornings of 25/11/16, 2/12/16, and 6/12/16. Monitoring occurred in the same period as the previous study completed in 2008.

Table 1: Coordinates of the bird counts on the Lincoln University Demonstration Dairy Farm.

Site	**Latitude**	**Longitude**
N1	43°38'23.60"S	172°26'29.30"E
N2	43°38'34.93"S	172°26'23.88"E
N3	43°38'33.52"S	172°26'15.54"E
N4	43°38'30.69"S	172°26'10.25"E
N5	43°38'21.74"S	172°26'16.44"E
N6	43°38'14.18"S	172°26'22.77"E
N7	43°38'11.31"S	172°26'30.99"E
N8	43°38'15.27"S	172°26'40.77"E
N9	43°38'21.77"S	172°26'44.63"E
N10	43°38'28.02"S	172°26'41.72"E
N11	43°38'33.46"S	172°26'35.33"E
S1	43°38'55.84"S	172°26'37.46"E
S2	43°38'46.46"S	172°26'36.61"E
S3	43°38'47.57"S	172°26'50.60"E
S4	43°38'57.96"S	172°26'52.90"E
S5	43°39'5.38"S	172°26'44.77"E
S6	43°39'6.43"S	172°26'32.25"E
S7	43°39'1.54"S	172°26'25.10"E
S8	43°38'53.54"S	172°26'23.03"E
S9	43°38'46.97"S	172°26'25.50"E

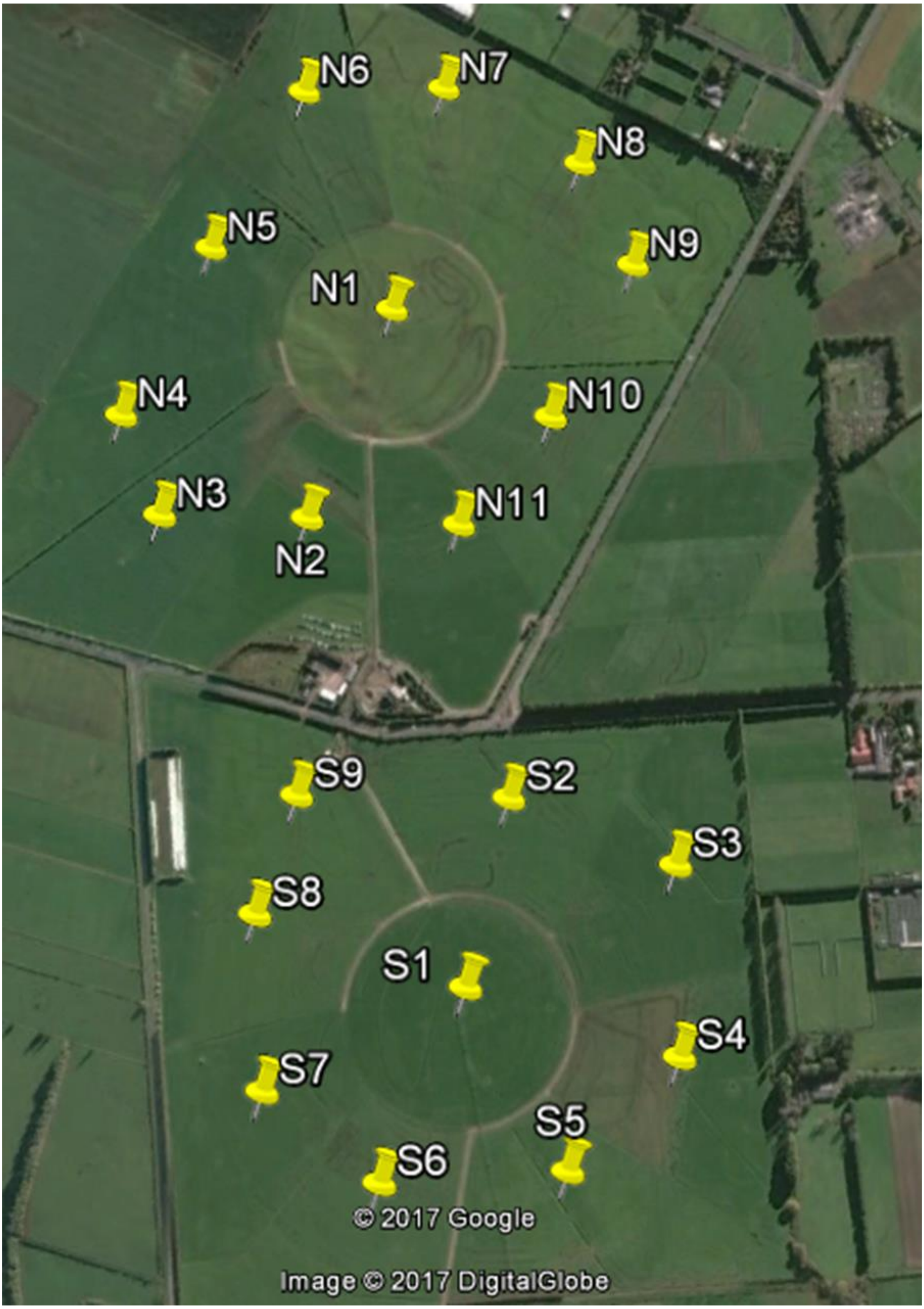

Figure 1: Aerial view of the bird count sites on the Lincoln University Demonstration Dairy Farm.

2.3 Invertebrates

2.3.1 Pitfall traps

Each site consisted of three pitfall traps (at least 15m apart) replicated at four locations, to detect ground dwelling invertebrates (Figure 2). Plastic cups were 69mm in diameter and were placed into the ground and were filled with 1/3 Monopropylene Glycol (antifreeze) to preserve the insects that fell into the cup. Square metal roofs were placed 1.5cm above the cups and were held down by four legs made of number 8 wire to prevent rain and other unwanted debris falling into the traps. The pitfall traps were set for one month.

2.3.2 Pan traps

Each site also had two different coloured pan traps to detect flying pollinators and other invertebrates. One pan trap was yellow and the other was a dark blue. Each pan trap was a standard coloured ice-cream container. Each was filled with two parts antifreeze and one part water. Each pan trap was secured with four long nails on each side of the container to prevent the wind blowing the trap over. The pan traps were put out for one week in December 2016 and one week in January 2017. Collecting the specimens from the pan traps, a sieve was used to drain the antifreeze from the pan traps and the specimens were then placed into a big vial. These were then placed into RTUs except for the spiders that where identified to species level.

2.3.3 Wooden discs

Two dry wooden discs cut from *Cupressus lusitanica* (white cedar) were placed into each site to detect invertebrates beneath. Each disc was similar in size and were approximately 400mm diameter. Smaller discs were used due to the size of the grassland plots being limited in space. Each disc was >1m away from the pitfall traps. Leaf litter and vegetation was removed so the wooden disc would sit on the bare soil. The disc was placed >10m apart on 7 December 2016 and the species and abundance of individuals underneath the disc were recorded on 3 February 2017. Unknown specimens were collected for identification later.

2.3.4 Leaf litter extraction

A total of twelve leaf litter samples (one at each site) were collected to detect the invertebrates present. The samples were the size of an A4 sheet of paper. Fresh litter samples were placed into a Berlese extractor with a 40 Watt bulb and specimens collected over one week were preserved in 70% ethanol for analysis.

3.0 Analysis

To analyse the five minute bird counts the means and standard errors were calculated for the 20 pasture sites for 2008 and 2016 surveys. The invertebrate data from all the pan traps, pitfall traps and leaf litter samples was analysed under a stereo microscope, counted, and placed in to RTUs in the laboratory at Lincoln University, New Zealand. Spiders were identified by using the following taxonomic literature (Forster 1973; Forster 1988; Paquin et al. 2010; Vink 2002). To measure the diversity of mites, hoverflies and beetles these individuals were analysed by looking at the different morphological features and placed into a RTU group. The other insects in the leaf litter, pan traps, and pitfall traps were put into family levels and counted. All the data was placed into a metadata sheet in Excel, and statistical graphs were constructed to show any significance in differences in the abundance and diversity found between the pasture, the corridors, and the native planting sites.

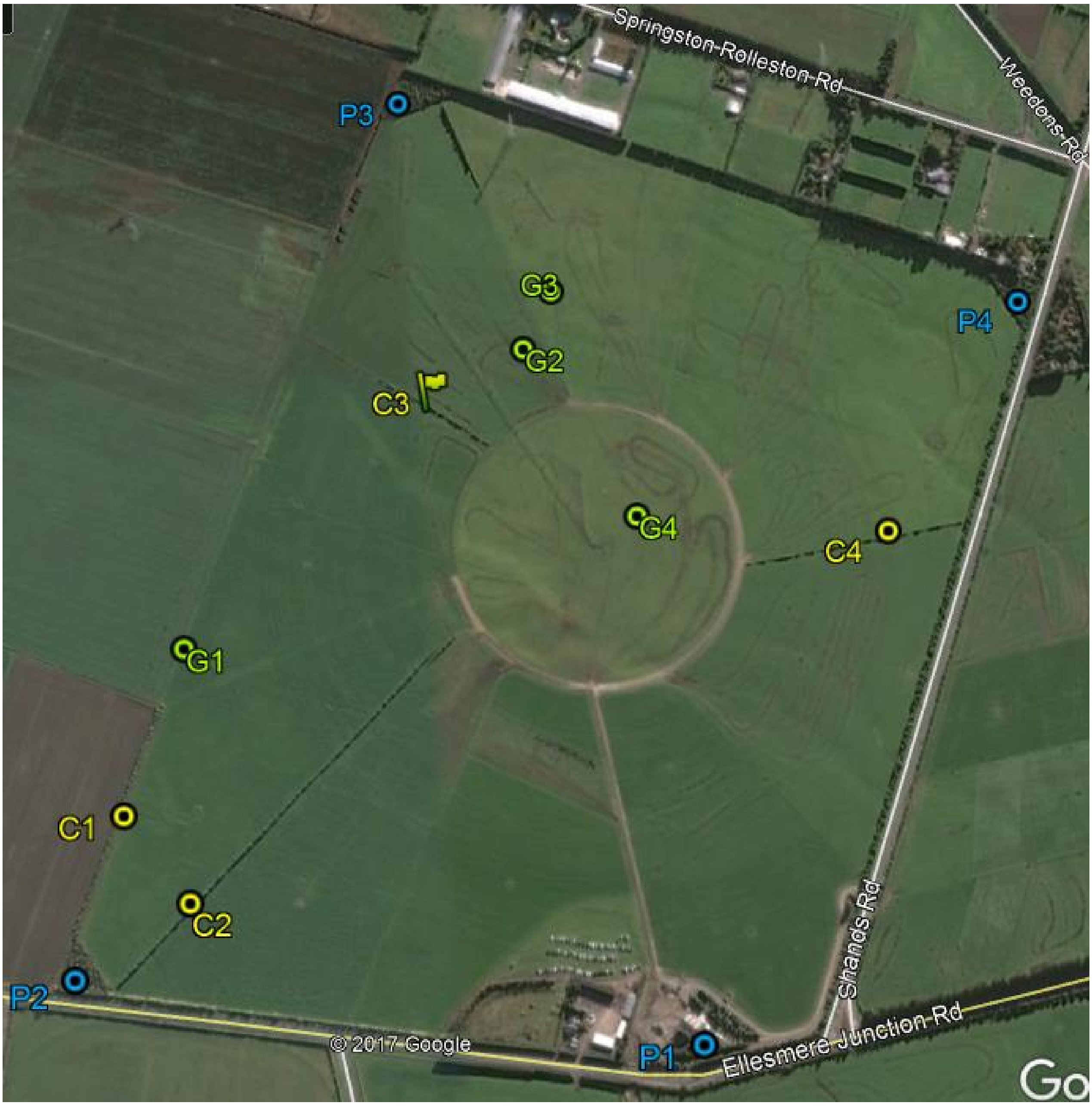

Figure 2. Aerial view of the invertebrate research sites showing the three vegetation types: (**G** - green) grass/pasture, (**C** - yellow) double fence line corridors of natives, and (**P** - blue) native corner plantings.

4.0 Results

4.1 Birds

A total of 26 species of birds were recorded in both paddock and native corner plantings (Table 2). In 2008 a total of 19 species of birds were found, compared to 22 species in 2016 (Figure 3). The pied stilt (*Himantopus himantopus*), pukeko (*Porphyrio melanotus*), and the yellowhammer (*Emberiza citrinella)* were the three extra species observed in 2016 (Figure 3). There was no difference in the number of native and exotic species found. In 2016 there were 11 native species and 11 exotic species found in the pasture bird counts (Figure 3). Compared to 2008 bird count there has been a slight rise in the number of native species found. In 2008 there were 9 native species and 10 exotic species (Figure 3).

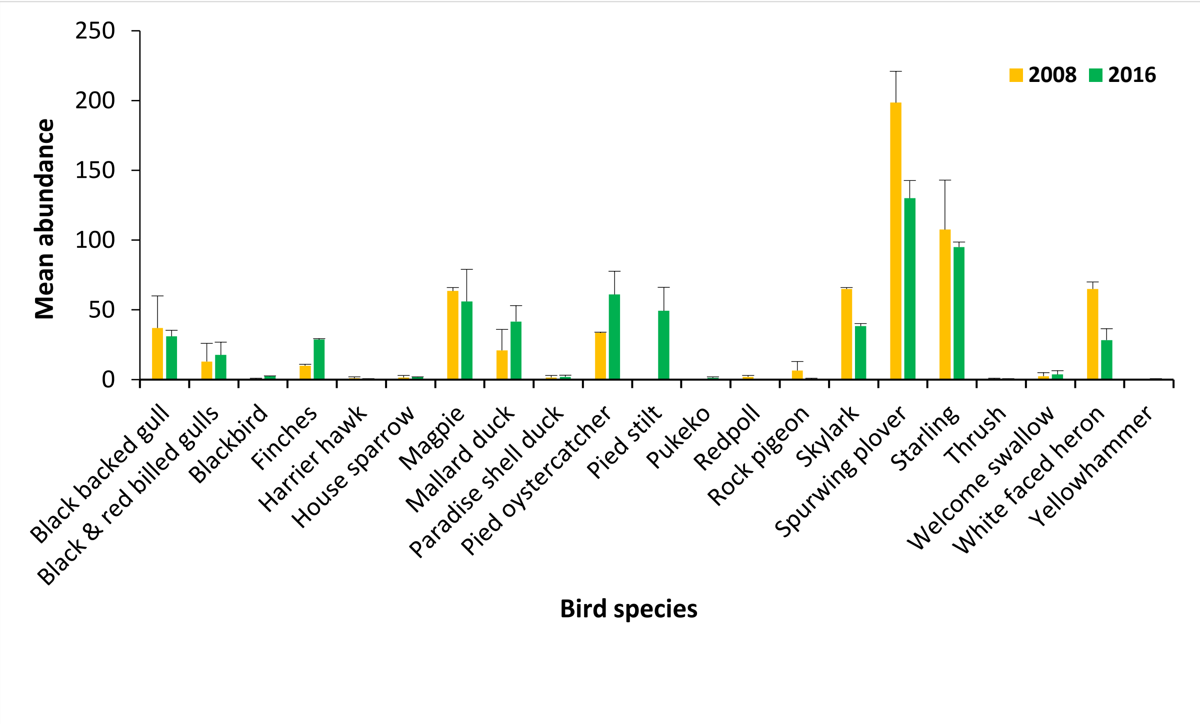

Figure 3: Mean abundance of bird species found in 20 pasture paddocks during 2008 and 2016 at Lincoln University Demonstration Dairy Farm (N=3).

Three native species of bird and seven exotic species of birds were found in the native corner planting counts (Figure 4). The House sparrow (*Passer domesticus*) had the highest mean abundance of 10.7 per site (Figure 4). The most common native was the silvereye (*Zosterops lateralis*), with a mean abundance of 4.7 (Figure 4). The bird nests that were identified were all exotic, however there were nests that were unidentified, some of which may have been native (Figure 5). Blackbirds (*Turdus merula*) had the highest mean abundance of 3 nests per site. House sparrows had a mean abundance of 2.25 nests per site. Song thrush (*Turdus philomelos*) had a mean abundance of 1.75 nests per site (Figure 5).

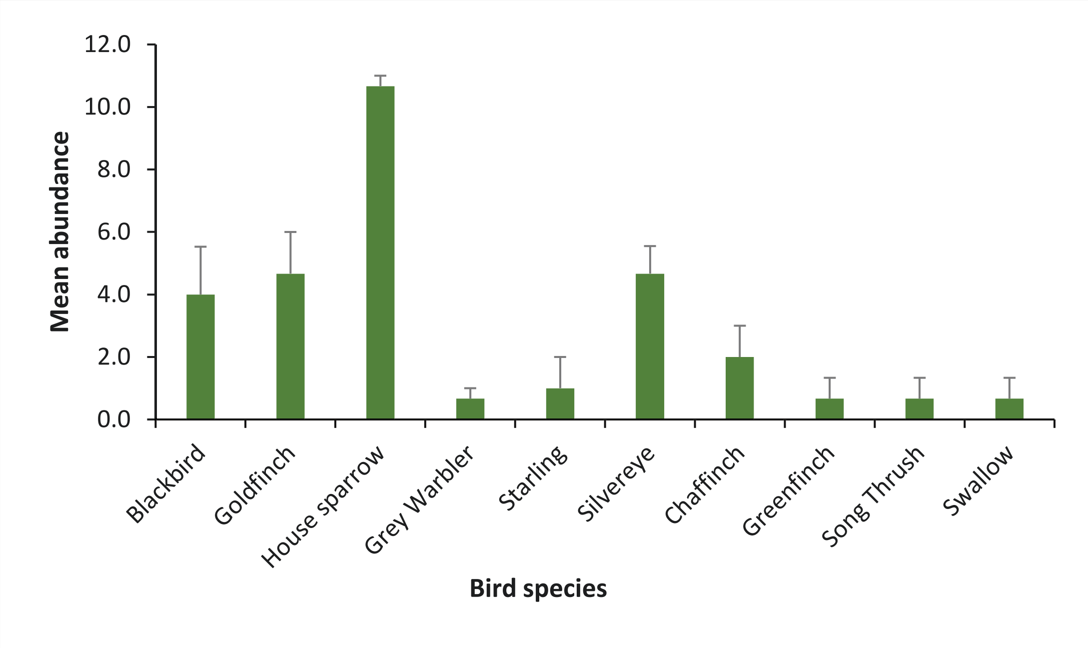

Figure 4: Mean abundance of bird species in the four native plantings corners of LUDDF (N=4).

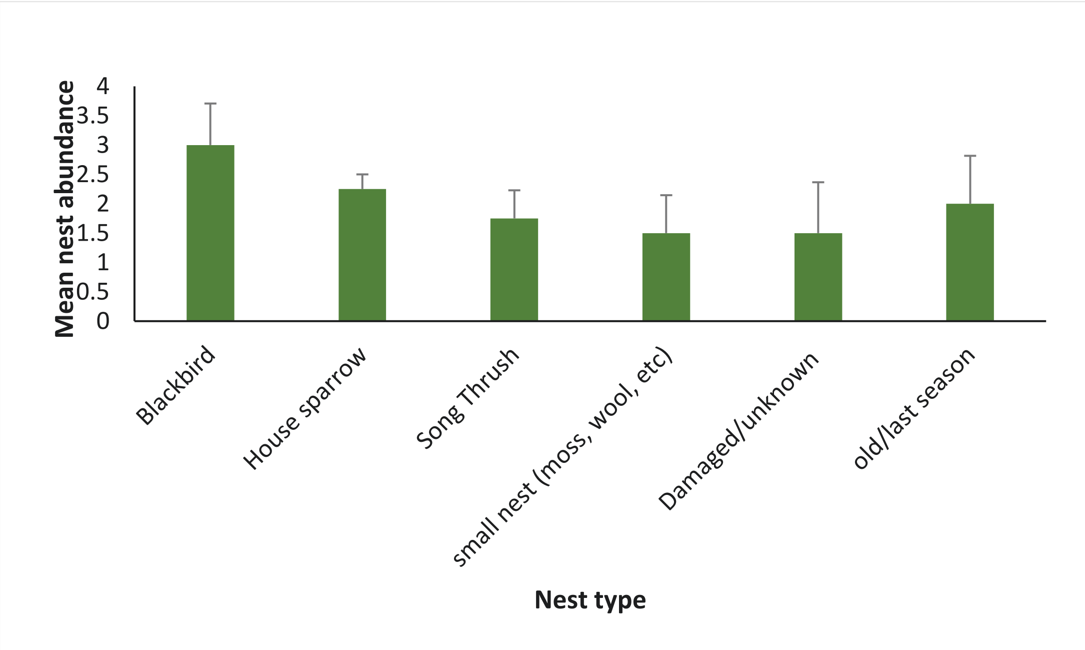

Figure 5: Mean abundance of nests found in the four native plantings corners of LUDDF (N=4).

Table 2: Bird species found on LUDDF, their native status (n=native species, e=endemic, i=introduced), likely diet on the farm, and possible pest/beneficial status ([1]*MacLeod Catriona J., Tompkins Daniel M., Drew Keven W., Pyke Nick (2011). Does farm scale habitat composition predict pest-bird numbers and distribution? Wildlife Research 38, 464-474.*)

Species	Diet (from: Heather & Robinson, 1996)	Pest/Beneficial
Black-backed gull[n] (*Larus dominicanus*)	Worms and insects, opportunistic e.g. placenta, dead lambs	Pest?
Black-billed gull[e] (*Larus bulleri)*	Earthworms, grass grub (adults and larvae)	Pest and Beneficial
Blackbird[i] (*Turdus merula*)	Invertebrates include worms, beetles, amphipods, caterpillars, slugs, millipedes, and spiders. Can cause a lot of damage to fruit.	Pest and Beneficial
Chaffinch[i] (*Fringilla coelebs*)	Seeds of cereals, brassicas, weeds, invertebrates including: spiders, caterpillars, moths, flies, aphids	Pest
Goldfinch[i] (*Carduelis carduelis*)	Mainly thistles seeds, meadow grass, aphids, bugs, flies, caterpillars and spiders in small amounts	Beneficial
Greenfinch[i] (*Chloris chloris*)	Mainly seeds of cereal, maize, oilseed rape, linseed, thistles, some insects	Pest[1]
Grey Warbler[e] (*Gerygone igata*)	Almost entirely invertebrates including spiders, caterpillars, flies, beetles and bugs	Beneficial
House sparrow[i] (*Passer domesticus*)	Cereals, grasses, beetles, weed seeds; Nestlings: caterpillars, leafhoppers, grasshoppers	Pest[1]
Hedge sparrow[i] (*Prunella modulris*)	Mainly small invertebrates: beetles, spiders, flies, aphids, ants and worms. Some small fruits & seeds also eaten	Beneficial
Australian Magpie[i] (*Gymnorhina tibicen*)	Grass grubs, weevils, porina, earthworms	Beneficial
Mallard duck[i] (*Anas platyrhynchos*)	Grass and clover, grain and pea seeds in stubble, some invertebrates	Pest
Pied oystercatcher[e] (*Haematopus finschi*)	Earthworms, insects and their larvae (e.g. grass grub)	Beneficial
Paradise shelduck[e] (*Tadorna variegata*)	Grass and clover, grain and pea seeds in stubble	Pest
Pied Stilt[n] (*Himantopus himantopus*)	Invertebrates including worms	Beneficial
Pukeko[n] (*Porphyrio melanotus*)	Pasture, especially clovers, invertebrates especially small insects and spiders. Known to eat and disperse *Coprosma robusta* seeds	Pest and Beneficial
Red-billed gull[n] (*Larus novaehollandiae*)	Earthworms and insects	Beneficial
Redpoll[i] (*Carduelis flammea*)	Small weed and grass seeds: clover, dock, fathen, thistles, brassicas, sedges, supplemented with invertebrates and fruit buds	Pest and Beneficial
Rock pigeon[i] (*Columba livia*)	Newly sown pea, bean or stubble grain, clover and weed seed, slugs, snails and worms	Pest
Silver eye[n] (*Zosterops lateralis*)	Invertebrates (caterpillars, spiders, bugs, flies, beetles) fruit and nectar	Beneficial
Skylark[i] (*Alauda arvensis)*	Mainly seeds of grasses, cereals, sedges, clover and weeds; invertebrates including beetles, flies, spiders, and various larvae	Pest and Beneficial
Song Thrush[i] (*Turdus philomelos*)	Snails, slugs, worms, amphipods, millipedes, spiders; Eat fruit which they can disperse and also peck at larger commercial fruits	Pest and Beneficial
Spur-winged plover[n] (*Vanellus miles*)	Earthworms, insects and their larvae	Beneficial
Starling[i] (*Sturnus vulgaris*)	Grass grub larvae, porina moth larvae, worms, slugs, snails, spiders, fruit & nectar	Beneficial
Welcome Swallow[n] (*Hirundo neoxena*)	Flying insects such as midges, blowflies, moths	Beneficial
White-faced heron[n] (*Egretta novaehollandiae*)	Earthworms, spiders, grass grub beetles and larvae	Beneficial
Yellowhammer[i] (*Emberiza citrinella*)	Introduced weed seeds, grasses, clover and cereal	Pest and Beneficial

4.2 Invertebrates

Many species of invertebrates were collected using several techniques. The following two tables (Table 3 & 4) summarise the findings.

Table 3: Mean spider abundance (and standard error) trapped from Grass/pasture, Corridor and Planted (native) corner sites. Trend: ↓indicates species favours grass/pasture, ↑indicates species prefer native plants. N=Native, I=Anthropogenic introduction, ?=Unknown (probably a mixture).

Spider species	Native / Introduced	Mean Grass	Mean Corridor	Mean Planted	Grass to planted Trend
Erigone spp.	I	**0.8**	**0.3**	**0.0**	↓
Anoteropsis hilaris	N	**4.5**	**2.8**	**3.0**	↓
Anoteropsis sp.	N	**0.3**	**1.3**	**2.5**	↑
Allotrochosina schauinslandi	N	**0.0**	**0.3**	**0.0**	-
Clubiona sp.	N	**0.0**	**0.0**	**0.3**	↑
Clubiona huttoni	N	**0.0**	**0.0**	**0.8**	↑
Cryptachaea blattea	N	**2.0**	**2.5**	**0.8**	↓
Cryptachaea veruculata	N	**0.3**	**0.0**	**0.3**	-
Diplocephalus cristatus	I	**0.0**	**0.0**	**0.5**	↑
Dolomedes minor	N	**0.0**	**0.0**	**0.3**	↑
Laetesia germana	N	**0.0**	**0.0**	**0.3**	↑
Lamponidae	I	**0.0**	**0.0**	**0.3**	↑
Linyphiidae	I	**2.5**	**0.0**	**0.3**	↓
Haplinis sp.	N	**2.5**	**0.0**	**0.0**	↓
Haplinis fucatina	N	**5.5**	**5.0**	**2.5**	↓
Nauhea tapa	N	**0.0**	**0.0**	**0.3**	↑
Taphiassa punctata	N	**0.0**	**0.3**	**5.5**	↑
Tenuiphantes tenuis	I	**24.8**	**3.8**	**1.0**	↓
Tetragnathidae	?	**0.0**	**0.3**	**0.0**	-
Theridiidae	?	**0.3**	**0.8**	**1.8**	↑
Salticidae	?	**0.0**	**0.3**	**0.5**	↑
Sidymella angulata	N	**0.0**	**0.0**	**0.3**	↑
Zealanapis sp.	N	**1.8**	**0.0**	**0.0**	↓
Zelanda sp.	N	**0.0**	**0.0**	**0.5**	↑
Zelanda kaituna	N	**0.0**	**0.0**	**0.3**	↑
Zelanda miranda	N	**0.0**	**0.0**	**1.0**	↑
Spider juveniles - unknown	?	**1.8**	**2.3**	**2.5**	↑
Spider species diversity	N & I	**12**	**13**	**22**	↑

Table 4: Summary of invertebrate abundance (excluding spiders) found in grass/pasture, double fenced corridors planted with natives & native planted corners. Native / introduced status, ecosystem service/disservice, and effect of native plants on taxa (trend).

Invertebrates	**Native/ Introduced**	**Ecosystem service/disservice**	**Grass** Mean	**Corridor** Mean	**Planted** Mean	**Grass to planted trend**
Earthworm	I	Soil conditioning	25.8	13.5	5.4	↓
Exotic slugs (*Derocerus* spp.)	I	Pest	138.8	47.9	13.0	↓
Large orange pear- shaped mite	?	Unknown	9.0	3.8	0.9	↓
Centipede	I	Predator	4.0	3.5	1.6	↓
Water beetle (Dytiscidae)	N?	Predator	0.3	0.3	5.6	↑
Grass grub (*Costelytra zealandica*)	N	Pest	2.0	1.8	6.2	↑
Weevils	N & I	Some pasture pests	1.0	1.3	2.3	↓
Moths & butterflies (Lepidoptera)	N & I	Pollination, Nutrient recycling	13.0	12.5	32.25	↑
Lacewings (Neuroptera**)**	N	Predator	2.0	7.0	7.8	↑
Hover fly (*Melangyna novaezelandiae*	N	Pollinator and predator	2.3	4.1	5.3	↑
Hover fly (*Melanostoma fasciatum*)	N	Pollinator and predator	4.8	1.4	11.6	↑
Stratiomyidae, *Beris* sp.	N	Predator, pollinator, organic breakdown	0.0	0.3	12.1	↑
Large flies (Diptera)	N & I	Pollinator & Pest	12.5	13.9	51.7	↑
Hump-back flies (Phoridae)	N & I	Organic matter breakdown	61.5	47.6	34.7	↓
Other smaller flies (Diptera)	N & I	Unknown (soil gnats, etc)	1952	2076	963	↓
Honeybee (*Apis mellifera*)	I	Pollinator	2.3	4.1	18.5	↑
Parasitic wasps	N	Biocontrol agents & pollinators	59.0	70.5	100.4	↑
Ants (Formicidae)	N & I	Predators, soil engineers, pest?	1.0	3.0	11.5	↑
Native bees (*Leioproctus* & *Lasioglossum*) spp.	N	Pollinators	0.8	7.9	15.7	↑
Thrips (Thysanoptera)	N & I	Pollinator & pest	2.5	9.4	56.8	↑
Mite (species diversity)	N & I	Soil conditioning & predators	8	12	14	↑

4.2.1 Pitfall traps

A total of 46 insects and 28 spider species were found in the pitfall traps. One mouse was captured in the pasture site and one skink was captured in a native planting site.

4.2.1.1 Slugs

Slugs (*Derocerus* spp.) had the highest mean abundance in the pasture sites at 139. This decreased to 48 slugs per site in the corridors, while native plantings had the lowest mean of 13 slugs per site (Figure 6).

4.2.1.2 Exotic earthworms

Pasture had the highest mean abundance at 25.8 exotic worms per site. Corridors had a mean of 13.5 per site, and native plantings had a mean of five exotic earthworms per site (Figure 7).

4.2.1.3 Harvestmen

The native short-legged harvestmen had the highest mean of 0.8 per site. Corridors had a mean of 0.5 per site. No short-legged harvestmen were found in the pasture sites (Figure 8).

A mean of two European harvestmen (*Phalangium opilio*) were found in the native planting sites. This decreased to 1.0 per site in the corridors and 0.3 per site in the pasture sites (Figure 9).

4.2.1.4 Staphylinidae (rove beetles)

Several species of rove beetles were collected. The species are likely to be predominately native, but because they are difficult to identify, they were lumped together for analysis. Most of the species are native, but there are a few exotic species. Corridors had the highest mean abundance of 10.5 per site. Pastures and native plantings had similar means. Pastures had a mean of 7.5 per site and native plantings had a mean of 7.0 per site.

4.2.1.5 Weevils

Several species of weevils were found, but generally those in pasture were exotic pest species and those in native plantings were native species. There were five different species of weevil found. Weevils were higher in the native planting sites with a mean abundance of 2.3/site. This decreased to a mean of 1.3 in the corridors and 1.0 per site in the pasture (Figure 10).

4.2.1.6 Centipedes

The exotic centipede *Lamyctes emarginatus* was the species collected. Pasture had the highest mean abundance of four centipedes per site. Corridors followed closely with a mean of 3.8 per site. Native plantings had the lowest mean of 1 centipede per site (Figure 11).

4.2.1.7 Moths

Moths were significantly higher in the native planting sites with a mean abundance of 6.3. Pastures sites had a mean abundance of three. Corridors had a mean abundance of 2.3 moths per site (Figure 12).

4.2.1.8 Spiders

Spiders were significantly higher in the native planting sites with a total of 22 species found. Corridors had a total of 13 species of spiders and was followed closely by the pasture sites with a total of 12 species found (Figure 13).

A total of 26 species of spiders were found in the pitfall traps (Appendix 3). Across all the sampling methods a total of 40 species of spiders were collected (Appendix 3).

The exotic *Tenuiphantes tenuis* had a high mean abundance in the pasture at 24.8 spiders per site. Corridors had a mean of 3.8 per site and native plantings had a mean of 1.0 per site (Figure 14).

The native *Anoteropsis hilaris* had a similar abundance across each vegetation type. Native plantings had a mean of 5.5/site. Pasture had a mean of 4.8/site and corridors had the lowest mean of 4/site.

The native *Haplinis fucatina* had the highest mean abundance in the pasture at 8/site. Corridors had a mean of 5/site, and native plantings had a mean of 2.5/site (Figure 15).

The native *Zelanda miranda* was more abundant in the native planting sites with a mean of 2/site. Corridors had a mean of 0.5/site. *Zelanda miranda* was absence in the pasture sites (Figure 16).

4.2.2 Pan traps

4.2.2.1 Harvestman

Blue pan traps in the pasture had the highest mean of three long-legged European harvestmen (*Phalangium opilio*) per site. Native planting blue pan traps had a mean of one/site. No long legged harvestman were found in the corridor blue pan traps. Each yellow pan trap had a mean of 0.3 long legged harvestman/site.

4.2.2.2 Hoverflies

The native hoverfly *Melangyna novaezelandiae* had the highest mean abundance in the yellow pan traps. Native planting yellow pan traps had the highest mean of 5/site. Corridors yellow pan traps had a mean of 3/site. Pasture yellow pan traps had the lowest mean of 1.8/site (Figure 17).

Another native hoverfly *Melanostoma fasciatum* had the highest mean abundance in the yellow pan traps. Native planting yellow pan traps had a mean of 13.8/site. Pasture yellow pan traps had a mean of 3.3/site (Figure 18)

4.2.2.3 Honeybees

Honeybees (*Apis mellifera*) were significantly higher in native plantings than in corridors or pasture with a mean abundance with 18.3/site in the yellow pan traps (Figure 19).

4.2.2.4 Parasitic wasps

Parasitic wasps were found in similar numbers across the blue and yellow pan traps. Native planting yellow pan trap had the highest mean abundance of 62.3/site. Corridor blue pan traps had a mean of 44.5/site. Pasture yellow pan traps had a mean of 39.3/site. Blue pan traps in the native plantings had a mean of 38.3/site. Corridor yellow pan traps had one of the lowest means at 19/site. Blue pan traps in the pasture had the lowest mean of 16.8/site (Figure 20).

4.2.2.5 Lacewing larvae

Tasmanian lacewing (*Micromus tasmaniae*) larvae had the highest mean abundance of 6.3/site in the corridor yellow pan traps. Native planting blue pan traps had a mean of 3.5/site. Corridor blue pan traps had a mean of 2.5/site. Pasture had the lowest mean with 0.3/site in the blue pan traps (Figure 21).

4.2.2.6 Diptera (flies)

The estimated small Diptera were all the flies apart from the larger blowflies (Calliphoridae). Yellow pan traps caught the highest mean abundance of Diptera. Pasture yellow pan traps had the highest mean of 1106/site. Corridor yellow pan traps had a similar mean of 1082/site. Pasture blue pan traps had a mean of 846.5/site. Corridor blue pan traps had a mean of 815.5/site. Both pan traps in the native plantings had the lowest mean abundance of estimated Diptera. The yellow pan traps had a mean of 497.8/site and the blue pan traps had a mean of 188.8/site.

4.2.3 Leaf litter extraction

A total of 17 RTU mites were found in total across each vegetation type (Table 5). The native plantings had a total of 14 RTU mites found. Corridors had a total of 12 RTU mites found, while pastures had the lowest number of mites found at only 8 RTUs found (Figure 22).

Mite RTU 3 was found in large numbers in the native plantings pitfall traps, and had a mean of 6.3/site. Corridors had a mean of 0.8/site and pasture had a mean of 0.3/site (Figure 23). Mite RTU 5 was also found in large numbers in pitfall traps. Pastures had the highest mean of Mite RTU 5 of 9/site. Corridors had a mean of 1.8/site. Native plantings had the lowest mean of 1/site (Figure 24).

4.2.4 Wooden discs

Native plantings had a total abundance of 17 invertebrates found. Corridors decreased in total abundance to 12 invertebrates. Pasture sites had the lowest total abundance of invertebrates found at 11 (Figure 25).

Centipedes had the highest mean abundance in the native plantings of 3.3/site. Corridors had a mean of 1.3/site. No centipedes were found under the wooden discs in the pasture sites (Figure 26).

Slaters were the most abundant in the pastures with a mean of 24.3/site. Corridors decreased with a mean of 6/site. Native plantings had the lowest mean of slaters at 4/site (Figure 27).

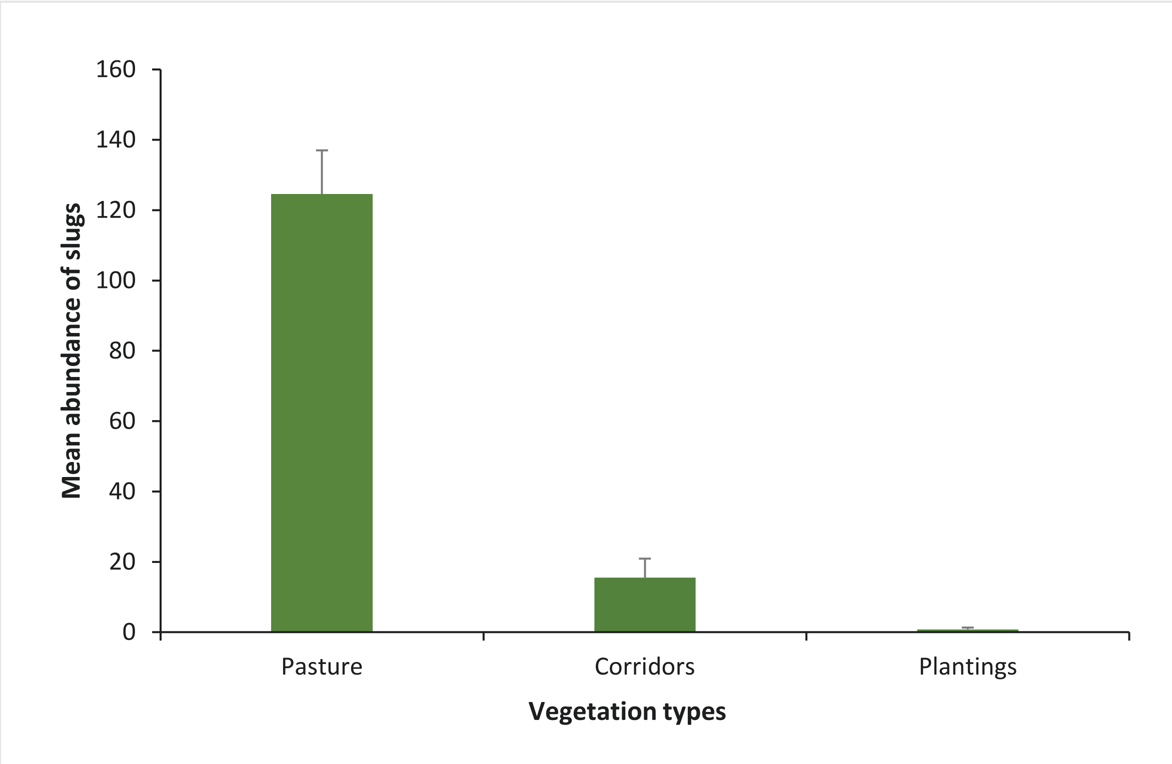

Figure 6: Mean abundance of slugs found in pitfall traps across three vegetation types (N=4)

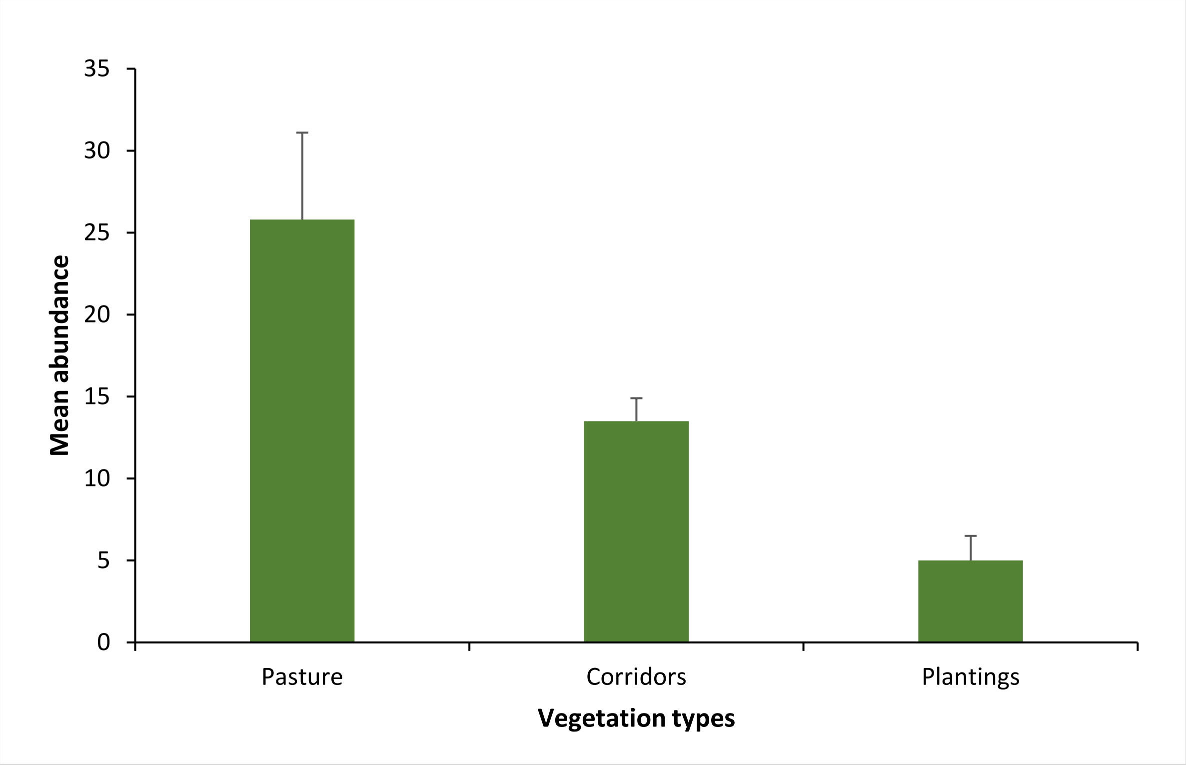

Figure 7: Mean abundance of exotic worms found in pitfall traps across three vegetation types.

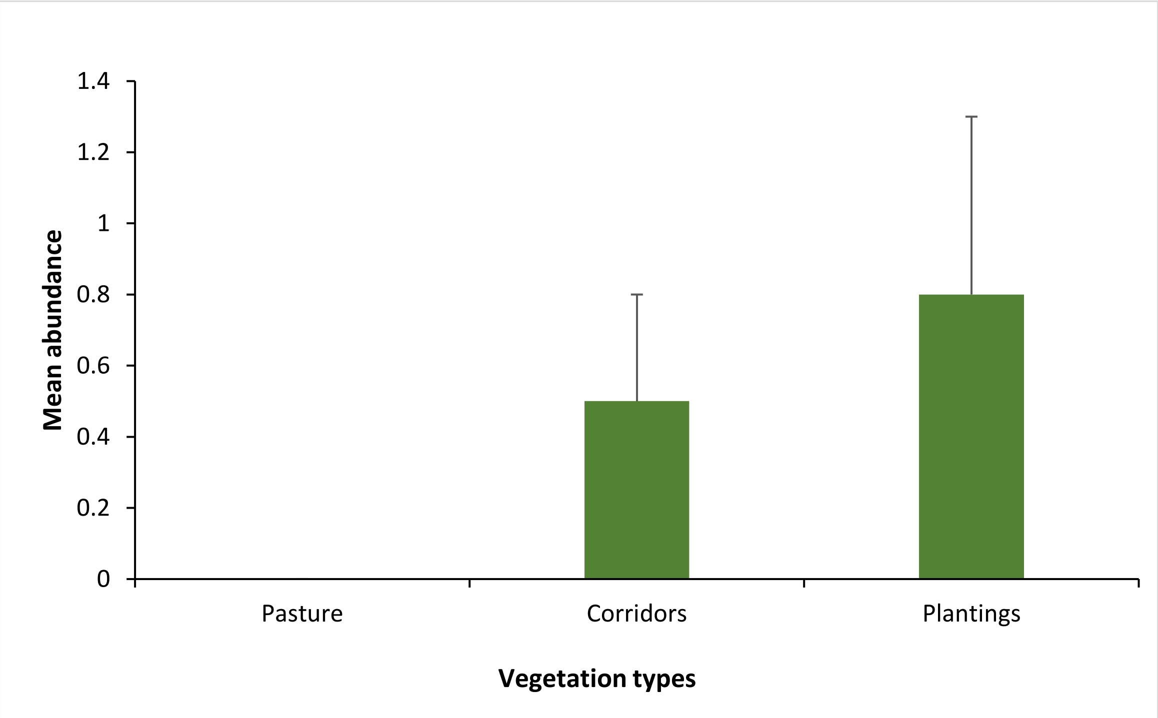

Figure 8: Mean abundance of the native short-legged harvestmen found in pitfall traps across three vegetation types.

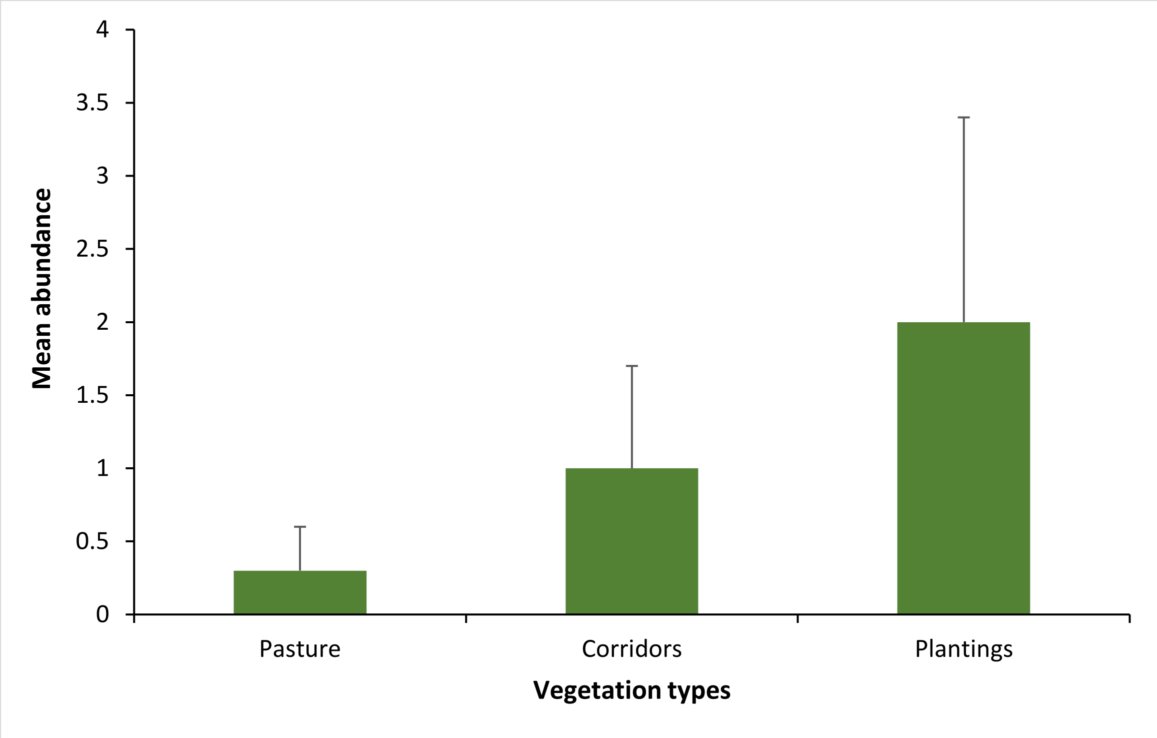

Figure 9: Mean abundance of the European long-legged harvestmen found in pitfall traps across three vegetation types.

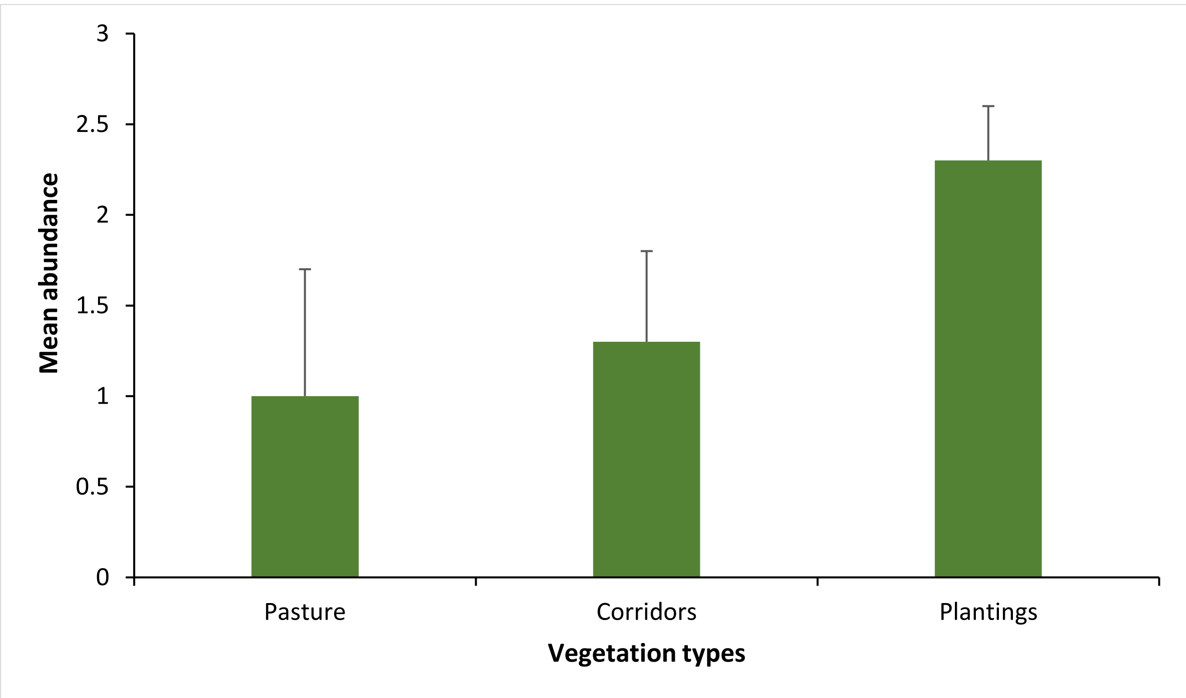

Figure 10: Mean abundance of weevils found in pitfall traps across three vegetation types.

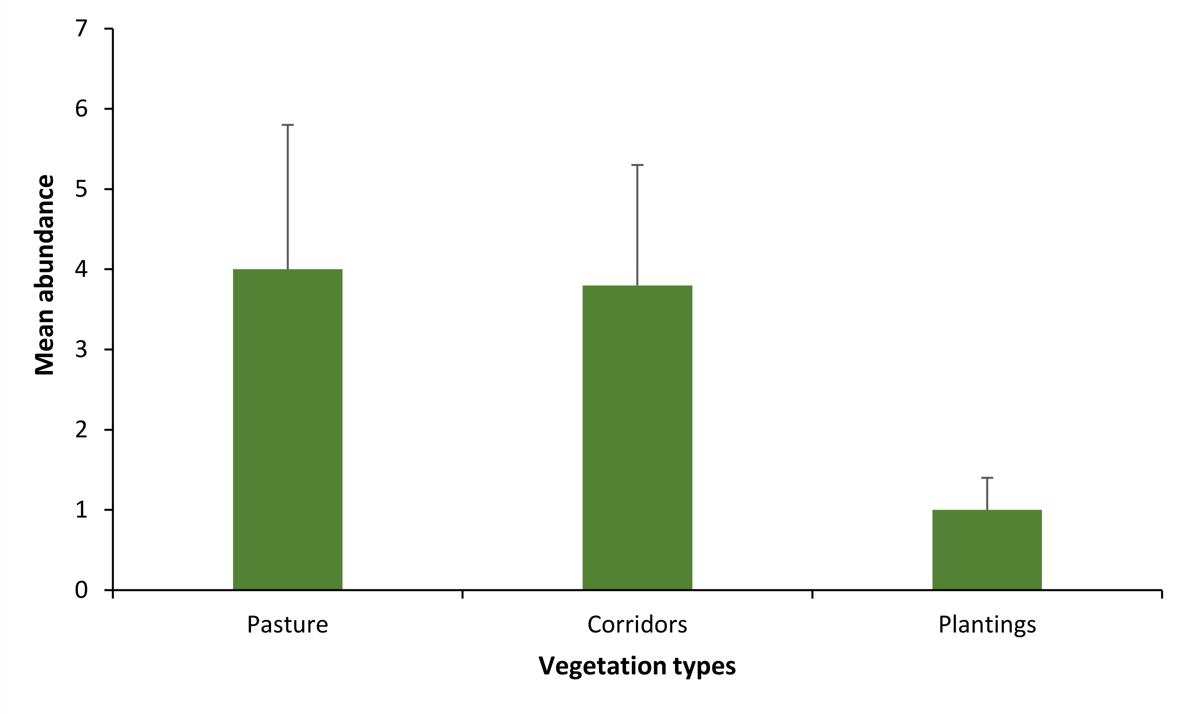

Figure 11: Mean abundance of centipedes found in pitfall traps across three vegetation types.

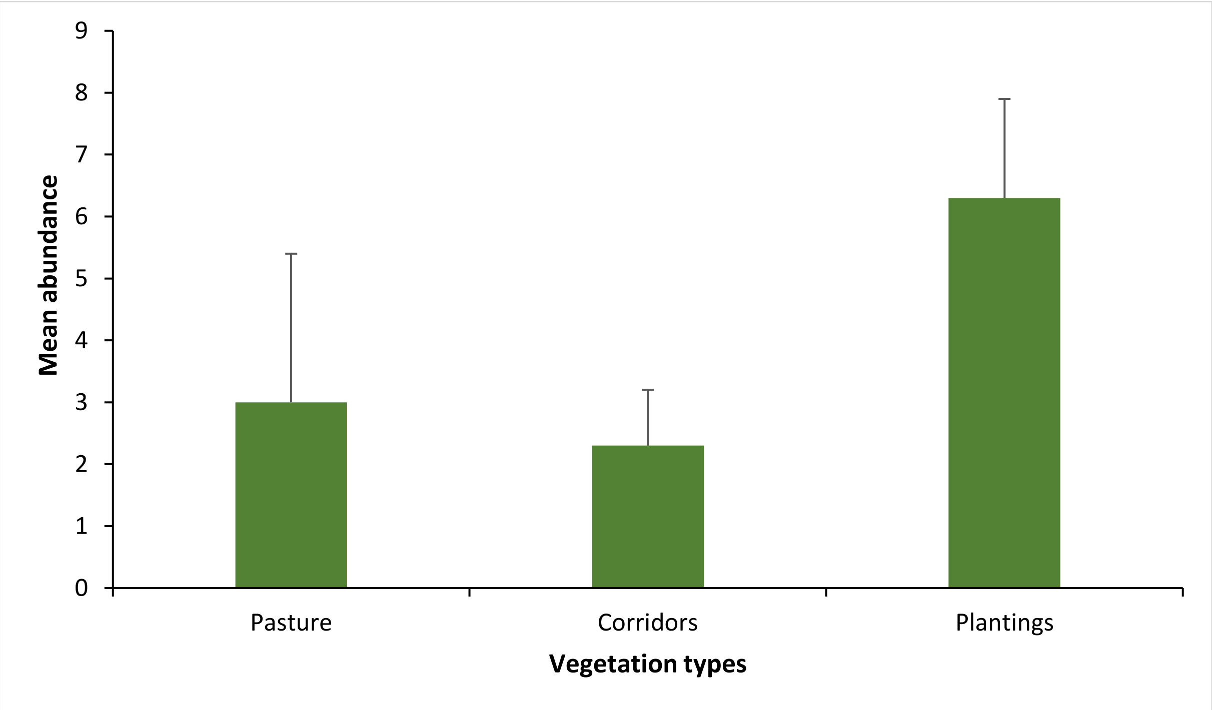

Figure 12: Mean abundance of moths found in pitfall traps across three vegetation sites.

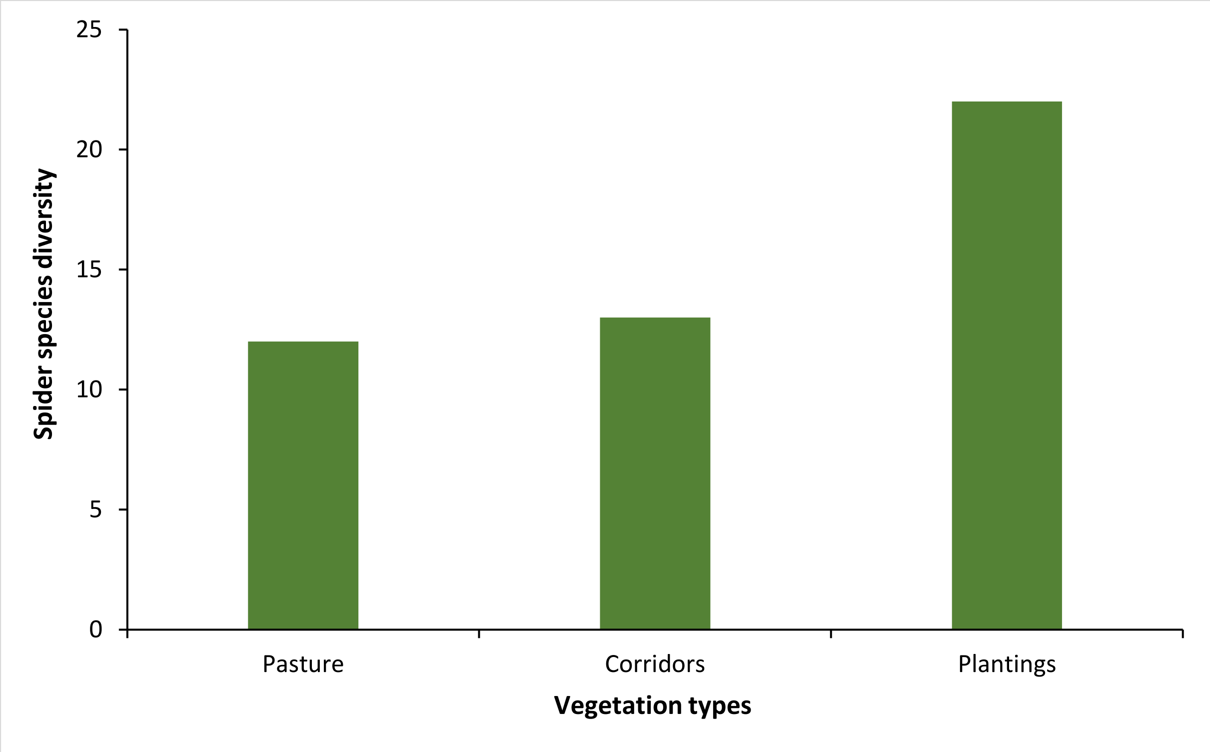

Figure 13: Spider species found in pitfall traps across three vegetation types.

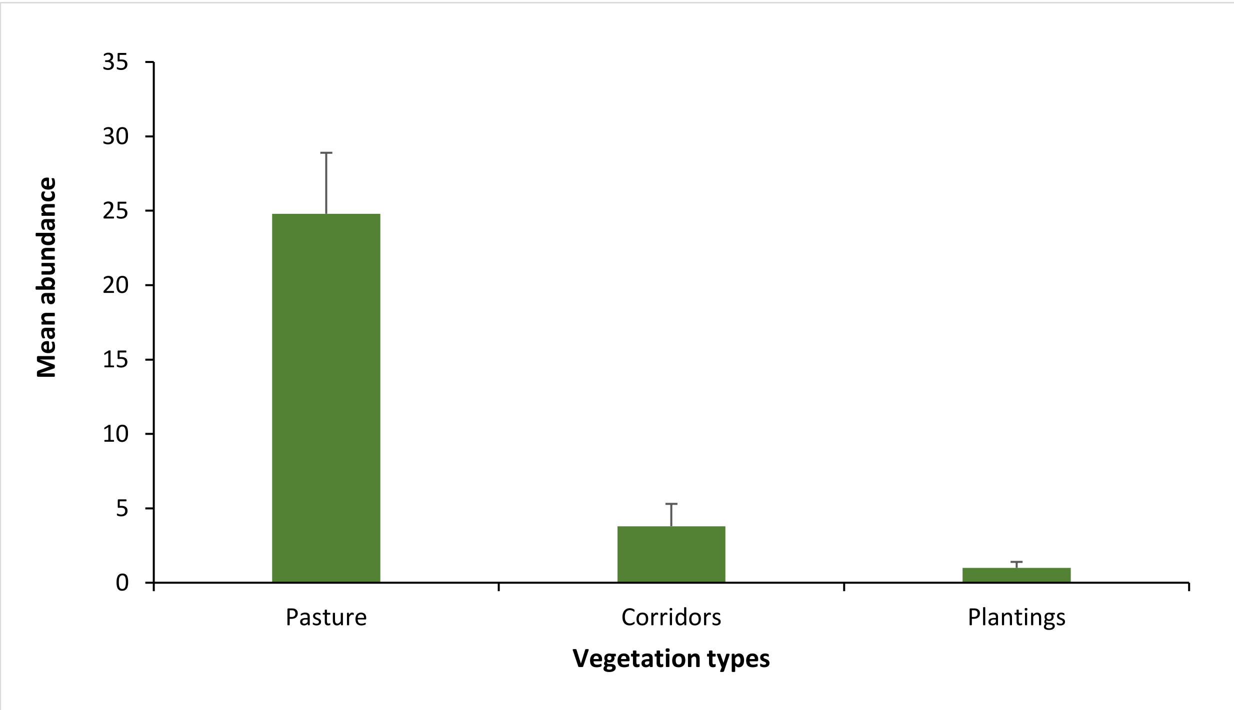

Figure 14: Mean abundance of *Tenuiphantes tenuis* found in pitfall traps across three vegetation types.

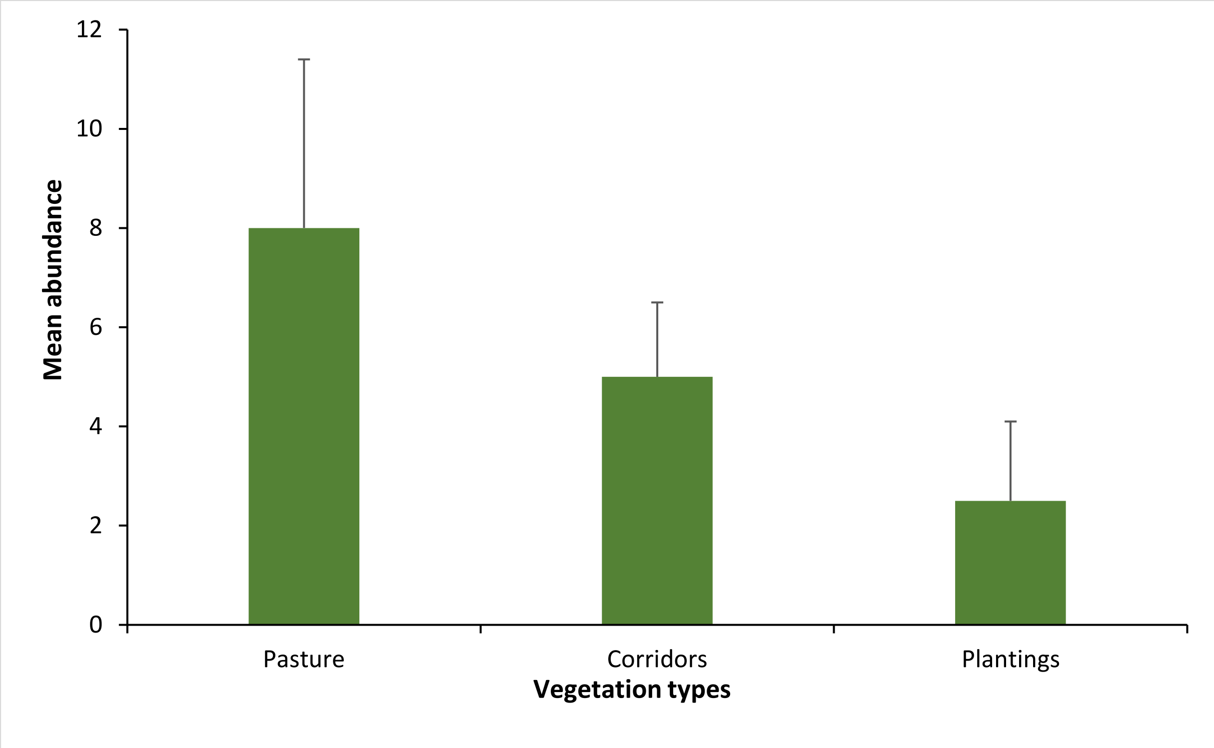

Figure 15: Mean abundance of *Haplinis fucatina* found in pitfall traps across three vegetation types.

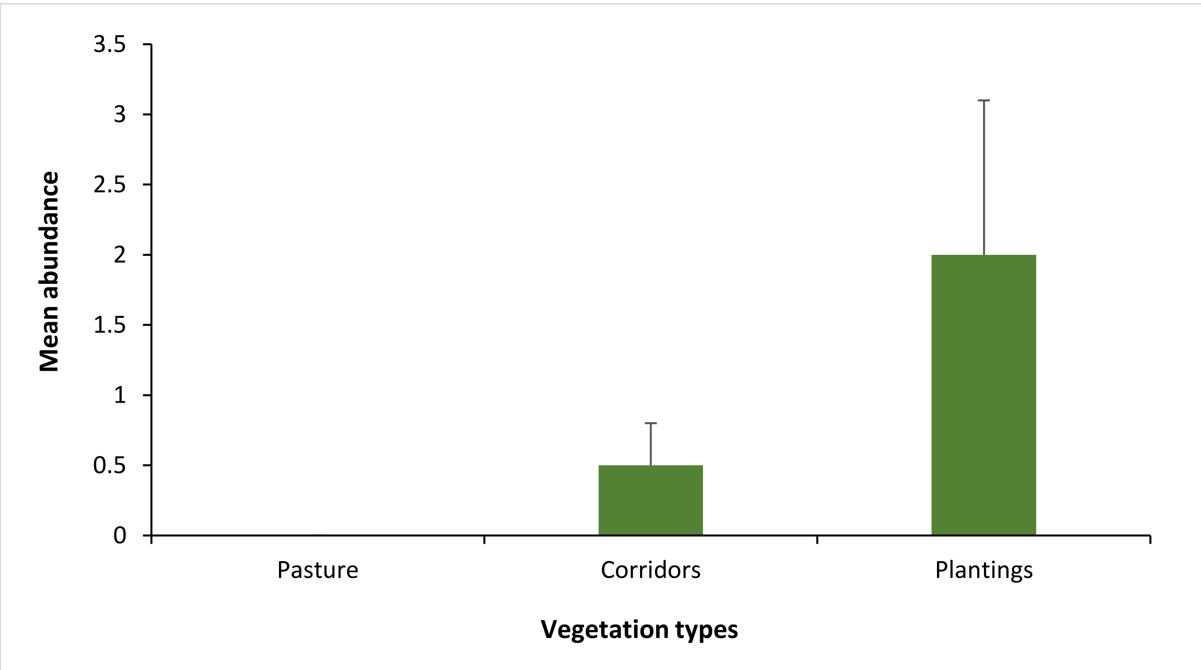

Figure 16: Mean abundance of *Zelanda miranda* found in pitfall traps across three vegetation types.

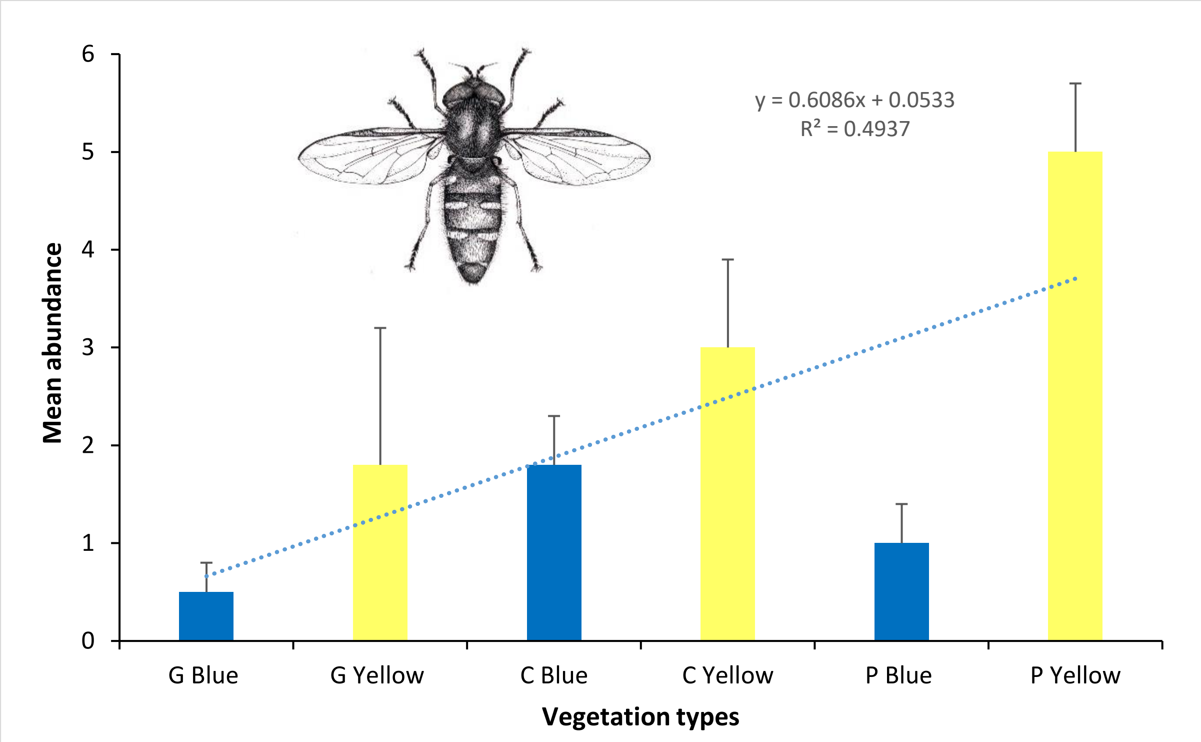

Figure 17: Mean abundance of large hoverfly *Melangyna novaezelandiae* found in pan traps across three vegetation types: (G) grass/pasture, (C) corridors, and (P) native plantings.

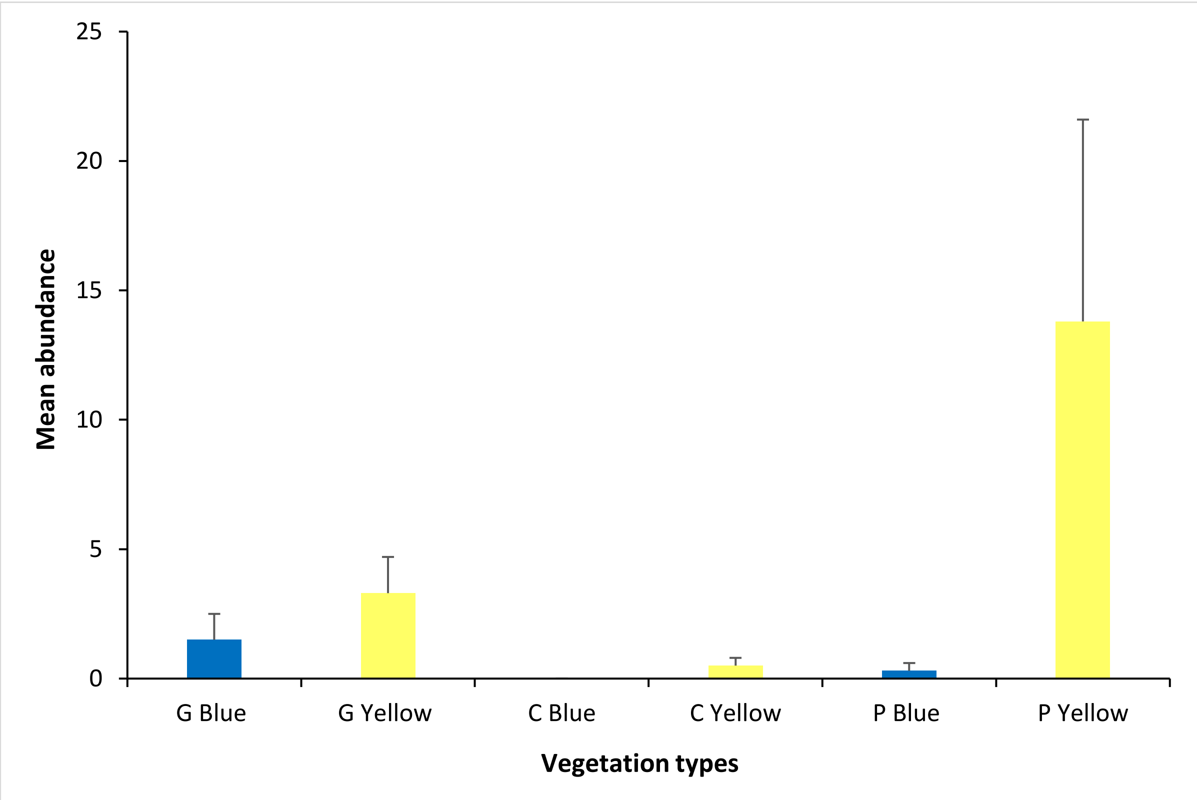

Figure 18: Mean abundance of small hoverfly *Melanostoma fasciatum* found in pan traps across three vegetation types: (G) grass/pasture, (C) corridors, and (P) native plantings.

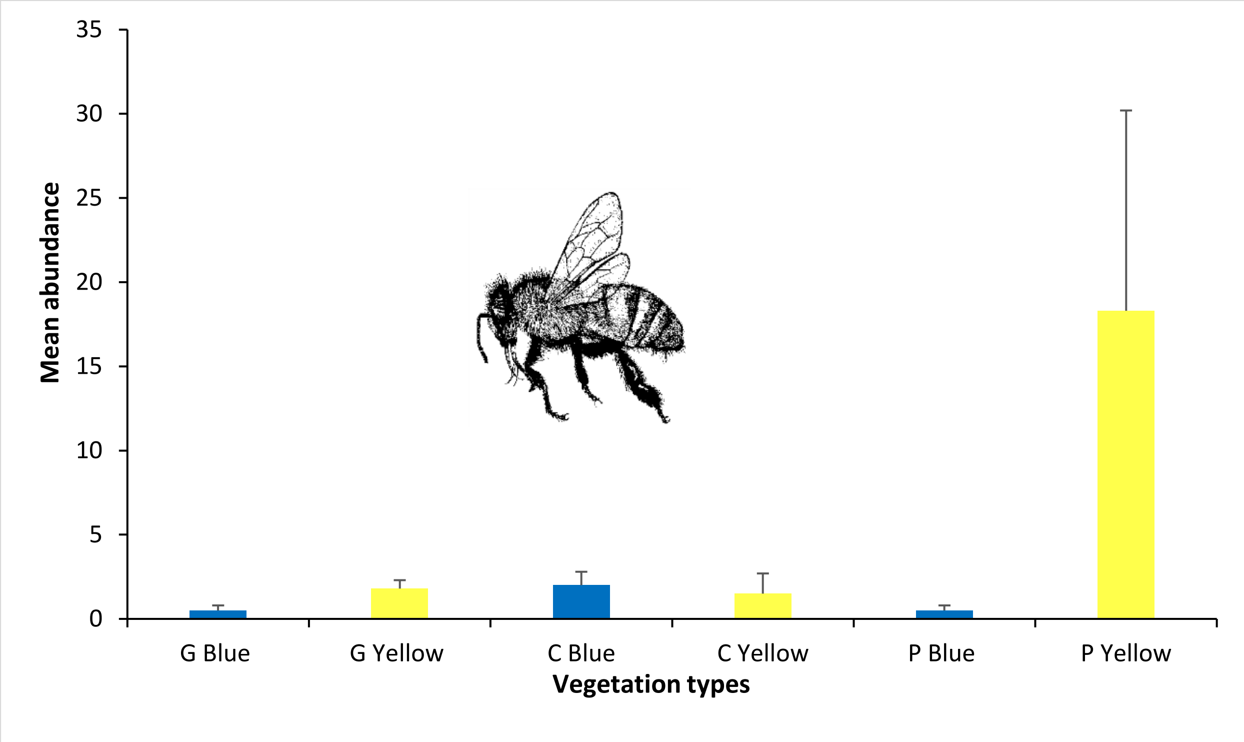

Figure 19: Mean abundance of honeybees found in pan traps across three vegetation types: (G) grass/pasture, (C) corridors, and (P) native plantings.

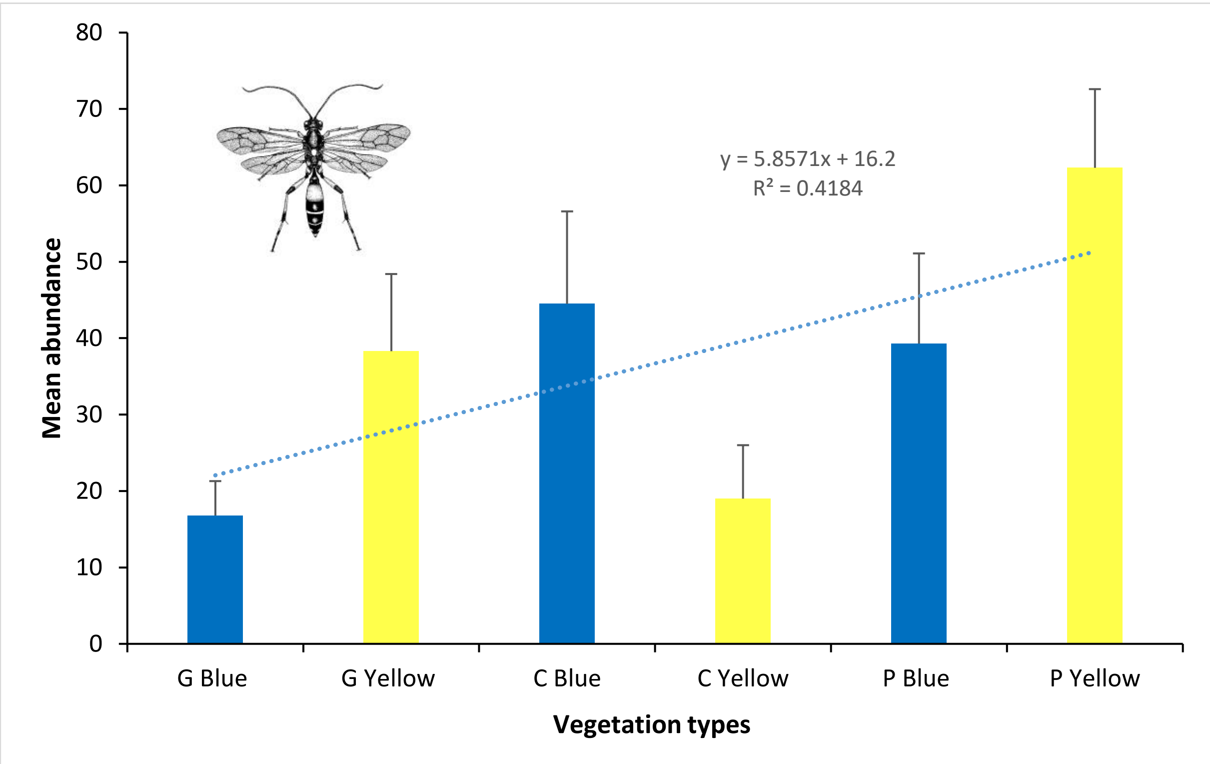

Figure 20: Mean abundance of parasitic wasps found in pan traps across three vegetation types: (G) grass/pasture, (C) corridors, and (P) native plantings.

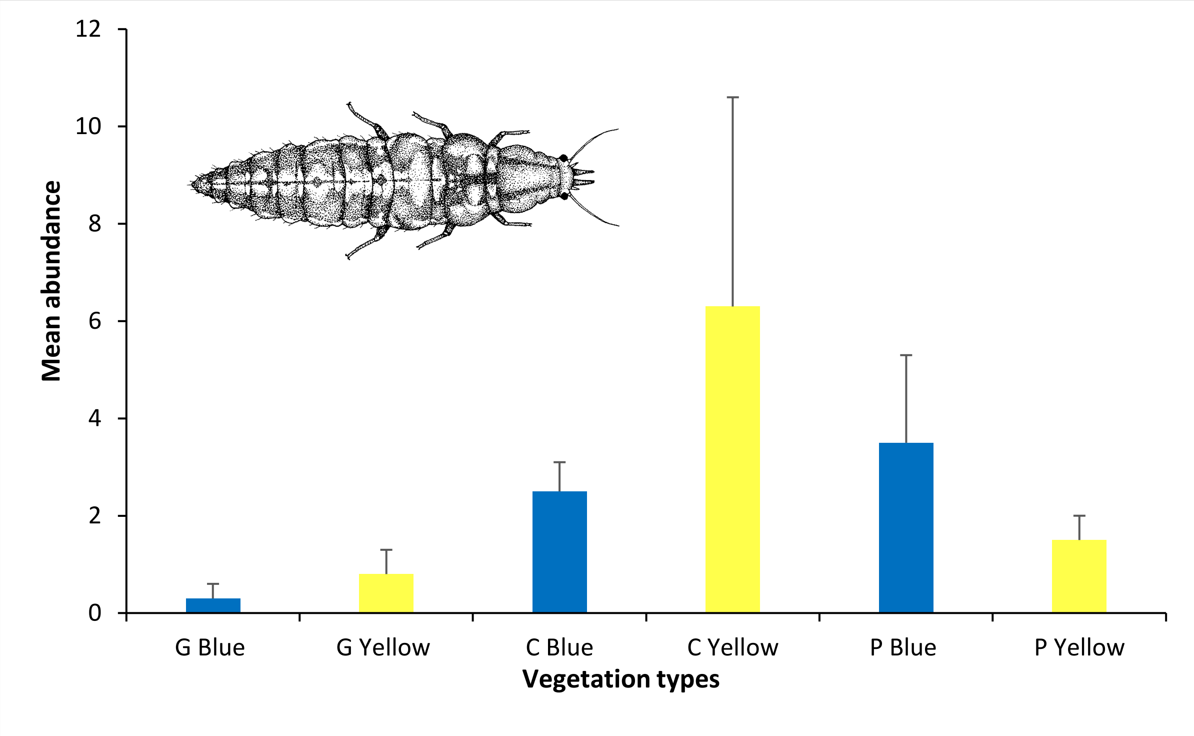

Figure 21: Mean abundance of predacious lacewing larvae found in pitfall traps across three vegetation types: (G) grass/pasture, (C) corridors, and (P) native plantings.

Table 5: Mite species present/absent by leaf litter extraction across three vegetation sites.

		Presence in litter at sites		
Recognisable Taxonomic Unit	**Photo**	**Pasture**	**Corridors**	**Plantings**
RTU 1				X
RTU2		X	X	X
RTU3		X	X	X
RTU4			X	X
RTU5		X	X	X
RTU6			X	X
RTU7			X	
RTU8		X	X	X
RTU9			X	

Recognisable Taxonomic Unit	Photo	Pasture	Corridors	Plantings
RTU10		X	X	X
RTU11			X	
RTU12			X	X
RTU13				X
RTU14		X		X
RTU15				X
RTU16		X		X
RTU17		X		X

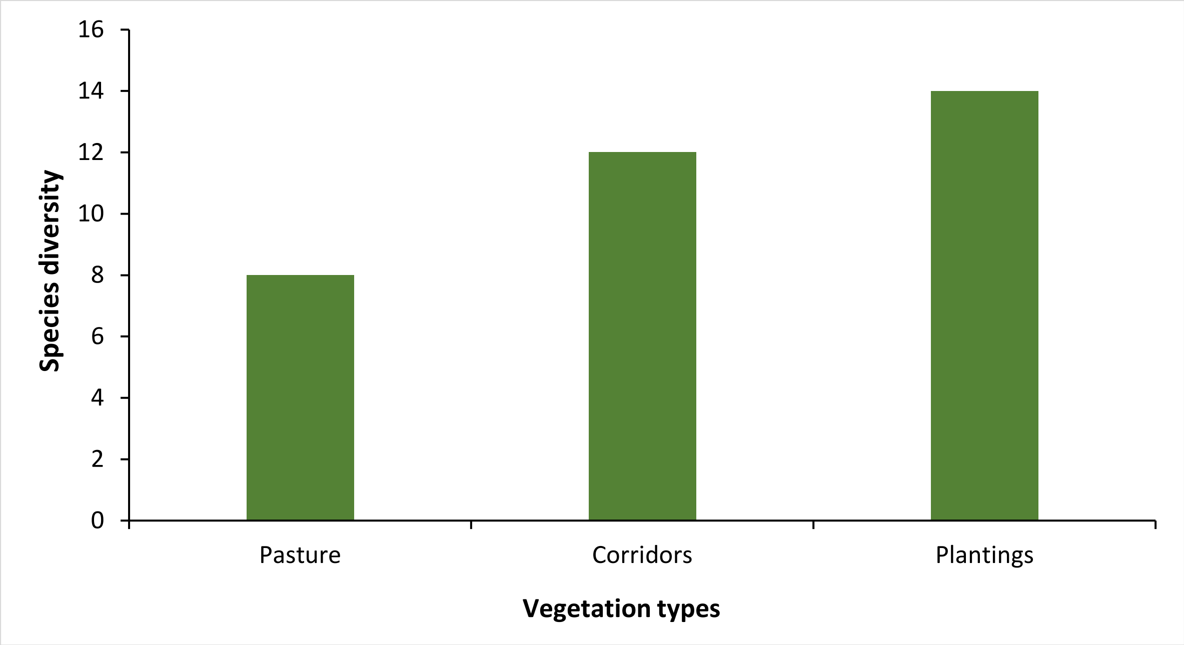

Figure 22: Mite diversity found in leaf litter across three vegetation types.

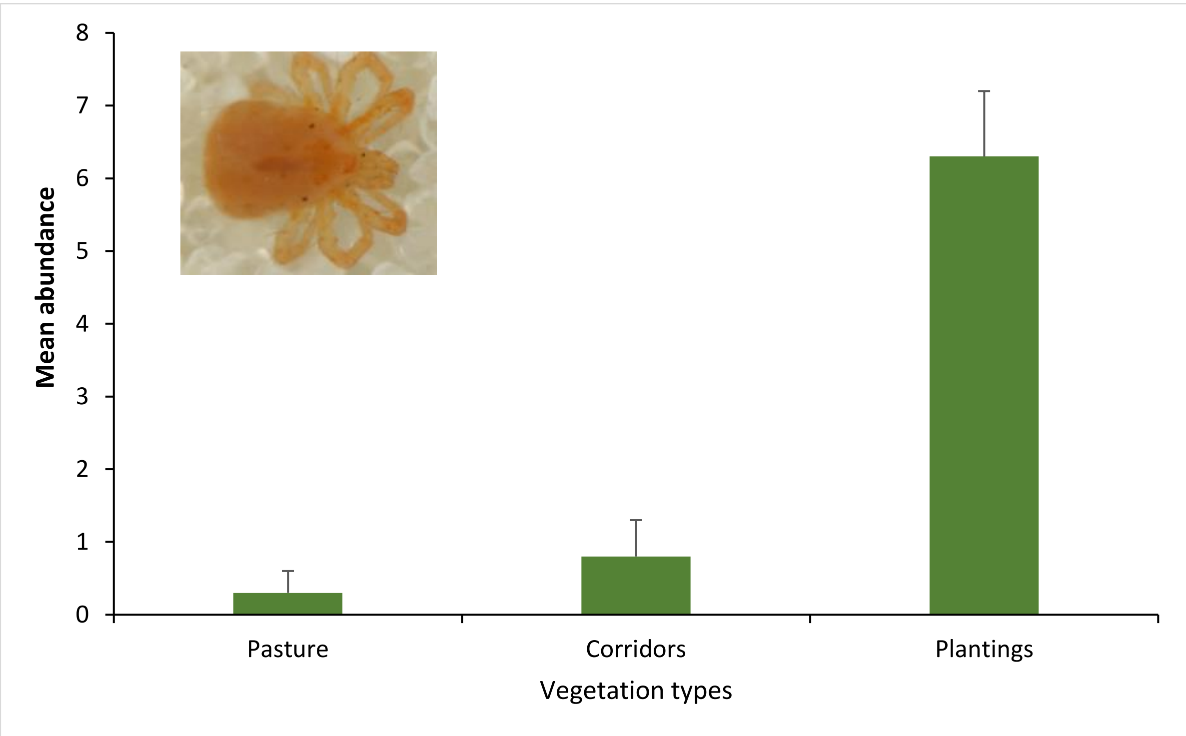

Figure 23: Mean abundance of mite RTU 3 found in pitfall traps across three vegetation sites.

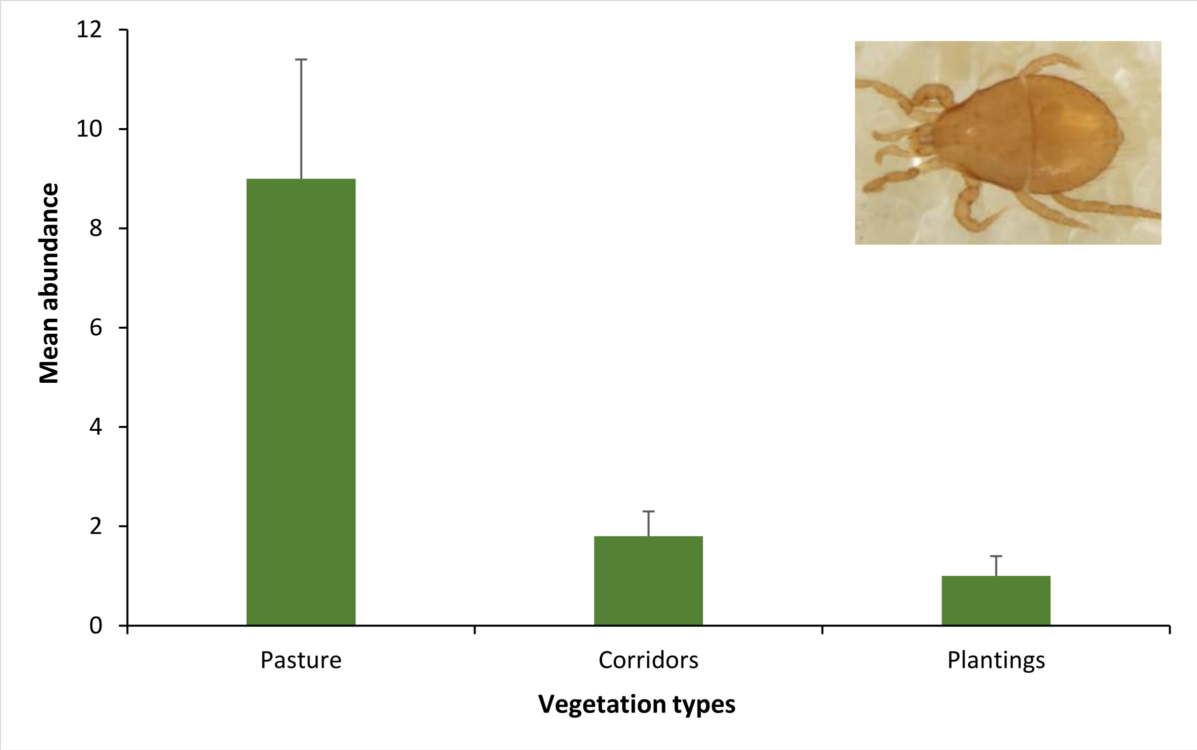

Figure 24: Mean abundance of mite RTU 5 found in pitfall traps across three vegetation sites.

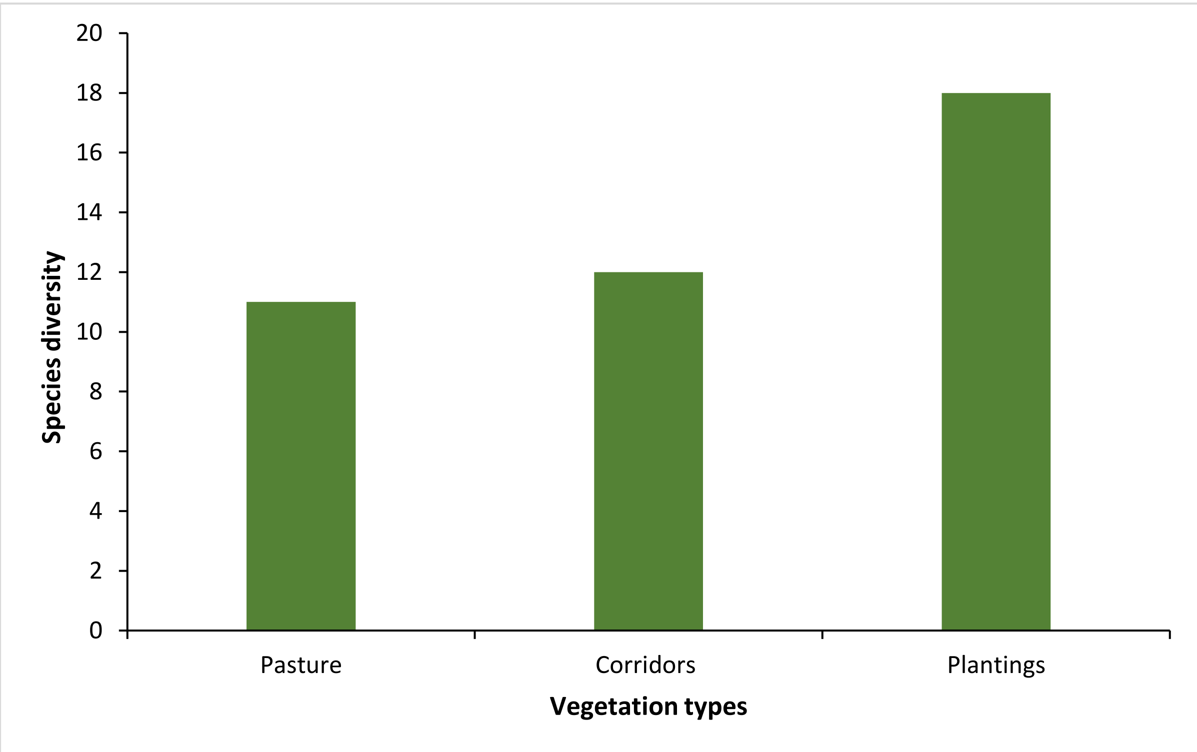

Figure 25: Invertebrate species diversity under wooden discs across three vegetation sites.

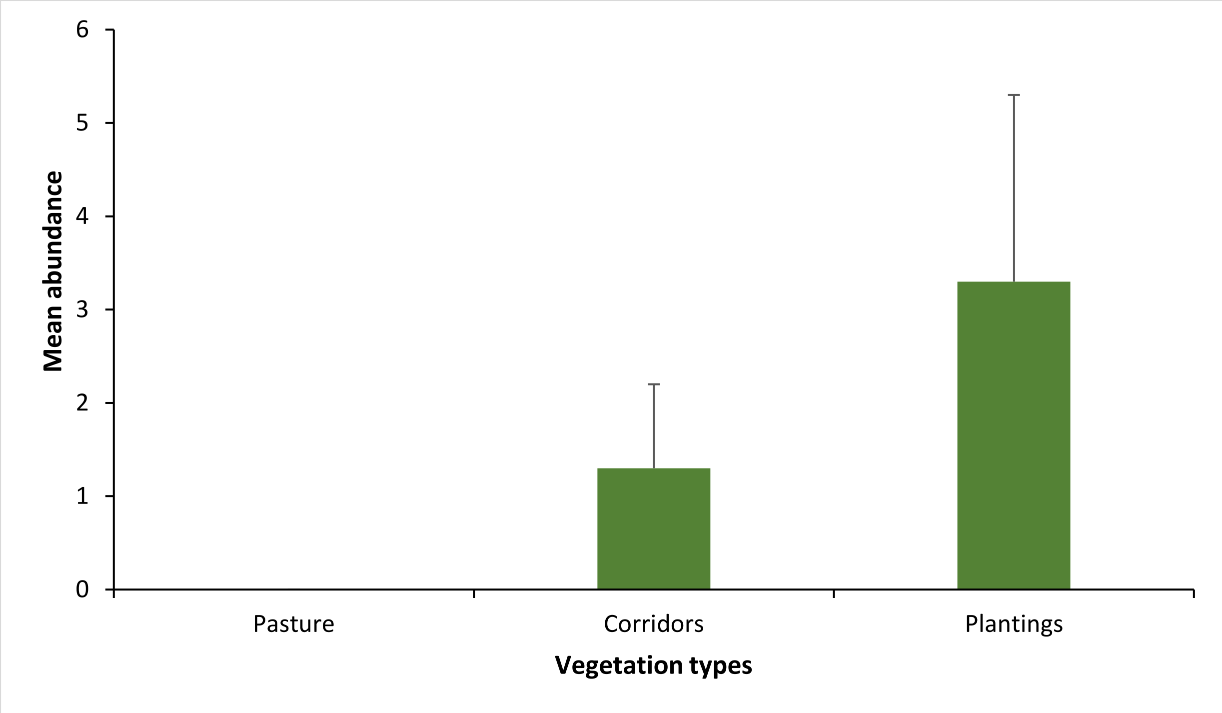

Figure 26: Mean abundance of centipedes found under wooden discs across three vegetation sites.

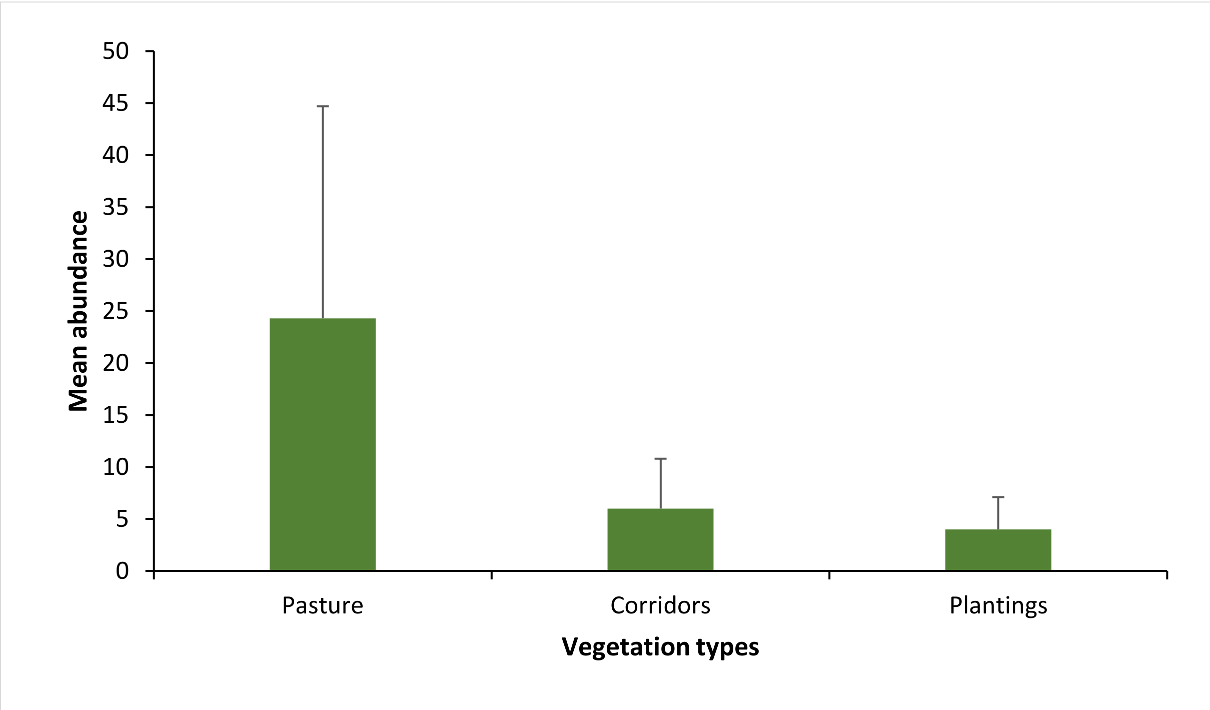

Figure 27: Mean abundance of slaters found under wooden discs across three vegetation types.

5.0 Discussion

This research is likely to be one the first studies of its type to investigate the effect of corner plantings and double fence line plantings on invertebrate diversity and abundance in New Zealand. It has shown that the establishment of the native planting corners and corridors has created native habitat for some invertebrate fauna that would otherwise be absent. The planted corners and corridors had a higher abundance of invertebrates compared to the pasture. The corridors and planted corners had greater insect diversity compared to the pasture showing that native plants can be used in shelterbelts between paddocks if increasing on-farm biodiversity was a goal. Corridors can provide shelter for stock and outside of centre-pivot path (e.g. along boundaries) taller native trees could provide shade in the summer months, as well as encouraging native birds and invertebrates, while providing aesthetic appeal.

5.1 Birds

In 2008 a baseline study was completed to assess the bird population just before the native plants were established. This study used the same method to assess if the native plants had altered the abundance and diversity of the birds previously found. In 2008 there were 19 species found compared to 22 species in 2016 - an increase of 2 native bird species and 1 exotic species. Only pied stilt nests were found in the pasture, while numerous other nests were found in the plantings. Ecosystem services provided by birds include predation (East & Pottinger, 1975) and pollination (Kelly et al. 2010). It is difficult to quantify how much of an impact birds have on pest species, but birds observed in this study, namely pied stilt, starlings and black-billed gulls, do prey on pest species such as grass grub (Table 2). Goldfinches feed on thistle seeds (Horn, 1995) which may reduce weed problems, while native birds such as silvereyes, will help with the pollination of the native plantings on the farm (Kelly et al. 2010). Bellbirds, although not recorded during this study, are also pollinators and are present at Lincoln University and township, only a few kilometres away.

5.2 Invertebrates

Ecosystems services may be provided by invertebrates such as beetles and spiders that will prey on pest species. Spiders, ground beetles (Carabidae) and ladybirds (Coccinellidae) will prey on most insects (Zhang et al. 2007) including pest species such as aphids, slugs, grass grubs and caterpillars. However, this can act as both as an ecosystem service by preying on these pests but can also be an ecosystem disservice by feeding on beneficial insects (Zhang et al. 2007). Ladybirds were observed in large numbers in the pastures in the South block during the bird counts. Ladybirds are predators too, and will often consume insects like aphids and scale insects (Dixon et al. 2007). Invertebrates can also provide pollination. Honeybees are not the only insects that pollinate crops - native hoverfly species are significant pollinators. This study observed the two most common hoverfly species found in New Zealand, *Melanostoma fasciatum* and *Melangyna novaezelandiae* (Appendix 3). Several studies have shown a large diversity of pollen in their gut (Irvin et al. 1999). These hoverfly species are also biocontrol agents, feeding on aphids and small caterpillars (Wratten et al. 1995).

Pastures had the lowest diversity of invertebrates because of low plant diversity and some those species present (e.g. exotic slugs) have negative effects such as eating the vegetation. The plantings had the higher diversity and abundance of invertebrates possibly due to habitat diversity and less habitat disturbance compared to the pasture with stock grazing and the irrigator movement. Invertebrate species mainly present in pasture consisted of slugs, exotic worms, slaters and *Tenuiphantes tenuis* (spider) which could be partially due to soil moisture levels, although *T. tenuis* is a known grassland species. A few dung beetles were found in the pasture that can provide an ecosystem service of breaking down a cow dung and can provide other functions such as nutrient cycling and suppression of certain parasites (Nichols et al. 2008). Larger exotic dung beetles have been imported and are now being introduced to farms around New Zealand (Dymock 1993; Forgie 2009; Le Jambre, 2009; Richardson & Richardson 2000; Ryan et al. 2011). Invertebrate monitoring was also studied using pan traps. Yellow and blue pan traps will mainly attract pollinator insects (Laubertie et al. 2006; Moreira et al. 2016). Pan traps monitor populations of beneficial insects and can evaluate their population recovery after a disturbance (Laubertie et al. 2006). In this study we used both yellow and blue pan traps. Yellow traps caught more species and had a higher abundance of species than the blue pan traps. Hoverflies and honeybees were more abundant in the yellow pan traps, while the parasitic wasps had an equal abundance in both blue and yellow pan traps. Although honeybees may be the most effective pollinators in large flowering crops, other pollinators such as syrphids, are significant particularly since the arrival of Varroa mite (Rader et al. 2009).

Three biocontrol agents were observed in the field during sampling – spider gorse mite, Canada thistle gall-fly and green thistle beetle. *Tetranychus lintearius,* a spider gorse mite, was observed on gorse (*Ulex europaeus*) near the shelter belts on the farm. The gorse mite *T. lintearius* feeds on gorse leaves which reduces photosynthetic activity within the plant (Marriott et al. 2013; Davies et al. 2007). *Urophora cardui,* also known as the Canada thistle gall fly, was observed on some Canada thistles (*Cirsium arvense*) in the pasture. Adult flies lay eggs on the stem of the plant where the larvae will hatch and burrow into the stem, in which a gall is formed preventing nutrient uptake by the plant. (Peschken and Harris, 2012). *Cassida rubiginosa*, green thistle beetle was observed on thistles in the pasture. The larvae of this beetle causes the most damage to the thistle by defoliating the leaves (Ang et al. 2006; Tipping, 1993).

6.0 Conclusions

The results of this study suggest that native corner plantings and corridors on agricultural land provide evidence of an increase in the abundance and diversity of some invertebrates and birds. Many of the birds and invertebrates attracted by the plantings will provide ecosystems services such as pollination and pest control, but for many species of invertebrates the diet is still unknown. Pollinators that increased with native plantings included honey bees (*Apis mellifera*), native bees (*Leioproctus* & *Lasiglossum* spp.), hover fly species (*Melangyna novaezelandiae* & *Melanostoma fasciatum*), large fly species and parasitic wasp species. These parasitic wasp species along with the hoverflies also provide biocontrol of a large range of pest insects including aphids, diamond-backed moth, and cabbage white butterfly amongst others. Other taxa such as the exotic slugs (*Derocerus* spp.) were significantly more abundant in the grass/pasture than in the corridor or native corner plantings. This may be remain the case as the irrigated pasture provides a preferred moist environment. Native plantings and corridors are likely to provide refugia for the slug predator such as ground beetles (Carabidae) and birds such as blackbirds, song thrushes, etc. Native plantings can also provide shelter and shade for stock, shade drains to reduce water temperature and algae, reduce runoff of nutrients and stabilise banks. The plantings also provide a more diverse landscape, increasing the aesthetic value of the farm through attractive trees and wildlife.

Future monitoring to observe changes to the bird and invertebrate fauna at these sites and attributing a dollar value to the ecosystem services and disservices provided to agriculture (Zhang et al. 2007) would be beneficial in determining the long-term benefits of native plantings.

7.0 Recommendations for further study

Further studies at the Lincoln University Demonstration Dairy Farm could include:

- Monitoring for moths and aquatic insects using light traps. Moths are good pollinators and provide food for insectivores such as grey warblers and fantails. Assessment of this fauna will give a better assessment of the farm's biodiversity.
- Earthworm sampling in pasture, corridor and the corner native plantings will provide an insight into the endemic and exotic earthworms in these habitats. Research has shown that native earthworms are found in greater densities in native sites and can increase following native restoration planting.
- Soil analysis could be conducted to confirm the native planting sites are not limited by degraded soil. An assessment of the pasture and corridors sites could also be completed as there maybe phytoremediation (some plants can remove, stabilize, or destroy contaminants in the soil and groundwater) effect by planting some natives.
- Continuation of this study would continue to build on existing knowledge.
- Analysis of bird foraging in pasture as bird pecks were observed in several cowpats on the farm. Research could look at what are the main biological contributors to the dung breakdown e.g. earthworms, fly species, beetles, fungi, birds, etc?
- Take some of the key species identified from this report and calculate the ecosystem service values they provide.

8.0 Recommendations for planted sites

- Add some butterfly host species to the plant mix e.g. Ongaonga (*Urtica ferox*), for red and yellow admiral butterflies. Pohuehue (*Muehlenbeckia complexa*) for copper butterfly (*Lycaena* spp.), native skink species (*Oligosoma* spp.) and native *Muehlenbeckia* aphid (*Aphis cotterii*).
- Plant some lizard species particularly in the drier, stonier and open corners to the north. Species to include: mikimiki (*Coprosma propinqua*, *Coprosma crassifolia*), porcupine shrub (*Melicytus alpinus*), pohuehue (*Muehlenbeckia complexa*) and *Muehlenbeckia astonii.* Wooden discs can be added to these sites for lizard refugia and overwintering sites.
- Removal of weeds including: gorse, broom, willow and ivy

9.0 Acknowledgements

This study would not have been possible without the help of the following people and organisations. Our appreciation and thanks to:

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- Lincoln University – Funding and equipment.
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- Myles Mackintosh – Assisted with the bird counts.

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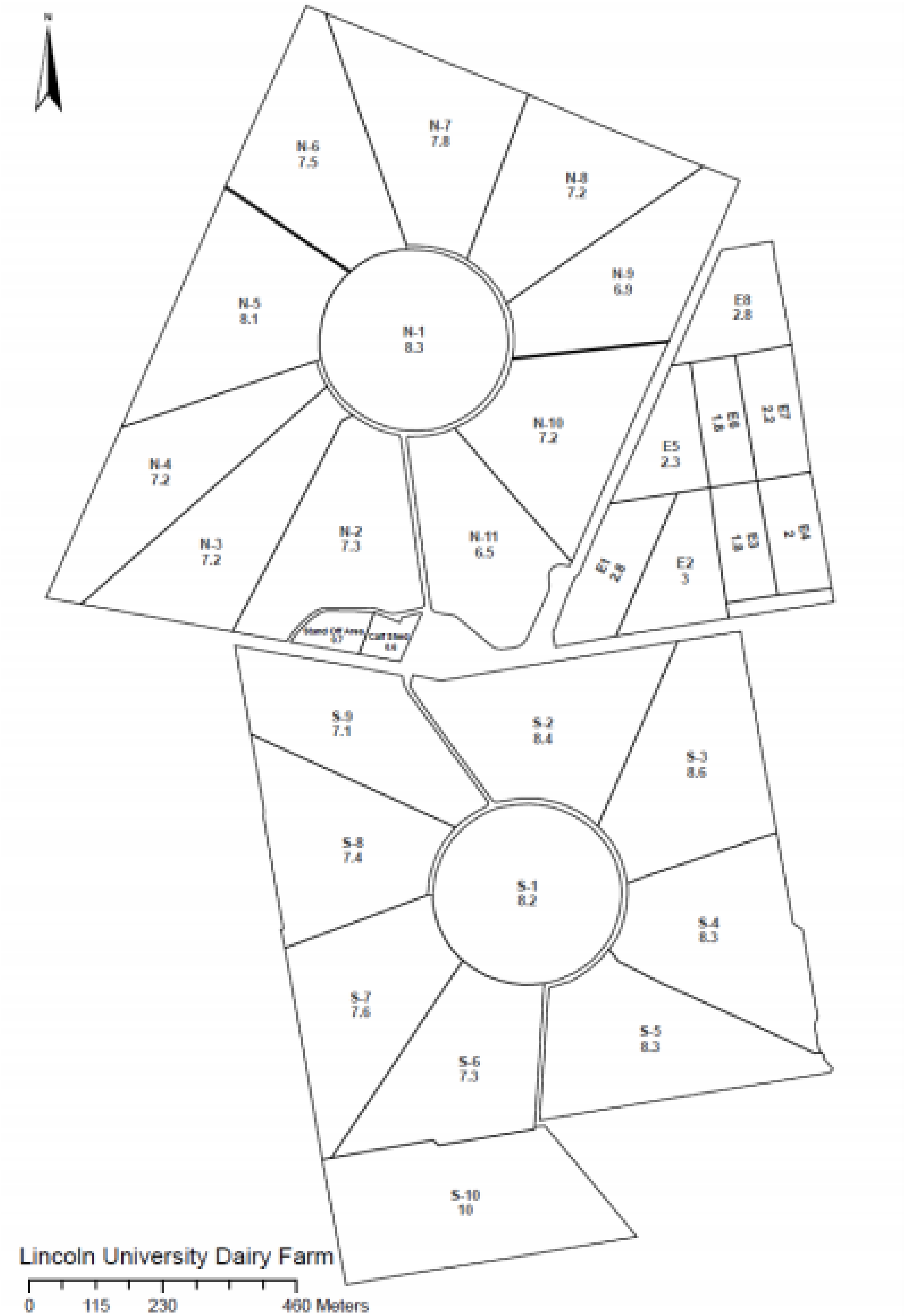
11.0 Appendices

Appendix 1: Plan of Lincoln University Demonstration Dairy Farm.



Appendix 2: Native species planted at the Lincoln University Demonstration Dairy Farm.

Species Name	**Common Name**
Anemathele lessoniana	Windgrass
Carex secta	Pukio / sedge
Carmichaelia australis	NZ broom, makaka
Cassinia vauvillers	Tauhinu
Chionochloa rubra	Red Tussock
Coprosma crassifolia	Thick leaved mikimiki
Coprosma propinqua	Mikimiki
Coprosma propinqua hbrid	Hyrid Coprosma
Coprosma rigida	Mikimiki
Coprosma robusta	Karamu
Coprosma rubra	Mikimiki
Coprosma virescens	Mikimiki
Coprosma wallii	Mikimiki
Cordyline australis	Ti kouka / Cabbage tree
Cortaderia richardii	Toetoe
Dodonaea viscose	Akeake
Griselinia littoralis	Broadleaf
Hebe salicifolia	Koromiko
Hoheria augustifolia	Narrowleaved hourhere
Isolepis nodosa	Oiooi / Jointed rush
Kunzea ericoides	Kanuka
Libertia ixiodes	Mikoikoi
Muehlenbeckia astonii	Rare shrub pohuehue
Muehlenbeckia complexa	Shrub pohuehue
Myrsine divaricata	Weeping mapou
Olearia fragrantissima	Fragrant olearia
Olearia paniculata	Golden akeake
Phormium tenax	Harakeke / Flax
Phormium cookianum	Mountain Flax
Pittosporum eugenioides	Tarata / Lemonwood
Pittosporum tenuifoliium	Kohuhu / Matipo
Plagianthus regius	Manatu / Ribbonwood
Plagianthus divaricatus	Saitmarsh Ribbonwood
Podocarpus totara	Totara
Pseudopanax arboreus	Five finger
Pseudopanax crassifolius	Lancewood / horoeka
Pseudopanax ferox	Fierce Lancewood
Sophora microphylla	Kowhai
Teucridium parvifolium	NZ Shrub verbena

Appendix 3: Invertebrate species list with collection method, location & ecosystem service (*=predator, $^{+}$=dung removal, ^{P}=pollinator, b= plant biocontrol agent

Order	Family/Subfamily	Species	Common name	Collection method /Location
ARANEAE	Anapidae	*Zealanapis* sp.*	Ground Orb weavers	Pitfall trap in the grassland
	Araneidae	*Eriophora pustulosa* *	Common garden orb-web spider	Seen in the planting sites
	Clubionidae	*Clubiona contritia**	Leaf curling sac spider	Blue pan trap in the plantings
		Clubiona huttoni	Leaf curling sac spider	Pitfall trap and leaf litter in the plantings
		Clubiona sp.*	Leaf curling sac spider	Pitfall trap in the planting sites
	Desidae	*Badumna longinqua**	Grey House spider	Blue pan trap in the pasture sites
	Dysderidae	*Dysdera crocata**	Slater spider	Yellow pan trap in the plantings
	Gnaphosidae	*Anzacia gemmea**	Silvery Vagabond spider	Yellow and blue pan trap in the corridors
		*Nauhea tapa**	Ground spider	Pitfall trap in the planting sites
		*Zelanda kaituna**	Ground spider	Pitfall trap in the planting sites
		*Zelanda miranda**	Ground spider	Pitfall traps in the plantings and corridors sites
		Zelanda sp. *	Ground spider	Under wooden disc in the planting sites
	Idiopidae	*Cantuaria* sp. *	Trapdoor spider	Blue pan trap in the planting site and under wooden disc in the pasture
	Lamponidae	*Lampona cylindrata**	White tailed spider	Pitfall trap in the planting sites
	Linyphiidae	*Diplocephalus cristatus**	Common money spider	Pitfall trap in the planting sites
		*Erigone wiltoni**	Dwarf weaver spider	Pitfall trap in the pasture and corridor sites

		*Laetesia germana**	Dwarf weaver spider	Pitfall trap in the planting site
	Mynogleninae	*Haplinis fucatina**	Dwarf weaver spider	Pitfall traps in the planting, corridor and pasture sites. Blue pan trap in the planting site
	Mynogleninae	*Haplinis mundenia**	Dwarf weaver spider	Pitfall trap in the corridors sites
	Mynogleninae	*Haplinis* sp. *	Dwarf weaver spider	Pitfall trap in the pasture sites
	Linyphiidae	*Tenuiphantes tenuis**	Dwarf weaver spider	Pitfall traps in the pasture, corridors, and planting sites. Blue pan trap in the planting and pasture sites
	Lycosidae	*Allotrochosina schauinslandi**	Brown wolf spider	Pitfall trap in the corridor sites
		*Anoteropsis hilaris**	Garden wolf spider	Pitfall trap in the pasture, corridors, and planting sites
		Anoteropsis sp. *	Wolf spider	Pitfall trap in the pasture, corridors, and planting sites
	Micropholcommatidae / Taphiassinae	*Taphiassa punctata**	Spider	Pitfall trap in the planting and corridor sites
	Pisauridae	*Dolomedes minor**	Nursery web spider	Pitfall trap in the planting and corridor sites
	Salticidae	*Holoplatys* sp. *	Chink jumping spider	Sited on a fence post in the P3 corner
		*Trite auricoma**	Golden brown jumping spider	Leaf litter sample in P3 (plantings)
		*Trite planiceps**	Black-headed jumping spider	Leaf litter sample in P2 (plantings corner)
	Stiphidiidae	*Cambridgea quadromaculata**	Sheetweb spider	Blue pan trap in the planting sites
	Tetragnathidae	*Tetragnatha* sp. *	Long-jawed orbweaver spider	Pitfall trap in the corridor sites
	Theridiidae	*Cryptachaea blattea**	Tangle web spider	Pitfall trap in the pasture, corridor and planting sites

		*Cryptachaea veruculata**	Diamond comb footed spider	Pitfall trap in the pasture and planting sites
		*Steatoda capensis**	Black cobweb spider	Under wooden disc in pasture, corridor, and planting sites
	Thomisidae	*Sidymella angulata**	Square ended crab spiders	Pitfall trap in the planting site
	Zoropsidae	*Uliodon albopunctatus**	Large brown vagrant spider	Under wooden disc in P2 (planting corner)
		Uliodon sp. *	Vagrant spider	Pitfall trap in the planting sites
COLEOPTERA	Cerambycidae	*Oemona hirta*	Lemon tree borer	Pitfall trap in the planting sites
	Chrysomelidae	*Cassida rubiginosa*	Green tortoise thistle beetle	Observed in the pasture sites near the fence lining
	Coccinellidae	*Coccinella undecimpunctata**	Eleven spotted ladybird	Pitfall trap in the pasture sites. Yellow pan trap in the planting, corridor, and pasture.
	Curculionidae	*Listronous bonariensis*	Argentine stem weevil	Found in blue pan trap and in pitfall traps in pasture
	Curculionidae	*Sitona lepidus*	Clover root weevil	Found in pitfall trap in the pasture
	Elateridae	*Conoderus exsul*	Pasture wireworm (Click beetle)	Pitfall trap in the planting and corridor sites
	Entiminae	*Naupactus* sp.	White-fringed weevil	Found in pitfall trap in the pasture and plantings
	Scarabaeidae	*Costelytra zealandica*	Grass grub beetle	Yellow pan trap in the planting and pasture sites
		Saphobius sp.[+]	Dung beetles	Pitfall trap found in the pasture site.
	Staphylinidae	Several species	Rove beetles	Pitfall trap in the planting, corridor, and pasture sites
	Zopheridae	*Pristoderus bakewelli*	Cylindrical bark beetles	Pitfall trap in the planting sites
DERMAPTERA	Forficulidae	*Forficula auricularia**	Common earwig	Found in blue and yellow pan traps in

				pasture, corridors, and plantings
DIPTERA	Calliphoridae	*Calliphora vicina*[P]	Bluebottle fly	Blue and yellow pan trap in the planting, corridor, and pasture sites
	Phoridae	Several species	Phorid flies	Blue and yellow pan trap in the planting, corridor, and pasture sites
	Syrphidae	*Eristalis tenax*[P]	Drone fly	Blue pan trap and yellow pan trap in the planting and corridor sites
		*Melanostoma fasciatum**[P]	Hoverfly	Blue trap and yellow trap in the planting, corridor, and pasture sites
		*Melangyna novaezelandiae**[P]	Hoverfly	Blue pan trap and yellow pan trap in the planting and corridor sites
	Stratiomyidae	*Beris* sp.	Green solider fly	Blue and yellow pan trap in the planting sites
	Tephritidae	*Urophora cardui* [b]	Canada thistle gall fly	Observed in the pasture sites
HYMENOPTERA	Apidae	*Apis mellifera*[P]	Western honey bee	Blue and yellow pan trap in the planting sites
		Bombus terrestris[P]	Buff-tailed bumblebee	Found in yellow pan traps in the planting sites
	Colletidae	*Leioproctus* sp.[P]	Plaster bee	Blue and yellow pan trap in the planting sites
	Halictidae	*Lasioglossum* sp.[P]	Sweat bee	Blue and yellow pan trap in the planting sites
LEPIDOPTERA	Crambidae	*Orocrambus flexuosellus*	Grass moth	Blue pan trap in the planting site
		Scoparia diphtheralis	Moss moth	Photographed in planted area
	Geometridae	*"Hydriomena" deltoidata*		Photographed in planted area

	Nymphalidae	*Danaus plexippus*[P]	Monarch butterfly	Observed in the native plantings site 1
		Vanessa itea[P]	Yellow admiral	Observed in the native plantings site 3
	Pieridae	*Pieris rapae*[P]	White butterfly	Blue pan trap in the planting site
MANTODEA	Mantidae	*Orthodera novaezealandiae**	New Zealand Praying Mantis	Observed in native planting site 4
NEUROPTERA	Hemerobiidae	Unidentified species*	Brown Lacewing	Blue and yellow pan trap in the pasture, corridors, and plantings site.
ODONATA	Coenagrionidae	*Xanthocnemis zealandica**	Red damselfly	Observed in native planting site 2
	Lestidae	*Austrolestes colensonis**	Blue damselfly	Observed in native planting site 2
OPILLIONES	Phalangiidae	*Phalangium opilio**	European harvestman	Found in blue pan traps and pitfall traps in pasture, corridors, and plantings
	Triaenonychidae	Unidentified species*	Short legged harvestman	Found in the pitfall trap in the planting site 3 and 4
TROMBIDIFORMES	Tetranychidae	*Tetranychus lintearius*[b]	Gorse spider mite	Observed in the pasture sites near the fence line
LIZARD				
SQUAMATA	Scincidae	*Oligosoma polychroma**	Common skink	Found in a pitfall trap in the planting site 4

Appendix 4: Photos of selected fauna found at Lincoln University Demonstration Dairy Farm

Garden wolf spider *Anoteropsis hilaris* is a common grassland predator species

Gorse spider mite *Tetranychus lintearius* is a biocontrol agent of gorse

Green tortoise thistle beetle larva *Cassida rubiginosa* is a useful biocontrol agent of thistles

Green tortoise thistle beetle *Cassida rubiginosa* is a useful biocontrol agent of Californian thistle

Empty egg case of the praying mantis (*Orthodera novaezealandiae*)

Native moth *"Hydriomena" deltoidata*

Nursery web spider *Dolomedes minor* is a large generalist predator

Short-legged harvestman (Triaenonychidae) is a generalist predator of mites, collembola, etc

Hover fly adult *Melanostoma fasciatum* is a pollinator and their larvae prey on aphids

Flatworm Geoplanidae are earthworm predators

Green solider fly *Odontomyia* sp.

Yellow admiral *Vanessa itea* larvae feed on stinging nettle and adults are pollinators

Native black bee *Leioproctus* sp. are important pollinators and often seen on hebe flowers

Hover fly *Melangyna novaezelandiae* is a pollinator and larvae prey on aphids

European goldfinch *Carduelis carduelis* eat thistle seeds reducing weeds

Pied oystercatcher (*Haematopus longirostris*) were very common in dairy landscape

Bird nest and egg found in native planting

Pied stilt (*Himantopus himantopus*) were very common on the farm and several nests were found