ECOLOGICAL MONITORING FOR TE TUMU KAITUNA 7B2 ECOLOGICAL RESTORATION PROJECT, 2013

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ECOLOGICAL MONITORING FOR TE TUMU KAITUNA 7B2 ECOLOGICAL RESTORATION PROJECT, 2013

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Project Team:
Sarah Beadel - Project management, fieldwork, report author
Fiona Wilcox - Report author, fieldwork
Brian Patrick - Report author, fieldwork
Steve Rate - Report author
Richard Gillies - Report author, fieldwork
Mandy Tocher - Report author
Annabel Shaw - Fieldwork
Chris Bycroft - Fieldwork

Prepared for:
Bay of Plenty Regional Council
P.O. Box 364
Whakatāne

99 SALA STREET, WHAKAREWAREWA, 3010, P.O. BOX 7137, TE NGAE, ROTORUA 3042
Ph 07-343-9017; Fax 07-343-9018, email ecology@wildlands.co.nz, www.wildlands.co.nz

CONTENTS

Reviewed and approved for release by:

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Sarah Beadel
Director
Wildland Consultants Ltd

1. INTRODUCTION

Coastal sand dunes that retain their natural character are a nationally rare habitat type and have been identified as a priority for the protection of biodiversity on private land (MfE and DOC 2007). At national, regional, and local scales coastal dunes have been greatly reduced in extent by development for agriculture, horticulture, and urban purposes, and modified by the impacts of a suite of introduced species of plants and animals.

In 2010, the Trustees and owners of Te Tumu Kaituna 7B2, Bay of Plenty Regional Council, and Nga Whenua Rahui entered into an agreement to restore the biodiversity and protect the cultural and archaeological heritage of coastal sand dunes east of Papamoa. Several initiatives have been implemented, including erection of a fence to exclude cattle and vehicles from the entire site, erection of a rabbit-proof fence around *c.*6.8 ha of the site (both fences completed in June 2011), and eradication of rabbits from inside the fence (completed October 2011) as well as simultaneous control of rabbits outside the fence.

Wildland Consultants Ltd was engaged to prepare a plan for monitoring change in the ecological condition of the site based on various items listed in Section 2.2 of the Te Tumu Kaituna 7B2 Biodiversity Management Plan and to implement monitoring.

This report (Volume 1) describes the methods used for monitoring changes in vegetation, flora, and fauna, and compares the baseline data from 2011 with data collected using the same methods in 2013. Comprehensive sets of photographs are presented in Volume 2.

2. SITE DESCRIPTION AND ECOLOGICAL VALUES

The study area comprises *c.*11.3 ha of coastal sand dunes bounded to the north by Papamoa Beach and the Pacific Ocean, and to the south by agricultural land (Figure 1). The site represents a small section of a dune system that extends, uninterrupted, from Mauao, which lies approximately 22 km to the northwest, to Maketu Estuary (*c.*7 km southeast of the study site). Much of this dune system has been modified or lost by development for residential housing, roads, and agriculture. The most highly modified parts of the dune system are located in or adjacent to the townships of Mount Maunganui, Papamoa, and Papamoa East.

In combination with the dunes that lie to both the west and east of the study area, and wetlands to the south associated with the Wairakei Stream, the study site has been ranked as being of national significance (Wildland Consultants 2009). It is identified as a Category 1 'Special Ecological Area' in the Tauranga City Plan (SEA 11 - Kaituna Sand Dunes and Wetlands) (Tauranga City Council 2013) and as a significant area of indigenous vegetation in the Regional Coastal Environment Plan (Site SSL-32 - Kaituna Sand Dunes) (Bay of Plenty Regional Council 2011).

Spinifex (*Spinifex sericeus*) and pīngao (*Ficinia spiralis*) dominate the front face of the foredune, with pōhuehue (*Muehlenbeckia australis*), wīwī (*Ficinia nodosa*) and *Carex testacea* occurring inland on stabilised dunes. Other indigenous species

include shore bindweed (*Calystegia soldanella*), *Carex pumila*, and *Lachnagrostis billardierei*. The study area includes part of the largest population of hinarepe (sand tussock; *Poa billardierei*) in the Bay of Plenty. Hinarepe is classified 'At Risk-Declining' in the New Zealand threatened plant classification lists (de Lange *et al.* 2012). Three vascular plant species regarded as regionally uncommon (Beadel 2009) are also present at the site: *Oxalis rubens*, *Zoysia pauciflora*, and *Senecio biserratus*.

The dunes between Papamoa and Kaituna, including the study site, have been identified as an important habitat for katipo (*Latrodectus katipo*), mainly the form previously known as black katipo (*Latrodectus atritus*; Vink *et al.* 2008). Katipo are classified as 'At Risk-Declining' (Sirvid *et al.* 2012), are protected under the Wildlife Act, and are iconic fauna of the coastal sand dune systems of New Zealand.

Shore skink (*Oligosoma smithii*), classified as Not Threatened (Hitchmough *et al.* 2013) have been recorded in the vicinity of the project site, and in 1965 Moko skink (*Oligosoma moco*), classified as 'At Risk-Relict' were also recorded as being present (Bioweb Herpetofauna database, accessed online December 2013).

Avifauna recorded from the dunes and on the beach in this area include three species classified as 'Threatened-Nationally Vulnerable' by Robertson *et al.* 2013: New Zealand dotterel (*Charadrius obscurus aquilonius*), banded dotterel (*Charadrius bicinctus bicinctus*), and red-billed gull (*Larus novaehollandiae scopulinus*) (Wildland Consultants 2008). White-fronted tern (*Sterna striata striata*, 'At Risk-Declining') have also been recorded (ibid.). Variable oystercatcher (*Haematopus unicolor*), which is classified as 'At Risk-Recovering', also commonly use beaches in this area.

3. METHODS

3.1 Study design

Ecological monitoring at Te Tumu followed a pre-post, control-intervention design with respect to the eradication of rabbits from within the rabbit-exclusion fence. Pre-intervention monitoring occurred in 2011 during the construction phase of the rabbit-exclusion fence but while rabbits had access to the entire site, and while stock and vehicles either continued to have access to the site, or had been very recently excluded. Exclusion of stock and vehicles from the entire site meant that there was no monitoring of a control site where stock, vehicles and rabbits continued to have access.

3.2 Vegetation mapping

The site was visited in July 2013. The vegetation and habitat type map prepared in 2011 on 2007 aerial photographs (Wildland Consultants 2011) was updated and refined. The seven vegetation and habitat types identified in 2011 were split into twenty-two vegetation and habitat types to reflect finer scale variations in vegetation assemblages. These were described and mapped onto colour aerial photographs that were taken in 2011 (refer to Figure 1 and Section 4.1 below).

Figure 1. Vegetation and habitat types, Te Tumu Kaituna 7B2, 2013

3.3 Selection and marking of permanent plots

In 2011, random GPS points were generated using the "Create Random points" data management tool in ArcView to create a specified number of random points both inside and outside the rabbit-proof fence. These random points were then used to establish 28 permanent vegetation plots distributed across the vegetation and habitat types that are present, both within and outside the rabbit-proof fence (refer to Figure 3).

A handheld GPS was used to locate each of the 28 randomly generated points. At each point, a square plot measuring 2 × 2 m was set out using a compass and tape measures to identify each corner of the plot. Corners D and P were marked using metal waratahs with a numbered metal tag. The exception is Plot 25, where corners A and M were marked. Once the corners were identified, the edges of the plot were defined by laying out a tape along each site (each side was 2 m). Each plot was then divided into 16 sub-plots, each measuring 0.5 × 0.5 m, using 2 m plastic rods (refer to Figure 2 below).

The compass bearings between corners were recorded on the plot record sheets. For more information on plot locations, including GPS coordinates and corner peg details, see Appendix 1. For vegetation and habitat type descriptions, see Section 4 below.

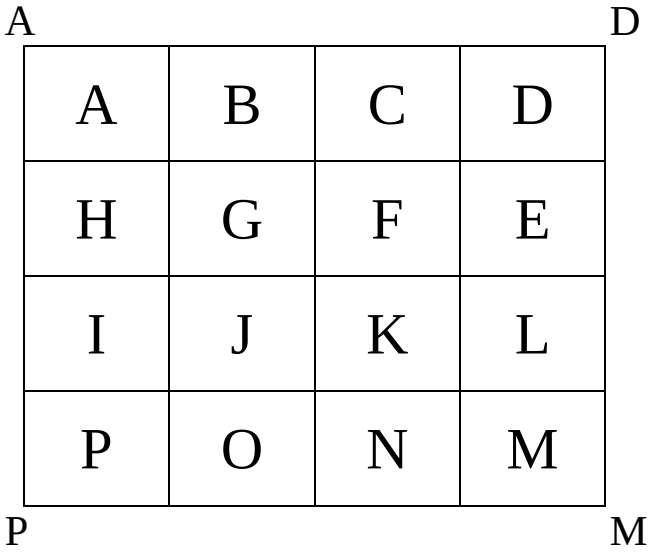

Figure 2: Layout of 2 × 2 m vegetation plots and sub-plots A to M established at Te Tumu Kaituna 7B2. Corners D and P are marked with waratahs and numbered metal tags.

In 2013, GPS coordinates taken of plot locations in 2011 were used to find plots. The GPS coordinates were updated where necessary to reflect the increased accuracy of current GPS devices. When GPS points were updated, the coordinate was taken from Corner P of the plot. Numbered tags at each plot were checked and were either replaced, or rewired where necessary. Where tags needed replacing, new tag numbers were recorded on the plot sheets.

3.4 Vegetation measurements

Field work was carried out over four days in July 2013. At each plot, general plot measurement information was recorded, including the date, initials of the ecologist(s) who measured the plot, the vegetation and habitat type, and the aspect of the plot. All vascular plant species present in each of the 16 sub-plots were recorded, including foliage of species that extended into the subplot but were not rooted in the subplot.

For each plot, the following data was recorded:

- Percent cover of each vascular plant species to the nearest 1%, with anything less than 1% recorded as 0.5%. Notes: 1. Percent cover was not estimated for standing, dead lupin (*Lupinus arboreus*) plants unless they were lying on the ground, when they were included as litter when estimating groundcover. 2. Total vegetation cover in a plot may exceed 100% if one species overhangs another.
- Percent of ground covered by bare sand, vascular plants, non-vascular plants, and litter. Dead lupin were included in the estimate of litter if they were lying on the ground.
- Maximum heights of spinifex, pīngao, and hinarepe.
- Number of plants of spinifex, hinarepe and pīngao rooted within the plot. Due to the growth habits of these species it was not always easy to define individual plants, so a plant was defined as an individual if it was 20 cm or more from the next nearest 'clump' and there was no obvious connection between the 'clumps'.
- The presence of inflorescences on hinarepe, pīngao, and spinifex.
- The number of rabbit pellets within the plot.
- Signs of browse on indigenous species within the plot.
- A photograph of each plot was taken looking from corner P towards corner D (these are presented in Volume 2).
- If deemed necessary, the plot was also photographed from a vantage point away from the plot, to facilitate plot relocation (photographs are presented in Volume 2). The location of the photograph was recorded as a GPS point and the angle was recorded as a compass bearing relative to magnetic north (refer to Appendix 1).

A template of the field sheet completed for each vegetation plot is provided in Appendix 3.

3.5 Flora

All species of vascular plants within the study area were recorded and their abundances within and outside the rabbit-proof fence were estimated using the following five descriptors of abundance and distribution:

- Common: the species dominates a vegetation tier of a vegetation and habitat type that covers at least 20% of the site.
- Scattered: the species is scattered throughout much of the site but does not achieve dominance.
- Locally common: the species is common in a limited number of confined areas.
- Locally scattered: the species is scattered through localised areas of habitat.
- Uncommon: the species comprises very few individuals and is not common anywhere.
- Rare: there are less than 10 individuals of the species present at the site, or 1-2 small populations.

The list of plant species observed at the site annotated with their abundance both inside and outside the rabbit-proof fence is presented in Appendix 9.

3.6 Threatened plants

The GPS locations, numbers of individuals, numbers of patches, and numbers of 'groups' of pīngao and hinarepe were recorded (refer to Figure 5) and were compared with 2011 measurements of these species. Individual plants were defined as a single stem (or tussock) that is more than 1 m away from the nearest 'patch' or other individual plant. A 'patch' was defined as tussocks that are a maximum of 1 m apart (measured from centre to centre). A 'group' was defined as one or more plants at least 20 m or more from the closest other 'group', and each group comprises one or more 'patches' and/or individual plants. Within each 'group', the size of each 'patch' was estimated and individual plants were counted. The size of each 'patch' was estimated by recording two measurements: the maximum length, and the maximum width of the patch along the perpendicular axis. Each 'patch' and 'plant' was recorded as fertile if flowers or seed heads were present.

3.7 Data analysis: vegetation

Mean values for plant species cover and frequency, percent cover of ground cover variables, and plant heights were calculated and tabulated. T-tests were used to test for significant differences in mean values of each variable between years.

Changes in plant species composition between years were assessed using non-metric multidimensional scaling (NMDS) based on plant species cover and Bray-Curtis similarities. Two-way crossed Analysis of Similarities (ANOSIM) was used to test for significance of differences between broad vegetation types and years.

3.8 Avifauna

At each of the permanent plots a 5-minute bird count was undertaken (generally as per Dawson and Bull 1975) and a list was compiled of all species observed during the fieldwork in 2013. A template of the field sheet completed for each vegetation plot is provided in Appendix 5.

3.9 Lizards

Lizard detection was undertaken using two-layer Onduline Artificial Cover Objects (ACOs), as this method has proven effective at detecting and monitoring lizards in sand dune systems (see Lettink *et al*. 2010). This method has potential advantages compared with alternative methods such as pitfall traps or hand searching of vegetation and retreats, such as cost-effectiveness, simplicity, and ease of replicating surveys over time. Although ACOs are very effective at lizard-detection, and therefore at determining the age/size classes of each species present, they have limitations for monitoring changes in the abundance or changes in the species assemblage through time for a given site. As such, results pertaining to monitoring should be interpreted with caution e.g. an increase in the number of ACOs occupied by lizards through time is encouraging but does not necessarily reflect a similar increase in the lizard-population of the surrounding area. The opposite can also be true: if the lizard species present is highly territorial and aggressive and they take up residence in the ACOs they may exclude other individuals from being detected and thus falsely represent the lizard population.

Twenty clusters of five two-layer Onduline ACOs were put in place on 22 April 2011, as per Lettink *et al*. (2010); 10 clusters inside and 10 outside the rabbit-excluded area (Figure 4 and Appendix 3). ACOs were located subjectively, adjacent to areas of dense vegetation (e.g. patches of *Muehlenbeckia* sp. or spinifex) considered to be lizard habitat (and/or spider habitat; see Section 3.10), and were placed to ensure all vegetation types were sampled. The central ACO in each cluster of five was marked with a short pole and flagging tape to assist with relocating them over later surveys. ACOs were checked on four occasions over May-June 2011, between 1-2 months after initial placement, and then left *in situ*. ACOs were then relocated in November-December 2013, checked on four occasions, and then removed from the site.

Despite the flagging tape marking each cluster, 12 two-layer ACOs were not relocated over the 2013 survey (8 within the rabbit-proof fence and 4 outside), presumably due to very dense vegetation obscuring them, or removal by humans. ACOs left *in situ* between 2011 and 2013 had the potential to increase the habitat quality for lizards at the site (an objective of the BOPRC Biodiversity Management Plan); we assume here any enhancement that occurred was *equal* both inside and outside of the rabbit-exclusion areas.

Numbers and species (for those that did not avoid capture) located within and under the ACOs were recorded for both the 2011 and 2013 samples. All skinks were counted on each visit (sample/check) to the ACOs, even those that escaped and all escapees were assumed to be shore skinks for the purposes of this report.[1]

3.10 Katipo spiders

The same Artificial Cover Objects (ACOs) in the same configuration that were used to detect lizards were also used to detect katipo (see Lettink and Patrick 2006 and Section 3.9).

[1] It is acknowledged here that in the future as the vegetation continues to rehabilitate, there is a possibility that other lizard species may appear at the site e.g. Moko skink.

Sutton *et al.* (2006) was used as a guide to the field identification of katipo, as well as several on-line resources (Te Papa Tongarewa www.tepapa.govt.nz, Biosecurity New Zealand www.biosecurity.govt.nz, Landcare Research www.landcareresearch.co.nz).

Numbers of katipo in ACOs were recorded, and used to calculate occupancy rates**.**

3.11 Invertebrates

A field survey of the invertebrates of the project site was carried out on 12-13 November 2013. Insects active by day were surveyed on both days, while on the night of 12 November a light trap was run to sample nocturnal species at the site. Insects were sampled using the following methods:

- Sweeping with a sturdy net of vegetation for adults and larvae;
- Netting of day-flying species;
- Beating of shrubs, lianes and tall herbs for larvae;
- Hand searching under logs and debris;
- 12 volt powered, ultra-violet lamp at night, set over white sheet.

Warm, dry, and calm weather by day allowed a thorough survey of the insects to be carried out, whereas cool (8² C) and breezy conditions by night were less than ideal for a thorough sampling of nocturnal species.

Where possible, the larvae found were reared to adults back in Christchurch. Voucher specimens of most species are stored in the author's collection in Christchurch.

3.12 Permanent photopoints

The permanent photopoint locations established in 2011 were relocated and photographed based on 2011 photographs and instructions. Twenty-seven photographs were taken at 15 permanently marked photopoints spread throughout the study area. Six photopoints are located on the rabbit-proof fence, four are located within the fence, and five are located outside the fence (Figure 2). At five locations only one photograph was taken. At eight locations, two photographs were taken on different compass bearings, and at two locations three photographs were taken. Twelve photographs show the inside of the rabbit-proof fence, nine photographs show areas outside the fence, and six photographs show areas both within and outside the fence. This equates to thirty-three possible vegetation comparisons. One or more photographs were also taken of each permanent vegetation plot (see Section 3.3 above).

For the six photopoints located on the fence line, numbered metal tags were nailed into the top of the fence post located at the photopoint. The other photopoints are marked with waratahs that have a numbered metal tag wired to the top. Two of the photopoints are located at the corner of permanent vegetation plots. Plot locations, tag numbers, and the compass bearing of each photograph, are given in Appendix 2. The numbered metal tags were checked for corrosion and were rewired to the waratah or replaced where necessary. Where tags needed replacing, new tag numbers were recorded on the photopoint sheets.

4. RESULTS

4.1 Vegetation and flora

4.1.1 Vegetation and habitat types

Twenty-four vegetation and habitat types were identified. These are mapped in Figure 1 and are described below:

1. Spinifex-pīngao sandfield

Spinifex dominates the most seaward face of the foredune, with patches of pīngao. Other species present include *Lachnagrostis billardierei*, catsear (*Hypochoeris radicata*), shore bindweed, and local sea rocket (*Cakile maritima*). Hinarepe occurs at two locations in this vegetation and habitat type (Figure 5).

2. Spinifex grassland

Spinifex sandfield and grassland dominates the landward face of the foredune and extends inland to the dune crest of the mid-dune. The density of vegetative cover is variable. Spinifex dominated grassland is more likely to occur on faces with a southerly aspect, and more sparsely vegetated sandfield is more likely to occur on north-facing slopes. Spinifex is the dominant species on the foredune. Farther back, other species are scattered throughout including catsear, harestail (*Lagurus ovatus*), and *Lachnagrostis billardierei*. Lupin occurs locally.

Dune hollows and wind channels towards the eastern end of the site include patches of *Carex pumila* sandfield. Dune hollows in the western half of the site are generally more densely vegetated and some appear to be relatively stable, with a cover of grassland dominated by spinifex and *Lachnagrostis billardierei*, with catsear and lupin, and scattered pōhuehue and wīwī. Most of the lupin were dead in 2011, however in 2013 most of the lupin were alive. Other species present in this vegetation and habitat type include shore bindweed, *Carex testacea*, local moss and sand oxalis (*Oxalis rubens*). There are also small patches of pōhuehue vineland and occasional pīngao. Tauhinu (*Ozothamnus leptophylla*) is present at six locations in this vegetation and habitat type (refer to Figure 5).

3. Spinifex-*Lachnagrostis billardierei*-hinarepe sandfield

Sandfield with scattered spinifex, *Lachnagrostis billardierei*, and hinarepe occurs in a hollow towards the eastern end of the site. It is bisected by a vehicle track. Other species present include catsear, hawkbit (*Leontodon taraxacoides*), and lupin.

4. Lupin/spinifex/harestail sedge-grass-sandfield

This vegetation and habitat type comprises a small area variously dominated by either spinifex or harestail. Where harestail is the dominant species, scattered to local clumps of lupin occur over harestail grassland and sandfield. Where spinifex is the dominant species, harestail is common with scattered *Lachnagrostis billardierei*. Small patches of pōhuehue and wīwī are present within this type in association with Kentucky bluegrass (*Poa pratensis*) and *Carex pumila*.

5. Harestail-*Carex pumila*-catsear-*Lachnagrostis billardierei*-pōhuehue sandfield

A variable type located in the centre of the site between the southwestern side of the rabbit-proof fence and the cattle-proof fence. Harestail, *Carex pumila*, catsear, and *Lachnagrostis billardierei* with patches of pōhuehue and bracken (*Pteridium esculentum*) are the dominant species amongst bare sand. One or two lupin and three spinifex plants are also present.

6. *Lachnagrostis billardierei*-bracken-catsear-harestail sandfield

This vegetation and habitat type comprises a small area of sandfield along the southwestern rabbit-proof fence boundary. *Lachnagrostis billardierei* and bracken are dominant in association with catsear and harestail, with local moss and scattered *Carex pumila*. A few spinifex plants are also present.

7. (Spinifex)/harestail-*Lachnagrostis billardierei*-catsear grassland

This vegetation and habitat type occurs as patches within Vegetation Type 3 ((wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland). Some were relatively large and were mapped; other smaller areas were not mapped. Unmapped examples of this type are also present within Vegetation Type 1 (spinifex-pīngao sandfield), in dune hollows and on faces with a southerly aspect. It is characterised by scattered spinifex and wīwī above harestail, *Lachnagrostis billardierei*, and catsear. Pōhuehue is also present, particularly on the edges, and shore bindweed is common in places. Other species present include *Carex pumila*, bracken, sheep's sorrel (*Rumex acetosella*) and sand oxalis.

8. (Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland

A wide swathe of the dunes is dominated by variable mixtures of pōhuehue, wīwī, and *Carex testacea* with frequent exotic grasses. Wīwī is most abundant on the seaward side of this vegetation and habitat type, near the dune crest, and along the southern edge, abutting the pasture where pasture weeds are also present. *Carex testacea* is most abundant in swales in the centre of the type. In the dune swales pōhuehue is often the dominant species in association with *Carex testacea* and *Carex pumila*, with *Lachnagrostis billardierei*. Also within these areas are local bracken, wīwī, and exotic grasses, including Kentucky bluegrass.

Patches of *Senecio biserratus* are present close to the dune crest. Other species present include bracken, spinifex, sand oxalis, sheep's sorrel, *Lachnagrostis billardierei*, shore bindweed, *Carex pumila*, harestail, and lupin. There are also patches of bare sand.

A bach was previously located at the eastern end of the site within this vegetation and habitat type but has been removed. Vegetation around the vehicle accessway that led to the bach includes a greater diversity and abundance of exotic species such as broad-leaved fleabane (*Conyza sumatrensis*), purpletop (*Verbena bonariensis*), woolly mullein (*Verbascum thapsus*), gorse (*Ulex europaeus*), and exotic grasses including ripgut brome (*Bromus diandrus*), kikuyu grass (*Cenchrus clandestinus*), harestail, and cocksfoot (*Dactylis glomerata*). On the seaward side of the concrete pad for the bach, there is a patch of arctotis (*Arctotis stoechadifolia*). Two pampas (*Cortaderia selloana*) are also present within this area.

Two small piles of sand from the construction of the rabbit-proof fence are present within this vegetation type. These are now covered in exotic grasses, predominantly cocksfoot.

9. Wīwī/pōhuehue-bracken-kikuyu grass vine-sedgeland

Wīwī is common forming clumps that are emergent over mixtures of pōhuehue, bracken, and kikuyu grass. Other species present include shore bindweed, *Carex pumila*, cocksfoot, and *Lachnagrostis billardierei*, with local sand oxalis. Exotic grasses are more prominent one to two meters from the fence and include kikuyu grass, cocksfoot, and Yorkshire fog (*Holcus lanatus*). Piles of sand from fence construction are also present in this area. These are covered in exotic grasses including kikuyu grass, cocksfoot, and *Bromus* sp.

10. Spinifex/pōhuehue vineland

Spinifex is common over pōhuehue vineland with local scattered wīwī. Other species present include harestail, catsear, and *Lachnagrostis billardierei*, with local *Carex testacea* and shore bindweed.

11. Pōhuehue-harestail-*Carex testacea*-(lupin) vine-grassland

A variable vegetation association dominated by exotic grasses and herbs including harestail, Kentucky blue grass, and sheep's sorrel with local patches of pōhuehue, *Carex testacea*, and wīwī with scattered lupin. Fennel (*Foeniculum vulgare*) occurs locally near the rabbit-proof fence in association with gorse and dense exotic grasses including kikuyu grass and ripgut brome. Shore bindweed is scattered throughout and there are also patches of bare sand.

12. Wīwī/Indian doab-pōhuehue grassland

This vegetation and habitat type covers a small area in the northwestern corner of the site. Wīwī is common over a dense cover of Indian doab (*Cynodon dactylon*). Other species present include harestail, cocksfoot, and catsear. Local patches of pōhuehue and scattered gorse are present within this type, and blackberry (*Rubus fruticosus*) is present in the southwestern corner.

13. Harestail-ripgut brome-(gorse)-(wīwī) sand-grassland

Harestail and ripgut brome are common in open sandy areas with scattered wīwī and gorse. Two small patches of kikuyu grass are present within this type and there are two pampas clumps. Other species present include *Carex testacea* and catsear.

14. Wīwī/harestail-(sweet vernal)-(pōhuehue) sedge-grassland

This vegetation and habitat type is dominated by wīwī and harestail with local patches of pōhuehue and sweet vernal (*Anthoxanthum odoratum*) near the southeastern corner of the project area, outside the rabbit-proof fence. Other species present include browntop (*Agrostis capillaris*), shore bindweed, and ripgut brome.

15. Harestail-*Lachnagrostis billardierei*-catsear grassland

This vegetation and habitat type is similar to Vegetation Type 7. It is characterised by occasional wīwī above harestail, *Lachnagrostis billardierei*, and catsear. Other species present include pōhuehue, bracken, shore bindweed, sheep's sorrel, ripgut brome, sweet vernal, and Yorkshire fog..

16. Harestail-(catsear) grassland

This vegetation type comprises a narrow (*c.*2 m wide) band of bare ground and vegetation along the northern, northeastern and eastern margin of the rabbit-proof fence where the vegetation was cleared for construction of the rabbit-proof fence. Harestail dominates and catsear is scattered throughout, with occasional to common lupin. *Lachnagrostis billardierei*, woolly mullein, and blackberry are also present. Pīngao has been planted both inside and outside the fence along the northeastern margin of the fenceline, and seaward half of the eastern margin of the fenceline within this type. Wīwī and *Carex testacea* are present adjacent the fence further away from the coast.

17. Kikuyu grass-fennel grassland

This vegetation and habitat type comprises grassland dominated by kikuyu grass with cocksfoot and prairie grass (*Bromus willdenowii*) common near the southeastern corner of the rabbit-proof fence. Local patches of gorse and pampas are present within this type, as are scattered fennel and woolly mullein.

18. Exotic grasses grassland

This vegetation and habitat type occurs in the *c*.4-5 m strip between the rabbit-proof fence and the cattle-proof fence. Exotic grasses dominate this area including cocksfoot, paspalum (*Paspalum dilatatum*), *Bromus* sp., and kikuyu grass. Blackberry, pōhuehue, and bracken occur very locally. Fennel is common within this vegetation type where it borders Vegetation Type 7.

19. Cocksfoot-bracken-sheep's sorrel grass-sandfield

This vegetation and habitat type occurs in areas that were previously covered with wīwī sedgeland that was cleared to construct the rabbit-proof fence at the northern boundary of the rabbit-proof fence. It is dominated by cocksfoot, bracken, sheep's sorrel and bare sand with a few wīwī, lupin, and woolly mullein. Other species present include kikuyu grass, catsear, and local *Carex pumila*.

20. (Gorse)-(lupin)/exotic grasses grassland

This vegetation and habitat type covers a small area immediately adjacent to, and inside, the cattle-proof fence in the northwestern corner of the site. Exotic grasses dominate and include kikuyu grass and cocksfoot. A few scattered gorse and lupin shrubs are present emerging from the grass.

21. Gorse/exotic grasses grassland

This vegetation and habitat type contains scattered gorse over exotic grasses, including kikuyu grass, cocksfoot, and paspalum.

22. Gorse shrubland

Gorse forms the dominant cover in this area with local clumps of wīwī, pōhuehue, and bracken. Tall fescue (*Schedonorus arundinaceus*), prairie grass, blackberry, cocksfoot, Kentucky bluegrass, and bracken grow amongst the gorse.

23. (Lupin)/wīwī-pōhuehue-spinifex/harestail grassland

Local clumps of lupin are present within harestail dominated grassland with patches of wīwī, pōhuehue, and spinifex scattered throughout. Shore bindweed is common throughout.

24. Sweet vernal-(ripgut brome)-(Yorkshire fog) grassland

A small area of exotic species grassland dominated by sweet vernal but with common ripgut brome and Yorkshire fog. Shore bindweed is present throughout, and there are local patches of harestail and pōhuehue, and occasional patches of wīwī. Other species present include sheep's sorrel, narrow-leaved plantain (*Plantago lanceolata*), bracken, and cocksfoot.

4.1.2 Change in vegetation composition based on vegetation mapping

In 2011 vegetation mapping was undertaken at a relatively broad scale, as it was to be used to identify plot locations. 2013 mapping has been undertaken at a more detailed level, to better identify changes in the vegetation over time. Some observation can be made when comparing the two maps. Extent of spinifex dominated vegetation types from 2011 (2011 Vegetation and Habitat Types 1 and 2) have reduced slightly in extent as a result of increases in cover of species that previously formed minor patches or a minor role in the spinifex-dominated vegetation type (e.g. pōhuehue, *Lachnagrostis billardierei*, *Carex testacea*, harestail, and lupin). Better quality aerial photographs have also contributed to the change in the mapped extent of spinifex-dominant vegetation types. A large proportion of the site was classified in 2011 as dominated by pōhuehue and *Carex testacea* with locally common wīwī. This one broad vegetation type has been split into eight types, with five of these having little to no pōhuehue and *Carex testacea*. Based on study of the aerial photographs and vegetation descriptions from 2011, gorse and exotic grass cover have spread within the 2011 type to become dominant or co-dominant in areas that previously had only small patches of these species. Cover of *Carex testacea* also appears to have increased, and cover of wīwī appears to be similar (locally common to co-dominant).

The extent of Vegetation and Habitat Type 4 from 2011 has stayed relatively constant, with some minor encroachment by pōhuehue, exotic grasses, and gorse. The area covered by wīwī-dominant vegetation in 2011 has been split into three vegetation and habitat types in 2013. This does not appear to reflect a decrease in the extent or cover of wīwī, but rather an increase in the other species previously associated with wīwī; in particular pōhuehue, *Carex testacea*, and exotic grass cover appears to have increased within this area. The extent of the area dominated by spinifex, *Lachnagrostis billardierei*, and hinarepe (2011 Vegetation Type 6) is likely to have remained similar to that in 2011 but changes in the mapping are a result of better quality aerial photographs.

The 2011 Vegetation and Habitat Type 7 ((wīwī)-(pōhuehue)-(*Carex testacea*)/harestail-shore bindweed grassland), has changed significantly with pōhuehue and *Carex testacea* increasing in cover to become co-dominant with harestail, and wīwī and shore bindweed decreasing in cover. Wīwī and shore bindweed are still present within this area, but have reduced in extent.

The study area was similar in 2011, and did not include the part of the site which was mapped in 2013 as comprising Vegetation Types 14, 17, and 18. This is likely to be because the exact locations of the rabbit-proof and cattle fences were not known at the time of the 2011 survey. The changes observed in the extent and composition of the vegetation and habitat types can partially be attributed to a release from grazing pressure by stock. This is particularly pertinent to the increases in the cover of gorse, exotic grasses, and *Carex testacea*. Some of the change in mapped vegetation cover is likely the result of better quality aerial photographs being available in 2013.

4.1.3 Plot locations

Based on the vegetation and habitat types mapped in 2011, permanent vegetation plots were established in six of the seven vegetation and habitat types which occur within the study area; with the finer scale of vegetation and habitat remapping undertaken in

2013, plots are located in only six of the twenty-two identified habitat types (refer to Appendix 1 and Figure 3). Plots were not situated in Vegetation and Habitat Type 1 (spinifex-pīngao sandfield and grassland) because it does not occur inside the fence, so cannot be used to measure responses to rabbit exclusion. In addition, the front face of the foredune, where this vegetation and habitat type occurs, is a very dynamic environment where it would be difficult to relocate permanent vegetation plots.

Sixteen plots are located inside the rabbit-proof fence, with a further 12 plots outside the fence. Where possible, plots were established in each vegetation and habitat type both inside and outside of the rabbit-proof fence (based on 2011 vegetation and habitat types), to allow comparisons to be made over time. However, one 2011 vegetation type (Type 6) does not occur within the fence, one 2011 vegetation type (Type 7) does not occur outside the fence, and one 2011 type (Type 4) occurs outside the fence only at the location of a potential house site where the owners requested that plots not be established. Three 2011 vegetation and habitat types (Types 2, 3, and 5) were able to be sampled both inside and outside the fence.

Photographs of all permanent vegetation plots are included in Volume 2.

4.1.4 Vegetation cover

The cover of each plant taxa recorded in each plot in 2011 and 2013 is presented in Appendix 6. The mean cover of each plant taxa within all plots is presented in Table 1. Between 2011 and 2013, 15 vascular plant species increased in mean cover inside the rabbit-proof fence, and 14 vascular plant species decreased in cover inside the rabbit-proof fence. Eleven vascular species decreased in mean cover outside the fence, and 10 vascular plant species increased in cover outside the fence. Several plant taxa increased in mean cover both inside and outside the rabbit-proof fence, including *Carex testacea*, *Carex pumila*, harestail, moss, and lupin, while decreases in cover occurred for sweet vernal, spinifex, pōhuehue, sand oxalis, shore bindweed, wīwī, and sheep's sorrel (Table 1). For these species, changes in cover inside the rabbit-proof fence were mirrored by equivalent changes in cover outside the fence, suggesting an environmental cause that was independent of the fence (e.g. domestic stock have been removed from inside and outside the fence; also rabbit density is currently very low outside the fence, at least in part due to rabbit control operations, last undertaken on site in 2011).

Several species were recorded in plots inside, but not outside, the rabbit-proof fence for the first time in 2013: ripgut broome, *Carex solandri*, broad-leaved fleabane, pīngao, cleavers (*Galium aparine*), lichen, broomrape (*Orobanche minor*), kikuyu grass, and Kentucky bluegrass. The presence of pīngao within plots in 2013 is the result of planting of this species within the site since 2011. Some or all of the species may have been missed in the previous monitoring or their distributions may be expanding due to construction of the rabbit-proof fence.

For some species, the rabbit-proof fence appeared to be a factor in the observed changes in cover. For example, mean bracken and rye grass (*Lolium perenne*) cover increased inside the rabbit-proof fence between 2011 and 2013, but decreased outside the fence, and cover of Yorkshire fog was relatively constant inside the fence, but decreased outside the fence. However, none of these differences were significant.

Figure 3. Location of permanent vegetation plots and permanent photopoints at Te Tumu Kaituna 7B2, 2013

Table 1: Mean cover of plant taxa in plots inside and outside a rabbit-proof fence at Te Tumu Kaituna 7B2, in 2011 and 2013.

Taxon	2011			2013		
	Inside Fence	Outside Fence	Total	Inside Fence	Outside Fence	Total
Anthoxanthum odoratum[1]	2.00	0.50	1.41	0.00	0.18	0.07
Bromus diandrus[2]	0.00	0.00	0.00	0.21	0.00	0.13
Calystegia soldanella[1]	2.88	1.77	2.45	0.53	0.14	0.38
Carex pumila[3]	0.06	0.18	0.11	0.24	0.55	0.36
Carex solandri[2]	0.00	0.00	0.00	0.15	0.00	0.09
Carex testacea[3]	4.68	3.36	4.16	8.94	7.73	8.46
Cenchrus clandestinus[2]	0.00	0.00	0.00	0.06	0.00	0.04
Cerastium fontanum[4]	0.26	0.00	0.16	0.03	0.00	0.02
Conyza sumatrensis[2]	0.00	0.00	0.00	0.06	0.00	0.04
Crepis capillaris[5]	0.09	0.18	0.13	0.00	0.00	0.00
Dactylis glomerata[4]	0.29	0.00	0.18	0.24	0.00	0.14
Ficinia nodosa[1]	9.41	6.45	8.25	7.74	3.27	5.98
Ficinia spiralis[2]	0.00	0.00	0.00	0.00	0.45	0.18
Galium aparine[2]	0.00	0.00	0.00	0.00	0.05	0.02
Holcus lanatus[5]	0.65	3.91	1.93	0.68	0.91	0.77
Hypochoeris radicata[1]	2.29	1.91	2.14	1.85	1.09	1.55
Lachnagrostis billardierei	2.53	0.45	1.71	2.44	0.77	1.79
Lagurus ovatus[3]	2.44	5.64	3.70	7.47	7.41	7.45
Leontodon taraxacoides[4]	0.88	0.41	0.70	0.47	0.45	0.46
Lichen[2]	0.00	0.00	0.00	0.06	0.00	0.04
Ligustrum sinense[6]	0.00	0.27	0.11	0.00	0.18	0.07
Lolium perenne[7]	3.38	0.09	2.09	3.79	0.00	2.30
Lupinus arboreus[3]	0.09	0.23	0.14	0.88	1.73	1.21
Moss[3]	4.71	0.73	3.14	4.85	1.45	3.52
Muehlenbeckia complexa[1]	20.41	5.09	14.39	14.65	3.09	10.11
Orobanche minor[2]	0.00	0.00	0.00	0.03	0.00	0.02
Oxalis rubens[1]	1.41	0.64	1.11	1.03	0.41	0.79
Paspalum dilatatum[4]	0.12	0.00	0.07	0.00	0.00	0.00
Poa billardierei[5]	0.00	0.23	0.09	0.00	0.05	0.02
Poa pratensis[2]	0.00	0.00	0.00	0.24	0.27	0.25
Pteridium esculentum[7]	0.65	1.18	0.86	1.24	0.91	1.11
Rumex acetosella[1]	5.41	1.91	4.04	2.47	0.55	1.71
Spinifex sericeus[1]	5.76	8.73	6.93	5.06	7.00	5.82
Stellaria media[8]	0.09	0.00	0.05	0.24	0.00	0.14
Taraxacum officinale[9]	0.00	0.09	0.04	0.00	0.27	0.11
Trifolium species[10]	0.03	0.00	0.02	0.03	0.00	0.02
Zoysia pauciflora[8]	0.03	0.00	0.02	0.12	0.00	0.07
Total	**70.55**	**43.95**	**60.13**	**65.8**	**38.91**	**55.24**

1. Decreased in mean cover between 2011 and 2013 both inside and outside the fence.
2. Recorded for first time inside the fence in 2013.
3. Increased in mean cover between 2011 and 2013 both inside and outside the rabbit-proof fence.
4. Decreased in mean cover inside the fence, but relatively constant outside fence 2011-2013.
5. Relatively constant cover inside the fence, but decreased outside the fence between 2011 and 2013.
6. Decreased in cover outside, but relatively constant cover inside the fence between 2011 and 2013.
7. Increased cover inside, decreased in cover outside between 2011 and 2013.
8. Increased cover inside, relatively constant cover outside the fence between 2011 and 2013.
9. Relatively constant cover inside, increased cover outside the fence between 2011 and 2013.
10. No change in cover between 2011 and 2013.

The mean cover of all indigenous vascular species, exotic species, moss, and lichen was lower in 2013 than 2011 both inside and outside the rabbit-proof fence (although this difference was not statistically significant). This decrease in cover between years

could be related to the drought conditions that occurred in summer 2012-2013. A decrease in water availability may lead to nutrient deficiency, a reduction in photosynthesis, and a subsequent loss of energy reserves. Plants may respond to drought conditions by wilting, losing foliage, reducing growth, dying back, or becoming dormant, or dying.

4.1.5 Plant species frequency

The frequency of each plant taxa recorded in each of 16 subplots in each plot in 2011 and 2013 is presented in Appendix 7. The mean frequency of plant taxa recorded in all subplots is presented in Table 2.

Several taxa (e.g. *Carex pumila, Carex testacea*, catsear, *Lachnagrostis billardierei*, harestail, wīwī, spinifex, and moss) increased in mean frequency between years both inside and outside the rabbit-proof fence (Table 2). However, mean frequency of other taxa (e.g. sweet vernal, shore bindweed) decreased both inside and outside the fence.

Changes in frequencies of some species between years appeared to be related to whether they were inside or outside of the rabbit-proof fence. For example, mean frequencies of pōhuehue and Yorkshire fog increased inside the rabbit-proof fence and decreased outside the rabbit-proof fence (Table 2). Mean frequencies of bracken, lupin, sand oxalis, and *Zoysia pauciflora* also increased inside the fence, but remained constant outside the fence. Mean frequency of perennial ryegrass between 2011 and 2013 was constant inside the fence, but decreased outside the fence over the same period (Table 2). However, none of these differences were statistically significant.

Table 2: Mean frequency of plant taxa in plots inside and outside a rabbit-proof fence at Te Tumu Kaituna 7B2, in 2011 and 2013.

Taxon	2011			2013		
	Inside Fence	Outside Fence	Total	Inside Fence	Outside Fence	Total
Anthoxanthum odoratum	1.00[1]	0.45	0.79	0.00	0.36	0.14
Bromus diandrus	0.00	0.00	0.00	0.82	0.00	0.50
Calystegia soldanella	9.94	6.45	8.57	2.94	1.09	2.21
Carex pumila	0.18	0.09	0.14	0.71	1.36	0.96
Carex solandri	0.00	0.00	0.00	0.59	0.00	0.36
Carex testacea	3.00	2.00	2.61	4.47	3.18	3.96
Cerastium fontanum	0.47	0.00	0.29	0.06	0.00	0.04
Conyza sumatrensis	0.00	0.00	0.00	0.12	0.00	0.07
Crepis capillaris	0.29	0.91	0.54	0.00	0.00	0.00
Dactylis glomerata	0.12	0.00	0.07	0.41	0.00	0.25
Ficinia nodosa	2.06	2.55	2.25	2.59	2.64	2.61
Ficinia spiralis	0.00	0.00	0.00	0.00	0.82	0.32
Galium aparine	0.00	0.00	0.00	0.00	0.55	0.21
Holcus lanatus	0.65	2.73	1.46	0.88	1.36	1.07
Hypochoeris radicata	4.53	4.27	4.43	5.18	5.00	5.11
Lachnagrostis billardierei	2.65	0.36	1.75	4.41	1.91	3.43
Lagurus ovatus	7.82	7.27	7.61	9.65	10.64	10.04
Leontodon taraxacoides	1.18	1.18	1.18	1.29	1.82	1.50

[1] This means that sweet vernal was present in an average of one subplot in each plot inside the fence in 2011.

Taxon	2011			2013		
	Inside Fence	Outside Fence	Total	Inside Fence	Outside Fence	Total
Lichen	0.00	0.00	0.00	0.18	0.00	0.11
Ligustrum sinense	0.00	0.18	0.07	0.00	0.36	0.14
Lolium perenne	2.88	0.18	1.82	2.88	0.00	1.75
Lupinus arboreus	0.59	1.82	1.07	1.53	1.82	1.64
Moss	3.88	0.91	2.71	4.53	2.64	3.79
Muehlenbeckia complexa	8.29	3.45	6.39	8.82	2.45	6.32
Orobanche minor	0.00	0.00	0.00	0.06	0.00	0.04
Oxalis rubens	3.00	1.45	2.39	3.53	1.45	2.71
Paspalum dilatatum	0.18	0.00	0.11	0.00	0.00	0.00
Cenchrus clandestinus	0.00	0.00	0.00	0.41	0.00	0.25
Poa billardierei	0.00	0.45	0.18	0.00	0.09	0.04
Poa pratensis	0.00	0.00	0.00	0.76	1.27	0.96
Pteridium esculentum	0.82	1.55	1.11	2.00	1.45	1.79
Rumex acetosella	5.59	3.55	4.79	5.41	2.27	4.18
Spinifex sericeus	3.76	5.91	4.61	4.00	6.45	4.96
Stellaria media	0.35	0.00	0.21	0.94	0.00	0.57
Taraxacum officinale	0.00	0.09	0.04	0.00	1.00	0.39
Trifolium species	0.06	0.00	0.04	0.06	0.00	0.04
Zoysia pauciflora	0.12	0.00	0.07	0.71	0.00	0.43

4.1.6 Vegetation composition

Vegetation composition changed little between 2011 and 2013 (Figure 4). In a non-metric multidimensional scaling (NMDS) analysis based on plant species cover, groups were separated by the broad vegetation types (wīwī-dominant types or spinifex-dominant) identified in Wildland Consultants (2011) (2-way crossed ANOSIM: R=0.818, p<0.001), but not by year (R=0.017, p=0.258). Plot 25 showed a large apparent change between 2011 and 2013 (Figure 4), which was primarily due to planting of pīngao, a species not recorded in any other plots.

4.1.7 Ground cover composition

The percentage cover of four ground cover variables measured in each plot in 2013 is presented in Appendix 8. There was a difference in mean cover of litter between 2011 and 2013 (F=3.248, p=0.015). Further investigation revealed that this was because mean cover of litter inside the fence was lower in 2013 compared to 2011 (F=23.683, p=0.006). Outside the fence, mean litter cover was also lower in 2013 than in 2011, but this difference was not significant. No significant differences were found between years or between the inside and outside of the fence for any of the other groundcover variables.

Table 3: Mean cover of four ground cover variables in at Te Tumu Kaituna 7B2, 2011 and 2013. (**Bold type** denotes statistically significant difference).

Location	Year	Bare Sand	Litter	Moss/ Nostoc	Vascular plants
Inside fence	2011	27.76	**6.47**	6.71	64.00
	2013	25.41	**1.15**	4.88	68.56
Outside fence	2011	54.77	6.82	0.73	41.64
	2013	49.86	3.55	1.45	45.14

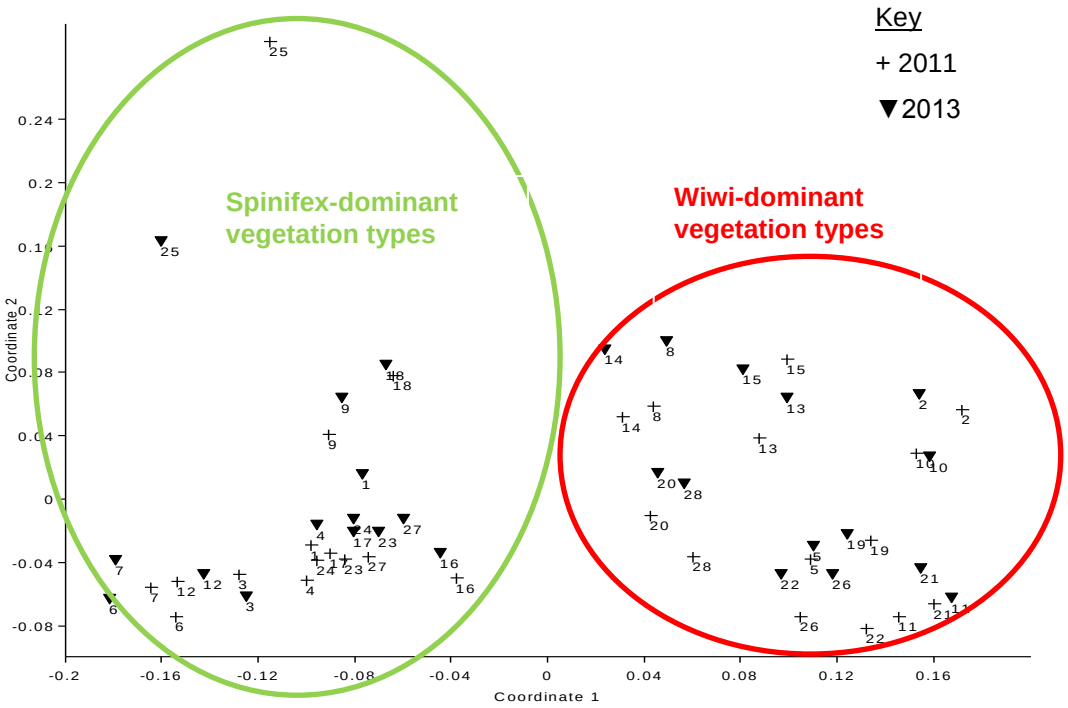

Figure 4: NMDS of plant species cover. Plots are numbered.

4.1.8 Plant heights

Maximum plant heights for Chinese privet, pōhuehue, and spinifex remained constant between 2011 and 2013 (Table 4). The maximum recorded height of live hinarepe decreased slightly between 2011 and 2013. Heights of the remaining species could not be compared between years.

4.1.9 Flora

The total number of plant taxa recorded in plots increased from 28 to 35 between 2011 and 2013. Nine new species were recorded in vegetation plots in 2013, and two species (hawksbeard (*Crepis capillaris*) and paspalum recorded in 2011 were not recorded in 2013. The identification of hawksbeard in plots in 2011 is likely the result of mis-identification of catsear; therefore the absence of hawksbeard in plots in 2013 is not the result of any real change in vegetation structure.

In 2011, three more species were recorded from vegetation plots within the fence than outside (25 versus 22 species), and this increased to six species in 2013 (29 versus 23 species).

Table 4: Mean maximum plant heights (in metres) recorded in each vegetation and habitat type and across all types at Te Tumu Kaituna 7B2, 2011 and 2013.

Species	2011 Vegetation and Habitat Type													
	2		3		4		5		6		7		All	
	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
Carex testacea				0.55										0.55
Ficinia nodosa				0.96				1.08				0.81		0.95
Ficinia spiralis										0.49				0.49
Lachnagrostis billardierei										0.26				0.26
Ligustrum sinense							1.00	1.00					1.00	1.00
Lupinus arboreus		0.34		0.02				0.02						0.13
Muehlenbeckia australis			0.60	0.56			0.80	0.80					0.70	0.68
Poa billardierei (live)									0.30	0.22			0.30	0.22
Poa billardierei (dead)									0.20				0.20	
Spinifex sericeus	0.60	0.59	0.10	0.12	0.70	0.70			0.40	0.40			0.45	0.45

A total of 20 indigenous vascular plant species were recorded, including five species which are only present as a result of planting at the site (refer to Appendix 9). Two species are included in the New Zealand threat classification lists in the 'At Risk' category: pīngao ('At Risk-Relict') and hinarepe ('At Risk-Declining') (de Lange *et al.* 2012) (refer to Section 4.8.2 below). Three species - *Zoysia pauciflora*, sand oxalis, and *Senecio biserratus* - are regarded as being regionally uncommon. In 2013, *Zoysia pauciflora* was recorded in only one plot and sand oxalis was recorded in 15 plots. *Senecio biserratus* was not recorded in any plots. Apart from pīngao, overall abundance of the indigenous species identified within the site did not change between 2011 and 2013. Pīngao abundance changed as a result of extensive planting of this species within the site. Two other planted indigenous species (mānuka (*Leptospermum scoparium*) and kōhūhū (*Pittosporum tenuifolium*) are new to the site.

Sixty-one exotic vascular plant species were also recorded within the study area, including two species that are only present as a result of planting at the site (refer to Appendix 9), and seven species that have been recorded at the site for the first time in 2013. Many of the exotic species present within the site are common grasses and weeds of pasture, but some are potentially invasive weeds in sand dune habitats including pampas, gorse, lupin, climbing dock (*Rumex sagittatus*), blackberry, Chinese privet (*Ligustrum sinense*), and barberry (*Berberis glaucocarpa*). Lupin, pampas, gorse, and blackberry have spread within the site since the construction of the cattle and rabbit-proof fences. Broad-leaved fleabane and hawkbit have become less common within the site since 2011, which may be the result of fewer open sites for colonisation and/or because of the reduction in disturbance as a result of the construction of the fences.

Kikuyu grass, paspalum, and tall fescue were recorded outside the rabbit-proof fence in 2011 (inside the cattle fence) for the first time in 2013, and ratstail (*Sporobolus africanus*) was recorded inside the rabbit-proof fence for the first time in 2013. These species may have been present in 2011 but, due to stock grazing may not have been easy to identify.

4.1.10 Spinifex

Spinifex dominates the vegetation in the northeastern half of the site on the front foredune and immediately behind the front foredune. Towards the back of the site, spinifex becomes a minor component of the vegetation as it is replaced by wīwī, *Carex testacea*, and pōhuehue. Along the southernmost portion of the site, spinifex is absent or rare. In 2011 and 2013, spinifex was present in 0.46 and 0.50 of all the plots, and 0.29 and 0.31 of all subplots, respectively. These plots were located in (spinifex)/harestail-*Lachnagrostis billardierei*-catsear grassland (one plot), (wīwī)/ pōhuehue-*Carex testacea* sedgeland and vineland (two plots), spinifex-dominated sandfield and grassland (nine plots), and spinifex-*Lachnagrostis billardierei*-hinarepe sandfield (two plots). Mean cover of spinifex decreased slightly (<1%) in plots between 2011 and 2013, both inside and outside the fence (see Section 4.3). This suggests that spinifex abundance has changed little over this period.

4.1.11 Threatened and uncommon species

Hinarepe

Hinarepe, which is classified as 'At Risk-Declining' (de Lange *et al.* 2012), is a distinctive component of Vegetation and Habitat Type 3 (spinifex-*Lachnagrostis billardierei*-hinarepe sandfield) and occasional individuals are present on the front face of the foredune in Vegetation and Habitat Type 1 (locations are shown in Figure 5). In 2013, hinarepe was recorded in one plot and subplot, which is less than that recorded in 2011 (two plots and five subplots) (see Section 4.3).

However, in 2013, 84 individual plants of hinarepe were counted, including 41 with infloresences, which is more than that recorded in 2011 (68 plants, although 56 had inflorescences). The small decrease in hinarepe abundance within plots has been greatly offset by the large increase in the number of plants outside plots. Hinarepe was not planted within the site between the 2011 and 2013 measurements (P. de Monchy pers. comm.), therefore the increase in hinarepe plants is indicative of an increase in the population of this species. At the time of the July 2013 monitoring, hinarepe was only present outside the rabbit-proof fence; however, in October 2013, 480 hinarepe plants were planted inside the rabbit-proof fence, on the seaward side of the northern end of the block (P. de Monchy pers.comm.).

Pīngao

Pīngao, which is classified as 'At Risk-Declining' (de Lange *et al.* 2012), is naturally present on the front face of the foredune (in Vegetation and Habitat Type 1), and in Vegetation and Habitat Type 2 (location of pīngao populations are shown in Figure 5). In 2013, pīngao was recorded in Plot 25 (where it had been planted) for the first time[1]. Pīngao has also been planted in Vegetation and Habitat Type 2 (spinifex grassland) near the northern corner of the rabbit-proof fence.

It is difficult to compare counts of individual plants and clump areas due to the merging of clumps as a result of planting that has been undertaken beside the rabbit proof fence, both inside and outside the fence. However, the planting of pīngao that has been undertaken in the site since 2011 has resulted in a substantial increase in pīngao plants within the site.

4.2 Fauna

4.2.1 Birds

Twelve bird species (five native and seven introduced) were recorded from plots in 2011 and 11 species (six native and five introduced) in 2013 (Table 5). Six species were only recorded in 2011 and five species were only recorded in 2013. Of the native species, welcome swallows (*Hirundo neoxena neoxena*) were common in both years and spur-winged plovers were common in 2013 but absent in 2011. Of the introduced species, skylarks (*Alauda arvensis*) were the most commonly observed

[1] Most, or all of the pingao recorded in the group that surrounds, and includes Plot 25 have been planted, some are in poor health, and some have been browsed by rabbits.

species. In 2011, total native and introduced species frequencies were similar for plots on both sides of the fence, but in 2013 there was double the number of observations within the fence compared to outside (Table 5). The Threatened and At Risk species recorded in 2011 (Caspian tern (*Hydroprogne caspia*) and variable oystercatcher (*Haematopus unicolor*)) were not recorded in 2013.

Table 5: Number of observations for each bird taxa recorded from plots at Te Tumu Kaituna 7B2, Papamoa East, in 2011 and 2013.

Species	2011			2013		
	Inside Fence	Outside Fence	Total	Inside Fence	Outside Fence	Total
Native						
Australasian harrier	1	2	3	1	1	2
Black-backed gull	3	4	7	4	1	5
Caspian tern	1		1			
Kingfisher					1	1
Variable oystercatcher		1	1			
Paradise shelduck				1		1
Spur-winged plover				11	4	15
Welcome swallow	6	4	10	9	6	15
Total Native	16	17	33	24	12	16
Introduced						
Australian magpie	2	1	3	2	2	4
Blackbird					1	1
Goldfinch		1	1			
Mallard		1	1			
Mynah		1	1			
Pheasant				1		1
Skylark	13	11	24	15	9	24
Starling		1	1			
Yellowhammer	1	1	2	6		6
Total Introduced	**28**	**28**	**56**	**50**	**25**	**75**

4.2.2 Lizards

Only shore skinks were captured at Te Tumu Kaituna 7B2 over the 2011 and 2013 surveys (Plate 7), and although not all skinks sheltering within or beneath the ACOs were captured it is assumed that those that escaped were also shore skinks given the behavioural and physical similarities they showed to those that were captured. Although a greater number of shore skinks were detected in 2013 compared to the baseline survey of 2011, an equivalent number were captured inside and outside the rabbit-proof fence (Figure 6 and Table 6). Rabbits have been controlled both inside and outside the rabbit-proof fence, and rabbit sign was very low during the 2013 surey. The maximum number of skinks detected in a given sampling session in the rabbit exclusion area (7, see Figure 6) may be indicative of a trend that would require further survey to fully elucidate, but occupancy rates collected to date support the notion that shore skinks responded to rabbits being controlled both inside and outside the fence.

Figure 5. Notable plant species at Te Tumu Kaituna 7B2, 2013

The difference in shore skink detections between the winter surveys of 2011 (1-2 skinks detected per sampling session) versus the summer surveys of 2013 (5-7 skinks detected per sampling session) is almost certainly a seasonal effect; lizards, unless using ACOs as over-wintering retreats, are more detectable in ACOs when they are active over spring and summer. Of note, some of the skinks captured over 2013 were noticeably gravid indicating a reproducing population exists at the site (see Plate 7).

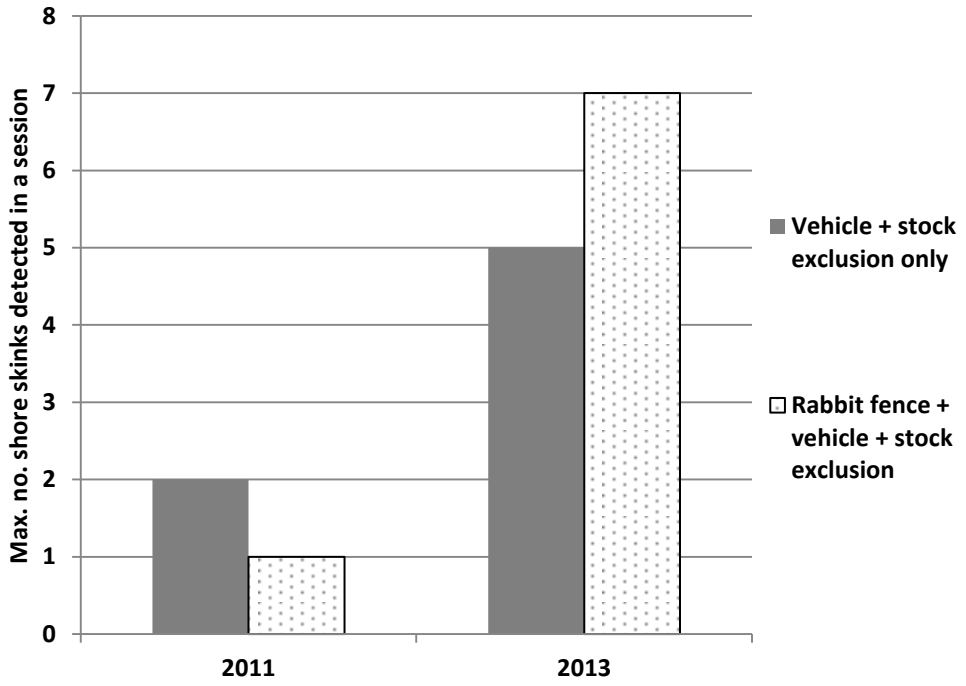

Figure 6: Maximum number of shore skinks detected over four sampling sessions per year in the two-layer Onduline ACOs placed inside and outside a rabbit-proof fence at Te Tumu Kaituna 7B2. 2011 samples were taken in May-June (winter) and 2013 samples were taken over November-December (summer).

Table 6: Detection of shore skinks within and beneath ACOs during May-June 2011 and November-December 2013 samples (checks). The number of shore skinks detected on any one sampling session is recorded. Occupancy is the average proportion of ACOs occupied by shore skinks over the four checks.

Management	Session	May-June 2011 (Pre-Management)			Nov-Dec 2013 (Post-Management)		
		ACOs	Skinks	Occupancy	ACOs	Skinks	Occupancy
Vehicle and stock exclusion	1	50	0	0.00	46	1	0.02
	2	50	**2**	0.04	46	3	0.07
	3	50	0	0.00	46	**5**	0.11
	4	50	1	0.02	46	**5**	0.11
	Mean Occupancy			**0.015**			**0.076**
Rabbit fence + vehicle and stock exclusion	1	50	0	0.00	42	2	0.05
	2	50	0	0.00	42	1	0.02
	3	50	0	0.00	42	**7**	0.17
	4	50	**1**	0.02	42	3	0.07
	Mean Occupancy			**0.005**			**0.077**

4.2.3 Katipo spiders

Katipo were detected at ACO Groups 9 and 10, with a total of 2-3 individual katipo spiders detected in each monitoring session. ACO Groups 9 and 10 are both located outside the rabbit-proof fence, on the inland face of the foredune, in spinifex dominated sandfield and grassland. Another katipo was located under driftwood, also outside the rabbit-proof fence, on the foredune, on 12 November 2013.

4.2.4 Invertebrates

This short survey revealed an invertebrate fauna of 71 species in 39 families across spiders, pseudoscorpions, harvestmen and ten orders of insect (see Appendix 11). Of these 71 invertebrate species, 16 species (23%) are introduced, reflecting the high degree of disturbance these coastal sites have experienced.

Many of the remaining 55 indigenous species are coastal sand dune specialists and have a significant population on the Papamoa dunes. These include:

- Black katipo spider - *Latrodectus atritus* - a northern North Island endemic - note that more recent studies consider the black katipo identical taxonomically to the red katipo *Latrodectus katipo*;
- North Island Rauparaha's copper butterfly - *Lycaena salustius* - a North Island endemic;
- Seashore earwig - *Anisolabis littorea*;
- Sand scarab - *Pericoptus truncatus*;
- Cottonwood cutworms - *Aletia temperata* and *Graphania homoscia*.

While none of these species are distributed along the entire New Zealand coast (they are often replaced by closely related species at other sites), the mix of species is typical and characteristic of New Zealand's coastal sand dunes, particularly those of northern New Zealand.

Fat larvae of the sand scarab beetle *Pericoptus truncatus* were found to be common, with 13 nearly full-grown larvae under one log in the foredune. The adult beetle is large, black and chunky, and about 3 cm in length. It is a weak flier and, although found throughout the summer months, is more common in early spring, when it flies just after sunset.

The presence of two noctuid moth species feeding together as larvae on *Ozothamnus* host plants is significant as this may be the first time they have been found together. Both these species (*Graphania homoscia* and *A. temperata*) have a very patchy distribution around the New Zealand coastline reflecting the distribution of their host plant, with *G. homoscia* found around the North Island and South Island coastline south to mid Canterbury, and *A. temperata* south to Foveaux Strait. Interestingly the younger larvae (under 15 mm in length) of both species are colourful and well camouflaged amongst the foliage of the host plant, but the later instars of *A. temperata* must hide by day in the sand at the base of the shrub as they are plain grey and white and far less camouflaged than those of *G. homoscia*. Each night they make

a long journey and crawl up the shrub from their daytime hiding place to browse foliage.

Black katipo spider

Some regard the black katipo spider (*Latrodectus atritus*) to be the same species as the red katipo *Latrodectus katipo*, which is found coastally in the central region of New Zealand south to about Dunedin and Greymouth. Interestingly, there is an area of overlap in the central region of the North Island on both the east and west coasts where both forms (or species) are found and remain distinct. As one combined species it has a threat classification of At Risk-Declining (Sirvid *et al*. 2012). Given the two entities are generally allopatric, but with a distinct area of overlap, and distinct morphologically, it may be wise to treat them separately as a precautionary measure to ensure that both species or colour morphs are fully conserved.

Nevertheless the Papamoa coastline population is important for the species (Patrick 2002) and the Te Tumu contribution to this population is important in maintaining continuity for gene flow along this coastline. The Te Tumu foredunes have several features that provide excellent quality habitat for katipo:

- Vegetation architecture - open and low-growing vegetation - gives maximum ecological variation for a range of species (i.e. food for katipo) for behavior such as feeding, hiding, courtship and mating.
- Mainly indigenous vegetation that supports abundant invertebrates - food for katipo.
- Consistently open vegetation provides a homogenous cover across the foredunes.
- Abundant driftwood and other debris to provide safe cover for katipo and other invertebrates.
- Indigenous plant species with a 'dense' growth form such as *Muehlenbeckia complexa* are abundant - providing refugia, and a supply of food of invertebrates that feed on these plants.

Effect of Introduced Predators

The compact nests of the Asian paper wasps were quite common in the dunes hanging from various shrubs and lianes. The paper wasps were observed to be systematically taking the larvae of the kowhai moth (*Uresiphita maorialis*) from lupin. Interestingly lupin itself is introduced and is an opportunistic host for this endemic moth, especially at this site, where no kowhai is present. Rates of predation appeared to be high, but the moth remains relatively common, feeding on every available lupin shrub.

The introduced ant *Iridomyrmex* species (Don 2007) is abundant at the site and appears to have benefitted from the presence of the ACOs, under which it has built very large colonies (note the ACOs have now been removed). This ant taxon remains undescribed, but it is very well known both in Australia and the northern third of New Zealand where it inhabits a wide range of ecosystems including urban and rural areas. In Australia, this ant genus is considered the most ecologically important and is often

highly abundant, aggressive and known for its swarming behaviour (Don 2007). These characteristics may result in adverse effects on indigenous invertebrates where this species is present in New Zealand.

4.2.5 Rabbit pellets

The number of rabbit pellets recorded inside the fence decreased from 105 to zero between 2011 and 2013[1] (Table 7). The number of plots where rabbit pellets were recorded also decreased between 2011 and 2013, both inside and outside the fence. This suggests that the fence has been effective at excluding rabbits since rabbits were exterminated within the fence.

Table 7: Number of rabbit pellets and plots where pellets were recorded at Te Tumu Kaituna 7B2 in 2011 and 2013.

	2011			2013		
	Inside Fence	**Outside Fence**	**Total**	**Inside Fence**	**Outside Fence**	**Total**
Number of pellets	105	16	121	0	32	32
Number of plots	1	2	3	0	1	1

4.3 Photopoints and photographs

Comparative photographs of each photopoint and each permanent vegetation plot from 2011 and 2013 are presented in Volume 2, along with a summary of the changes visible at each of the photopoints. Twenty-seven photographs were taken at 15 permanently marked photopoints spread throughout the study area. Twelve photographs show the inside of the rabbit-proof fence, nine photographs show areas outside the fence, and six photographs show areas both within and outside the fence. This equates to 33 possible vegetation comparisons.

There was no significant overall difference in the degree of vegetative change inside and outside the fence. Nine photographs (27%) of vegetation inside the fence showed minor visible change to vegetation, which predominantly comprised increases in vegetation height, density, or extent. Seven photographs (21%) of vegetation outside the fence showed minor visible change to vegetation, which predominantly comprised increases in vegetation extent and change as a result of planting of pīngao. Seven photographs (21%) of vegetation inside the fence showed moderate visible change to vegetation, which predominantly comprised increases in vegetation height, density, or extent. Six photographs (18%) of vegetation outside the fence showed moderate visible change to vegetation, which predominantly comprised increases in vegetation height, density, or extent.

Two photographs (6%) of vegetation inside the fence and two photographs (6%) of vegetation outside the fence, showed significant visible change to vegetation, which

[1] A large hare was seen near the eastern boundary of the site during the July monitoring period. All pellets located during fieldwork were identified as rabbit pellets.

was predominantly comprised of increases in vegetation extent and colonisation of the area by species not present in the area in 2011.

Most of the visible change in vegetation cover can be attributed to the expansion of pōhuehue and the colonisation and expansion of lupin. However growth and/or expansion of wīwī, harestail, and gorse were also significant contributors to the visible change recorded inside the rabbit-proof fence.

There has been significant visible change to the vegetation composition at two photopoints, which show vegetation inside and outside the rabbit-proof fence (Photopoints 10 and 14). These two photopoints show change in vegetation associated with the construction of the rabbit-proof fence. Most of the change evident in these photographs is due to the colonisation of the bare sand that was created through vegetation clearance for fence construction. Other change within these photographs includes an increase in height, density, and extent of both indigenous and exotic species, and the presence of pīngao planted within the area between 2011 and 2013.

Moderate visible change occurred within eleven photographs taken at seven photopoints (Photopoints 1 (two photographs), 4, 6, 7, 9 (two photographs), 10, 11 (two photographs), and 13). Most of the visible change in these photographs is as a result of increases in the height, density, and extent of both indigenous and exotic species.

Minor visible change has occurred within 14 photographs taken at 11 photopoints (Photopoints 2 (two photographs), 3 (two photographs), 4, 5, 6 (two photographs), 8, 10, 12, 13, 14, and 15). Most of the visible change in these photographs is as a result of increases in the height, density, and extent of both indigenous and exotic species, however six photographs show a minor visible decrease in the density and cover of spinifex.

The planting of pīngao within the site between 2011 and 2013 contributed to the visible vegetative change in nine photos at seven different photopoints.

Table 8: Degree of visible vegetative change between 2011 and 2013 in photographs taken at permanent photopoints which show vegetation inside and outside the rabbit-proof fence at Te Tumu Kaituna 7B2.

Photopoint	Bearing	Photograph In/Out Rabbit-proof Fence	Degree of Change	Increase in Vegetation Height or Density	Increase In Vegetation Extent	Decrease in Vegetation Height or Density	Decrease in Vegetation Extent	Colonisation by Species not Previously Present	Species Previously Present Now Absent	Pīngao Planted at Site
P1	310	Out	Moderate	✓	✓	X	X	X	X	X
P1	100	In	Moderate	✓	✓	X	X	✓	X	X
P2	90	Out and in	Minor	✓	✓	X	X	X	X	✓
P2	245	Out	Minor	✓	✓	X	X	X	X	X
P3	270	Out	Minor	X	✓	X	X	X	X	X
P3	140	Out	Minor	X	X	X	✓	X	X	✓
P4	180	In	Moderate	✓	✓	X	✓	X	X	X
P4	100	In	Minor	X	✓	X	X	✓	X	X
P5	220	In	Minor	✓	✓	X	X	X	✓	X
P6	240	In	Minor	X	✓	X	X	X	X	X
P6	90	In and out	Moderate	X	✓	✓	X	X	X	✓
P6	270	In and out	Minor	X	✓	✓	X	X	X	✓
P7	90	In	Moderate	✓	✓	✓	X	X	X	✓
P8	90	In	Minor	X	✓	✓	X	X	X	X
P9	280	In	Moderate	✓	✓	X	X	✓	X	X
P9	80	In	Moderate	✓	✓	X	✓	✓	X	X
P10	270	In (and out)	Significant	✓	✓	X	X	✓	X	X
P10	330	In	Minor	✓	✓	X	X	X	X	X
P10	E-NE	Out	Moderate	✓	✓	X	X	X	X	X
P11	120	Out	Moderate	X	✓	X	X	✓	X	✓
P11	260	Out and in	Moderate	X	✓	X	X	X	X	✓
P12	270	Out	Minor	X	✓	X	X	X	X	X
P13	270	Out	Minor	X	X	X	X	✓	X	✓
P13	120	Out	Moderate	X	✓	X	X	X	✓	X
P14	200	In	Minor	X	✓	✓	X	✓	X	X
P14	80	Out and in	Significant	X	✓	X	X	✓	X	✓
P15	70	In	Minor	✓	✓	X	X	✓	X	X

5. DISCUSSION

5.1 Vegetation and flora

Analysis of the permanent plot data revealed that the mean cover of all plant taxa decreased (although not significantly) both inside and outside the rabbit-proof fence between 2011 and 2013. However, individual plant taxa showed different responses over time. Taxa that showed an increase in mean cover both inside and outside the fence between 2011 and 2013 (e.g. *Carex testacea*, harestail, and lupin) may reflect a release from grazing pressure by stock (which are now absent both inside and outside the rabbit-proof fence). Taxa that increased in mean cover inside the fence, but decreased in cover or maintained a relatively constant cover outside the fence (e.g. perennial ryegrass, chickweed, and *Zoysia pauciflora*) may reflect a release from grazing pressure by rabbits alone. A decrease in the mean total vegetative cover or cover of species within the plots both inside and outside the fence may reflect a cause that is independent of the rabbit- and stock-proof fences such as the drought over the 2012-2013 summer.

Substantial decreases in the cover of three indigenous species (pōhuehue, wīwī, and sand bindweed) both inside and outside the rabbit-proof fences suggests a cause that is independent of the rabbit-proof fence. Based on changes observed in the permanent photopoints and photographs of vegetation plots, the substantial decrease in pōhuehue cover both inside and outside the rabbit-proof fence appears to be correlated with the substantial increase in *Carex testacea* cover both inside and outside the rabbit-proof fence. Reduction in sand bindweed cover may be the result of increases in moss and vascular plant species cover on the ground which would shade out potential microsites for sand bindweed.

Increased frequency of pōhuehue, Yorkshire fog, bracken, lupin, and *Oxalis rubens* inside the rabbit-proof fence compared to outside the fence (where frequency decreased or remained relatively constant) between 2011 and 2013 suggests that the increase may be related to the presence of the rabbit-proof fence.

Minor changes to the cover and frequency of plant taxa and ground cover were evident between years, but vegetation composition within the plots did not change significantly between 2011 and 2013. Therefore, two years between measurements may not be sufficient to see any statistically significant change in vegetation composition. Remeasurement of vegetation plots and photopoints was undertaken slightly later in the year than in 2011 (July compared with May); therefore differences, or lack of difference, in vegetation composition and cover between years may reflect this slight temporal mis-match.

5.2 Birds

The composition and abundance of birds monitored at Te Tumu 7B2 has not changed significantly since 2011 - this finding is not unexpected. The suite of birds present is mainly a combination of indigenous, non-threatened species, and introduced species. It is likely that the two Threatened or At Risk bird species recorded in 2011, Caspian tern (Threatened-Nationally Vulnerable), and variable oystercatcher (At Risk-Recovering), will continue to use Te Tumu 7B2 sporadically as a non-breeding site.

Specific monitoring of birds at Te Tumu 7B2 is relatively low priority, however the method used in this project - performing a 5 minute count at each vegetation plot - is low cost, and should be continued. A checklist of birds recorded at the site, including those observed outside formal 5 minute count locations, should be maintained for inventory purposes.

5.3 Lizards

The use of two-layer Onduline ACOs has provided data that indicate shore skink populations within the rabbit-proof fence at Te Tumu Kaituna 7B2 have not improved in a measureable way from 2011 to 2013 when compared to those present outside the fence. When seasonal influences are ignored (winter versus summer sampling), shore skink populations, as measured by detection within and beneath ACOs, were equivalent both within and outside of the rabbit exclusion area. Rabbit control that occurred in 2011 and, subsequently, outside the rabbit-proof fence may partly explain the results to date. There is a possibility that effects of the fence may require longer than the two-year duration of this work to manifest in the lizard detection data.

Section 3.9 provides an explanation for why data from ACOs were insufficient to determine trends in shore skink populations, both inside or outside the fence, but modifications to the use of ACOs can readily be made to achieve this goal. In order to deter lizards from guarding ACOs to the exclusion of other lizards, and therefore allow them to become effective sampling units for a monitoring programme, ACOs could be placed in the field, left to "weather in" for 1-2 months, checked (1-4 times) then removed. At the beginning of each monitoring session the ACOs are then redeployed in the same manner, and always removed. The removal of ACOs deters lizards setting up home within an ACO or even multiple ACOs. Each monitoring session should span the same calendar months (ideally November-January) to remove any seasonal bias. Using this refined methodology will allow the ACOs to collect shore skink population trend-data from both inside and outside of the rabbit-exclusion fence through time. Data on lizard detection collected over 2011 and 2013 can be used as important baseline, but as a *parallel* data set to data collected under this refined regime.

As the restoration work at Te Tumu Kaituna 7B2 progresses there is a possibility that other lizard species may begin using the site in detectable numbers, in particular moko skinks or even *Woodworthia maculata* (a gecko species). Both of these species may occur in the ACOs, but to avoid possible misidentification of moko skinks as shore skinks it is important that all skinks (and geckos) that use the ACOs are captured for identification. Checking ACOs at night or early in the morning, or on cooler days over summer, before conditions heat up and the skinks become fast and hard to capture will assist in lessening escapees and should be adopted over any future lizard work at Te Tumu Kaituna 7B2. In addition, should a new skink species be suspected to occur, a short period of targeted pitfall trapping should be employed to capture skinks for identification purposes (not monitoring).

5.4 Katipo spiders

The low numbers of katipo detected in November and December 2013 is in accord with the low numbers detected during katipo surveys undertaken on the Pāpāmoa-

Kaituna Dunes in 1999 (Patrick 2002), 2005, and 2007 (B. Christensen, DOC, *unpubl. data*). Non-detection of katipo during 2011 monitoring at Te Tumu may have been due to lower detectability of katipo during the sampling period (winter), or observer misidentification. The latter is likely to be an ongoing issue for any future katipo survey or monitoring at Te Tumu, because of the very similar appearance of the black form of katipo spider to *Steatoda capensis*.

Presence of katipo should continue to be recorded during any future ACO monitoring. There may be some merit in increasing the number of ACOs put out along the foredune to increase detectability. Any additional ACOs should also be removed at the conclusion of each monitoring round.

5.5 Invertebrates

In terms of invertebrate orders, families, and species, the sand dunes of Te Tumu contain a diverse invertebrate fauna that is typical of the more intact dunes of northern New Zealand. Taking into consideration the short duration of the survey and the seasonality of the New Zealand invertebrate fauna, particularly insects, the 71 species found is significant. Many of the invertebrate species were also found by Patrick (1996) on nearby Moutohora Island in similar habitat.

The sand dunes of Te Tumu are important because many specialist indigenous coastal species are present, many of which have a close association with particular indigenous plants or ecological features. Key ecological factors that make Te Tumu important for indigenous invertebrates are:

- Predator-prey interactions are numerous here (e.g. spider-hunting wasps) indicating high ecological integrity and intactness;
- The varied architecture of the flora providing numerous micro-habitats;
- Abundance of key indigenous plants such as pingao, *Muehlenbeckia complexa*, *Ozothamnus leptophyllus*, *Calystegia soldanella*, and *Spinifex*;
- Presence of driftwood and other ground cover (includes some debris);
- Sequence of foredunes and foredune plains in a natural setting;
- Abundance of bare sand on dunes and hollows which is important for invertebrate behavior.

Conspicuous Species

Three indigenous insect species standout in terms of their conspicuousness and high population numbers in the dunes at Te Tumu. All three are coastal specialists that have significant populations in these dunes:

- The North Island Rauparaha's copper butterfly *Lycaena salustius* is endemic to the North Island coast. It is a bright orange species with yellow undersides. Until recently the scientific name of this species has been misapplied but we now know it refers to this attractive coastal species found around the North Island coast where the larvae feed on *Muehlenbeckia complexa*. At Te Tumu it is common and conspicuous amongst the fore and hind dunes.

- The sand scarab beetle *Pericoptus truncatus* is also common and conspicuous in the dunes at Te Tumu where the larvae feed under driftwood, shrubs or grasses. The chunky larvae and adults are surprisingly large and the adults clumsy and weak fliers. Dead and desiccated adults will often be found by day on sand amongst the dunes.

- The large black indigenous earwig species *Amisolabis littorea* is quite common and very conspicuous under driftwood or debris in the dunes at Te Tumu. Adults appear to feed on detritus and are communal.

Threatened and Rare Species

The black katipo (*Latrodectus atritus*), sometimes considered a synonym of the red katipo, is ranked by the Department of Conservation as "At Risk, Declining" (Sirvid *et al.* 2012) and is fully protected under the Wildlife Act. Patrick (2002) in a nationwide survey of both katipo species found moderate numbers along the Pāpāmoa-Kaituna coastline and considered the Papamoa population of significance in the Bay of Plenty Region.

The noctuid moth *Aletia temperata* is a poorly known and this stage rare coastal moth species with a very patchy distribution nationally. Its larvae feed on *Ozothamnus leptophyllus*. It appears to have a significant population at Te Tumu.

Seasonality

New Zealand invertebrates, particularly some insect groups are highly seasonal in their emergence. Therefore this short spring survey will have missed some species such as cicadas, and many beetles and moths. A short two-day survey during January-April would resolve this, and increase the knowledge of invertebrates present.

5.6 Rabbits

Rabbit sign was not observed within the rabbit-proof fence, which indicates that the fence constructed is adequate for the task. Rabbit sign was infrequent throughout the rest of the site, with digging observed on only a few occasions, browse observed in only two plots, and pellets found in only one plot, which in part may reflect rabbit behaviour (using specific 'latrine' sites, especially buck rabbits), or rapid breakdown of pellets under high exposure to sun, wind, and rain, but also indicated the effectiveness of rabbit control that occurs at Te Tumu 7B2 and the wider Papamoa dune system. Each November the dunes are checked at 200 m intervals for rabbit sign using the Modified McLean Scale, by Regional Council staff or contractors. Rabbit control is triggered if two or more consecutive plots have a MMS > 2, and there is visual evidence of negative effects on plants from rabbits. The last round of rabbit control occurred in 2011. The 2013 MMS survey indicated rabbit numbers and impacts were insufficient to trigger another operation. The MMS survey results, combined with the vegetation plot pellet counts, suggests rabbit abundance outside the fence was low in July and November 2013. Subsequently, however, increased rabbit abundance elsewhere in Papamoa has triggered control operations (Pim de Monchy, BOPRC, pers. comm.).

6. CONCLUSIONS

The seven vegetation and habitat types identified and mapped within the study area in 2011 were expanded to twenty-two vegetation and habitat types, as these better reflect the vegetation patterns currently present at the site, and will allow any change occurring over time to be more easily identified. The 28 permanent 2 × 2 m vegetation plots and 15 permanent photopoint locations established in 2011 were remeasured in 2013 using the methods established in 2011. These plots and photopoints span a range of vegetation and habitat types both inside and outside the rabbit-proof fence.

Monitoring implemented in this study has the potential to detect any changes at the site that occur in response to fencing and eradication of rabbits, and exclusion of cattle and vehicles. The sample points within the rabbit-proof fence will detect changes that are a consequence of stock, vehicles, and rabbits being excluded. Sample points outside the rabbit-proof fence are within the stock-proof fence, so will change as a consequence of the exclusion of stock and vehicles, but not rabbits. To enable identification of changes in vegetation cover and habitat composition as a result of active management in the study area, it may also be useful to consider sampling of an area with similar vegetation cover that will not be subjected to any management during the course of the study.

Changes in vegetation composition and cover were apparent in the photopoints, but comparison of changes in plant species cover and frequency, vegetation composition, and ground cover within plots did not yield statistically significant differences except for a decrease in the cover of litter between 2011 and 2013. Therefore, two years may not be a sufficiently long time frame within which to see statistically significant vegetative change. It may, therefore, be appropriate to visually assess the site, with the aid of the photopoint data and plot photographs, more frequently than assessing the site using vegetation plots.

In addition, rabbit sign outside the rabbit-proof fence was relatively low at the time of the monitoring, however rabbit numbers will build up outside the rabbit-proof fence from time to time prior to being controlled by the Regional Council when high numbers are identified. Even if moderate-sized rabbit populations occurring from time to time will have an impact on vegetation quality over time, and therefore fauna (lizard and invertebrate) habitat quality. The quality of habitat within the rabbit-proof fence will continue to improve over time without the intermittent damage caused as a result of moderate-high rabbit numbers which are likely to occur outside the rabbit-proof fence from time to time.

Based on photopoint data, the most obvious change in vegetation cover is associated with vegetation clearance that was undertaken for construction of the fence. A large part of this cleared fence line has been planted with pīngao (*c.*663 m out of *c.*1,398 m). Elsewhere, however, these areas have mainly become colonised by exotic species. If weed control is carried out, the locations and target species should be recorded so that the results of future vegetation monitoring are not confounded by the effects of weed control.

Shore skinks have been the only lizard species recorded at Te Tumu Kaituna 7B2 to date, and when seasonal influences are ignored, shore skink populations were equivalent both within and outside of the rabbit exclusion area. Refinements to the method of ACO use are recommended to improve the data on shore skink population trends both within and outside of the rabbit exclusion area and to lessen the number of escapees. There is also the possibility that other lizard species will be found at the site as restoration works proceed and, if this occurs, further refinements to the lizard monitoring strategy will be required.

ACO monitoring in 2013 confirmed the presence of black katipo at Te Tumu Kaituna 7B2, in their preferred foredune habitat. Only four out of 20 current ACO locations are sited on or adjacent to the foredune. Setting up additional ACOs along the foredune may provide better information on katipo distribution and abundance at the site.

In future ACOs should be removed once shore skink and black katipo monitoring work is completed, in order to conform to ACO 'best practice', and also to reduce available habitat to introduced ant and cockroach species, which were found to be abundant in many ACOs.

Summary of Suggested Future Work

2015

- Remeasure all photopoints (May-June).
- Adopt refined methods for the deployment of ACOs both inside and outside of the rabbit exclusion fence to determine occupancy and to collect data on lizard population trends.
- Continue to collect data on katipo via ACO monitoring. Place additional ACOs on foredune where katipo are more likely to be detected.
- Survey for indigenous invertebrates for two days within period January to April would increase the knowledge of invertebrates present.
- General inspection to assess whether remeasurement of other components is appropriate (March-April).

2016

- Remeasure all vegetation monitoring plots, photopoints, threatened plant populations, bird records, and analyse data.
- Report on above.

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LOCATIONS OF PERMANENT 2 × 2 M SAMPLE VEGETATION PLOTS

Plot Number	Location Relative to Rabbit-Proof Fence	2013 Vegetation Type	Remeasurement Date	Easting	Northing	Aspect	P Tag	D Tag	Orientation from Corner P	Photograph Location 1	Photograph Location 2	Notes
1	Outside	Spinifex grassland	10/07/2013	2808030	6379841	14°	W2 6639	W2 6638	191° to A, 99° to M	From c.1 m behind corner P looking towards corner D	E2808006 N6379838 at 60°	Both corner peg tags missing. Both replaced.
2	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	16/07/2013	2807583	6380005	flat	W2 6695	W2 6694	192° to A, 276° to M	1.5m back from corner P looking towards corner D	140° and 6 m from corner A looking towards corner M, at 311°	
3	Outside	Spinifex grassland	16/07/2013	2807580	6380133	flat	W2 6692	W2 6691	354° to A, 89° to M	From P to D	from 2807599 6380138 at 235°. Over midden and plot toward bach.	
4	Outside	Spinifex grassland	8/07/2013	2807812	6379995	5°	W2 6679	W2 6697	0° to A, 90° to M	From P to D	From 6m east of D, looking west toward house & radio mast	260° to radio mast, 50° to Plate Is
5	Outside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	16/07/2013	2807553	6380097	S	W2 6606	W2 6690	20° to A, 107° to M	From point P, from ~5m E of plot looking W, from E2807562 N6380102 @ 210°	From corner P looking towards corner D	Could not replicate first photograph due to shade cast by house at time of measurement
6	Outside	Spinifex-*Lachnagrostis billardierei*-hinarepe sandfield	8/07/2013	2808174	6379743	N	W2 6673	W2 6674	0° to A, 90° to M	From P to D @45° in dune hollow	From E2808190 N6379735 @ 260°. A to P plot 25 located in background.	
7	Outside	Spinifex-*Lachnagrostis billardierei*-hinarepe sandfield	8/07/2013	2808157	6379728	flat	W2 6671	W2 6672	0° to A, 90° to M	P to D in dune hollow	@280° towards plot 25 in background, @ E2808170 N6379721	
8	Inside	Pōhuehue-harestail-*Carex testacea*-(lupin) vine-grassland	9/07/2013	2807987	6379751	flat	W2 6670	W2 6669	0° to A, 88° to M	1 m back from Corner P looking towards corner D @ 45°	10 m from corner D @ E2808002 N6379749 @ 266° towards old hay barn	bearing to Town Point 78°
9	Inside	Spinifex grassland	10/07/2013	2808019	6379827	N	W2 6688	W2 6640	178° to A, 272° to M	From corner P to D c.1m back from P.	From E2807998 N6379823 (x2) (60°, 85°)	Corner D tag replaced.
10	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	9/07/2013	2807941	6379815	N	P5177	P5178	180° to A, 96° to M	2m back from corner P looking towards corner D	from E2807928 N6379819 at 180°	
11	Inside	Wīwī/pōhuehue-bracken-kikuyu grass vine-sedgeland	10/07/2013	2807848	6379835	214°	P5183	P5182	188° to A, 95° to M	1m back from Corner P looking towards corner D. Looking 'down' on plot.	1m back from Corner P looking towards corner D. Looking out towards farmland	
12	Inside	Spinifex grassland	8/07/2013	2807770	6379992	N	W2 6609	W2 6608	180° to A, 270° to M	Looking from corner D to corner P	From E2807759 N6379988 @ 70°	
13	Outside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	16/07/2013	2807582	6380061	218°	W2 6665	W2 6666	0° to A, 88° to M	1m back from Corner P looking towards corner D	E2807587 N6380061 @270°	
14	Outside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	16/07/2013	2807566	6380033	180°	W2 6611	W2 6610	003° to A, 101° to M	1m behind corner P looking towards corner D	2m behind corner M looking towards corner A	
15	Outside	Wīwī/pōhuehue-bracken-kikuyu grass vine-sedgeland	16/07/2013	2807542	6380034	flat	W2 6612	W2 6613	004° to A, 90° to M	P to D @ 45° (post in midground)	M to A baches in background @ 315°	
16	Inside	Spinifex grassland	8/07/2013	2807842	6379927	NE	W2 6663	W2 6664	0° to A, 90° to M	P to D @ 45°	From E2807832 N6379932 @ 80 and 100°	
17	Inside	Spinifex grassland	8/07/2013	2807736	6380002	S	W2 6678	W2 6677	0° to A, 90° to M	From corner P towards corner D	From 10m east of plot @ 260°	
18	Inside	Spinifex grassland	8/07/2013	2807876	6379899	NE	W2 6662	W2 6661	0° to A, 90° to M	From corner P to corner D @ 45°	From E2807862 N6379906 @ 90°	
19	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	10/07/2013	2807728	6379935	176°	W2 6675	W2 6676	002° to A, 93° to M	1m back from corner P looking down on plot towards corner D	1m back from corner D looking towards corner P and farmland beyond	2011 plot coordinates off by *c.*10m
20	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	8/07/2013	2807829	6379904	S	W2 6668	W2 6667	0° to A, 90° to M	P to A	D to P	
21	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	10/07/2013	2807664	6379976	214°	W2 6615	W2 6614	003° to A, 99° to M	1.5m back from corner D, facing corner P (@225°) with farmland in background	1m back from corner P looking towards corner D @45°	

Plot Number	Location Relative to Rabbit-Proof Fence	2013 Vegetation Type	Remeasurement Date	Easting	Northing	Aspect	P Tag	D Tag	Orientation from Corner P	Photograph Location 1	Photograph Location 2	Notes
22	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	16/07/2013	2807626	6379975	N	W2 6694	W2 6618	0° to A, 91° to M	1m back from corner P looking towards corner D	Walk approx. 10m from plot @ 147°. Take pic @310°	Corner D tag replaced.
23	Inside	Spinifex grassland	9/07/2013	2808076	6379775	N	W2 6655	W2 6656	355° to A, 85° to M	1m back from corner P looking towards corner D (x2)		
24	Outside	Spinifex grassland	10/07/2013	2807946	6379897	268°	W2 6660	W2 6659	92° to A, 12° to M	1m back from corner P looking towards corner D @45°	1.5m back from corner D looking towards corner P (crouching down)	No hawksbeard in plot
25	Outside	Spinifex-*Lachnagrostis billardierei*-hinarepe sandfield	8/07/2013	2808133	6379720	flat	(A Tag) W2 6686	(M tag) P5190	180° to A, 270° to M	from A towards Cnr M		Four pīngao plants have been planted within the plot. Tags are on corners A and M rather than P and D.
26	Inside	(Wīwī)/pōhuehue-*Carex testacea* vine-sedgeland	8/07/2013	2808024	6379785	flat	W2 6657	W2 6658	0° to A, 90° to M	From corner P looking towards corner D @45°	From beside the plot looking east towards Maketu	Plot on high point/hilltop/knoll
27	Inside	(Spinifex)/harestail-*Lachnagrostis billardierei*-catsear grassland	8/07/2013	2807869	6379862	180°	P5180	P5181	0° to A, 270° to M	From corner P to corner D	From E2807868 N6379856 @ 140°	No hawksbeard in plot
28	Inside	Spinifex grassland	9/07/2013	2808034	6379743	E	P5191	W2 6641	295° to A, 25° to M	1.5m back from corner P	From E2807868 N6379856 @ 140°	Corner D tag replaced.

LOCATIONS OF PERMANENT PHOTOPOINTS

Photo-point	Location	E	N	Notes	Tag Number	Bearing	Photograph In/Out Rabbit-proof Fence
P1	On fence	2807575	6380029	Strainer post at bend in fence.	W2 6654	310	Out
P1	On fence	2807575	6380029	Strainer post at bend in fence.	W2 6654	100	In
P2	Outside of fence	2807595	6380080	15 m east of all bach site, on old fence line (not rabbit-proof fence). Marked with Waratah.	W2 6616	90	Out and in
P2	Outside of fence	2807595	6380080	15 m east of all bach site, on old fence line (not rabbit-proof fence). Marked with Waratah.	W2 6616	245	Out
P3	Outside of fence	2807612	6380123	Waratah 60 deg and 70 m from bach, east of Vegetation Plot 3.	W2 6652	270	Out
P3	Outside of fence	2807612	6380123	Waratah 60 deg and 70 m from bach, east of Vegetation Plot 3.	W2 6652	140	Out
P4	Inside of fence	2807649	6380046	Waratah 60 deg and 70 m from bach, east of Vegetation Plot 3.	W2 6653	180	In
P4	Inside of fence	2807649	6380046	Waratah 60 deg and 70 m from bach, east of Vegetation Plot 3.	W2 6653	100	In
P5	Inside of fence	2807697	6379969	Waratah.	W2 6650	220	In
P6	On fence	2807784	638009	Fence post.	W2 6649	240	In
P6	On fence	2807785	6380007	Fence post.	W2 6649	90	In and out
P6	On fence	2807785	6380007	Fence post.	W2 6649	270	In and out
P7	On fence	2807846	6379906	Fence post.	W2 6649	90	In
P8	Inside of fence	2807968	6379822	Waratah.	W2 6651	90	In
P9	Inside of fence	2807985	6379754	Waratah at Vegetation Plot 8.	W2 6651	280	In
P9	Inside of fence	2807985	6379754	Waratah at Vegetation Plot 8.	W2 6670	80	In
P10	On fence	2808065	6379708	Strainer post at bend in fence.	W2 6648	270	In (and out)
P10	On fence	2808065	6379708	Strainer post at bend in fence.	W2 6648	330	In
P10	On fence	2808065	6379708	Strainer post at bend in fence.	W2 6648	E-NE	Out
P11	Outside of fence	2808110	6379768	Waratah.	W2 6647	120	Out
P11	Outside of fence	2808110	6379768	Waratah.	W2 6647	260	Out and in
P12	Outside of fence	2808163	6379725	Waratah at Vegetation Plot 7.	W2 6643	270	Out
P13	Outside of fence	2808198	6379728	Waratah.	W2 6646	270	Out
P13	Outside of fence	2808198	6379728	Waratah.	W2 6646	120	Out
P14	On fence	2807983	6379863	Fence post.	W2 6645	200	In
P14	On fence	2807983	6379863	Fence post.	W2 6645	80	Out and in
P15	On fence	2807825	6379860	Fence post.	W2 6644	70	In

PERMANENT PHOTOPOINT MEASUREMENT SHEET

Plot Number:		**Date:**	
Veg. Type:		**Measured by:**	
GPS Coordinates:	Easting Northing	**Aspect:**	
Location: (delete one)	Inside rabbit-proof fence Outside rabbit-proof fence		

Orientation from Corner P	___ ^{o} to A	___ ^{o} to M	**P Tag No.**	**D Tag No.**

Vascular Species Present	No. Plants	Inflorescences Present?	Max. Height	Browse*
Pingao				
Spinifex				
Hinarepe				
Lupin		**N/A**	**N/A**	**N/A**
Gorse		**N/A**	**N/A**	**N/A**

*L - low; M - medium; H - high; VH - very high.

Number of Rabbit Pellets	

Groundcover	% Cover
Bare sand	
Moss	
Vascular plants	
Litter	

Location of Photograph(s):

Photograph 1:

Photograph 2:

Photograph 3:

Notes:

% Cover in Entire Plot and Presence in 0.5 × 0.5 m Sub-Plots

Species	Cover %	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

APPENDIX 4

PERMANENT PHOTOPOINT RECORD SHEET

Date:		Photopoint number:		Photographer:	

GPS Coordinates: E:
N:

Established: Aerial Photo No:

Camera and Lens Details:

Time: Compass bearing (mag):

Vegetation Description (photographed part):

Change in Vegetation:

Notes:

Site No. _____

Location Map:

FIVE-MINUTE BIRD COUNT SHEET

Observer		**Date**		**General Location**		**Specific Location**	

Plot Number											
Grid Ref (Easting, 7 digits)											
Grid Ref (Northing, 7 digits)											
Start Time (24 hour)											
Temperature (1-6)											
Wind (0-3)											
Other Noise (0-2)											
Sun (minutes)											
Precipitation Type (N,M,R,H,S)											
Precipitation Value (0-5)											
Species	**Seen**	**Heard**	**Seen**	**Heard**	**Seen**	**Heard**	**Seen**	**Heard**	**Seen**	**Heard**

Sun (0-5) Record approximate duration, in minutes, of bright sun on the canopy immediately overhead.

Seen and Heard
Birds that are first heard should be entered under **H** (even if they are later seen), birds that are first seen should be entered under **S**. Adding H and S should give the total number of birds observed.

Time 24 hour clock, at the beginning of each count

Unbounded Counts are unbounded

Temperature
1 freezing < 0°C
2 cold 0-5 °C
3 cool 6-10 °C
4 mild 11-15 °C
5 warm 16-22 °C
6 hot >22 °C

Wind The average for each five-minute count on a modified Beaufort scale:
0 Leaves still or move without noise (Beaufort 0 and 1)
1 Leaves rustle (Beaufort 2)
2 Leaves and branches in constant motion (Beaufort 3 and 4)
3 Branches or trees sway (Beaufort 5, 6 and 7)

Other Noise i.e. Other than wind the average for the five minutes
0 not important
1 moderate
2 loud

Precipitation Type
Average for each count
N None
M Mist
R Rain
H Hail
S Snow

Precipitation Value
0 None
1 Dripping foliage
2 Drizzle
3 Light
4 Moderate
5 Heavy

PERCENTAGE COVER OF PLANT TAXA IN PERMANENT PLOTS IN EACH VEGETATION AND HABITAT TYPE

Year	Binomial	2011 Vegetation and Habitat Type																										
		(Wīwī)-(pōhuehue)-(*Carex testacea*)/ harestail-shore bindweed grassland	(Spinifex)/harestail-*Lachnagrostis billardierei*/ catsear grassland	Wīwī sedgeland		(Wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland										Spinifex- dominated sandfield and grassland										Spinifex-hinarepe-*Lachnagrostis billardiereil* sandfield		
		8	27	2	15	5	10	11	13	14	19	20	21	22	26	28	1	3	4	9	12	16	17	18	23	24	6	7	25
2011	*Anthoxanthum odoratum*	1		1	5				0.5				2	30														
	Calystegia soldanella	10	2	2	2	2	1	7	2	3	2	3	2	3	2	4	5	0.5	2	2		3	1	2	3	3			
	Carex pumila						1											2											
	Carex testacea	0.5				15	3		15	7	50	12	10		4														
	Cerastium fontanum			1				3						0.5															
	Crepis capillaris								0.5														1		0.5		0.5	0.5	0.5	
	Dactylis glomerata										5																		
	Ficinia nodosa	15		80	50	1	60		20							5													
	Holcus lanatus	2		1	5	18		0.5	10	10		0.5		5		2													
	Hypochoeris radicata	0.5	2			0.5				0.5		10		0.5	1	1	3	2	10	1	1	9	3	5	5	5	0.5	0.5	
	Lachnagrostis billardierei	2	0.5				3				3				0.5	7	2	1		15			2	10		2			
	Lagurus ovatus	15	3		20	3			20	15		5			2	5	1	0.5	1	1	0.5	4	2	2	2	1		0.5	
	Leontodon taraxacoides		0.5													1	4		0.5	13			0.5						
	Ligustrum sinense				3																								
	Lolium perenne	1				1	0.5	21			3		30	2															
	Lupinus arboreus							0.5		0.5		0					0.5		1	0.5					0.5				0.5
	Moss	6	12						3	5		5				20						30	2		5				
	Muehlenbeckia complexa	2		18	6	40	30	48	10		25	5	55	45	75	40						4							
	Oxalis rubens	0.5				4	1		2	1	2		7	1	6	3				2		1	0.5						
	Paspalum dilatatum	2																											
	Poa billardierei																										1	2.5	
	Pteridium esculentum			3	10			2	2	1			5	1															
	Rumex acetosella	15		5	5	1		18	10	5	2	20		10	20	2													
	Spinifex sericeus		13												0	1	14	12	25	7	12	25	20		20	15	20	10	
	Stellaria media		0.5													1													
	Taraxacum officinale																		1										
	Trifolium species																			0.5									
	Zoysia pauciflora														0.5														
2013	*Anthoxanthum odoratum*				2																								
	Bromus diandrus		3													0.5													
	Calystegia soldanella		2.5	2.5		0.5		1.5	0.5	2	2	1.5	1	1.5	1.5	1.5	1.5		1			1	1	1	2.5	2.5			
	Carex pumila					1	0.5					0.5		3				5											
	Carex solandri	4					1.5													1.5									
	Carex testacea	2				25	19		55	5	36	25	30		40														
	Cenchrus clandestinus																							1					
	Cerastium fontanum													0.5															
	Conyza sumatrensis													0.5	0.5														
	Dactylis glomerata										4																		
	Ficinia nodosa	15		63	20	1	50	0.5	15	3						3													
	Ficinia spiralis																												5
	Galium aparine				0.5																								
	Holcus lanatus	0.5		2	10			3						8															
	Hypochoeris radicata	0.5	3			0.5						7			0.5	0.5	3		2	1	2	5	3	5	4	5	0.5	0.5	0.5
	Lachnagrostis billardierei		0.5		0.5		2		1	0.5	0.5	0.5	0.5	3	2	9	2	2	0.5	10	0.5	2	3	10		1		1	

Year	Binomial	2011 Vegetation and Habitat Type																											
		(Wīwī)-(pōhuehue)-(*Carex testacea*)/ harestail-shore bindweed grassland	(Spinifex)/harestail-*Lachnagrostis billardierei* catsear grassland	Wīwī sedgeland		(Wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland											Spinifex- dominated sandfield and grassland										Spinifex-hinarepe-*Lachnagrostis billardiereil* sandfield		
		8	27	2	15	5	10	11	13	14	19	20	21	22	26	28	1	3	4	9	12	16	17	18	23	24	6	7	25
	Lagurus ovatus	37	15		5	2			3	36	1	15		0.5	1	24	18	1	8	8	0.5	6	7	3	9	8			0.5
	Leontodon taraxacoides		1														1	2		6					1	2			
	Lichen										0.5	0.5																	
	Ligustrum sinense				2																								
	Lolium perenne						0.5	36			13		15																
	Lupinus arboreus	2		0.5					0.5	1	1					1	10		1	10				0.5		0.5			6
	Moss	3	21	0.5	10	1			2	3	0.5	3		2		20				0.5		25	2		5				
	Muehlenbeckia complexa	2		15	5	27	25	38	2		20	6	34	30	50	25						4							
	Orobanche minor																						0.5						
	Oxalis rubens	0.5			0.5	3	2		0.5		2	2	4	1	3	1				0.5			0.5		1	0.5			
	Poa billardierei																										0.5		
	Poa pratensis			0.5	2	0.5			0.5			0.5		3															
	Pteridium esculentum			8	10			5	0.5	0.5			2	6															
	Rumex acetosella	5		2	2			7	3	1	3	5		15	3	2													
	Spinifex sericeus		15.5														12	17	20.5	4.5	13	20	20.5		18	15.5	8	6	
	Stellaria media		0.5	0.5				2						0.5								0.5							
	Taraxacum officinale								3																				
	Trifolium species																			0.5									
	Zoysia pauciflora														2														

NUMBER OF SUBPLOTS WITHIN EACH PERMANENT VEGETATION PLOT IN WHICH EACH PLANT TAXON WAS RECORDED

*There were16 subplots per plot.

Year	Taxon	Vegetation and Habitat Type					
		(Wīwī)-(pōhuehue)-(*Carex testacea*)/ harestail-shore bindweed grassland	**(Spinifex)/harestail-*Lachnagrostis billardiereil* catsear grassland**	**Wīwī sedgeland**	**(Wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland**	**Spinifex- dominated sandfield and grassland**	**Spinifex-hinarepe-*Lachnagrostis billardiereil* sandfield**
2011	*Anthoxanthum odoratum*	1		6	15		
	Calystegia soldanella	15	14	11	90	110	
	Carex pumila				3	1	
	Carex testacea	2			71		
	Cerastium fontanum			4	4		
	Crepis capillaris				2	7	6
	Dactylis glomerata				2		
	Ficinia nodosa	6		30	27		
	Holcus lanatus	1		4	36		
	Hypochoeris radicata	1	5		17	101	5
	Lachnagrostis billardierei	2	1		21	25	
	Lagurus ovatus	14	13	3	67	115	1
	Leontodon taraxacoides		1		1	31	
	Ligustrum sinense			2			
	Lolium perenne	1			50		
	Lupinus arboreus				4	27	8
	Moss	5	15		31	25	
	Muehlenbeckia complexa	5		27	144	3	
	Oxalis rubens	1			58	8	
	Paspalum dilatatum	3					
	Poa billardierei						8
	Pteridium esculentum			13	18		
	Rumex acetosella	13		23	98		
	Spinifex sericeus		6		2	104	17
	Stellaria media		2		4		
	Taraxacum officinale					1	
	Trifolium species					1	
	Zoysia pauciflora				2		

Year	Taxon	Vegetation and Habitat Type					
		(Wīwī)-(pōhuehue)-(*Carex testacea*)/ harestail-shore bindweed grassland	(Spinifex)/harestail-*Lachnagrostis billardiereil* catsear grassland	Wīwī sedgeland	(Wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland	Spinifex- dominated sandfield and grassland	Spinifex-hinarepe-*Lachnagrostis billardiereil* sandfield
2013	*Anthoxanthum odoratum*			4			
	Bromus diandrus		12		2		
	Calystegia soldanella		14	14	87	94	
	Carex pumila				15	12	
	Carex solandri	17			12	11	
	Carex testacea	7			104		
	Cenchrus clandestinus					7	
	Cerastium fontanum				1		
	Conyza sumatrensis				2		
	Dactylis glomerata				7		
	Ficinia nodosa	7		30	45		
	Ficinia spiralis						9
	Galium aparine			6			
	Holcus lanatus	1		20	14		
	Hypochoeris radicata	1	5		14	106	17
	Lachnagrostis billardierei		1	1	48	46	1
	Lagurus ovatus	16	16	6	97	140	6
	Leontodon taraxacoides		4			38	
	Lichen species				3		
	Ligustrum sinense			4			
	Lolium perenne				49		
	Lupinus arboreus	1		1	12	28	4
	Moss	9	12	10	46	29	
	Muehlenbeckia complexa	5		22	145	5	
	Orobanche minor					1	
	Oxalis rubens	4		1	65	6	
	Poa billardierei						1
	Poa pratensis			10	17		
	Pteridium esculentum			27	26		
	Rumex acetosella	10		14	93		
	Spinifex sericeus		5			140	22
	Stellaria media		3	3	8	2	
	Taraxacum officinale				11		
	Trifolium species					1	
	Zoysia pauciflora				12		

PERCENTAGE COVER OF GROUNDCOVER COMPONENTS IN PERMANENT PLOTS (SORTED BY VEGETATION TYPE)

Year	Vegetation Type	Plot	Bare Sand (% Cover)	Litter (% Cover)	Moss/ Nostoc[1] (% Cover)	Vascular Plants (% Cover)
2013	(Wīwī)-(pōhuehue)-(*Carex testacea*)/harestail-shore bindweed grassland	8	19	3	3	75
	(Spinifex)/harestail-*Lachnagrostis billardiereil* catsear grassland	27	40	1	21	38
	Wīwī sedgeland	2	2	0	0.5	97.5
		15	0	0	10	90
	(Wīwī)/pōhuehue-*Carex testacea* sedgeland and vineland	5	3	2	1	94
		10	0	0	0	100
		11	0	3	0	97
		13	2	1	2	95
		14	27	25	3	45
		19	1	0	1	98
		20	7	1	3	89
		21	0	0	0	100
		22	2	0	2	96
		26	0	0	0	100
		28	5	1	20	74
	Spinifex-dominated sandfield and grassland	1	48	5	0	47
		3	75	2	0	23
		4	65	1	0	34
		9	49	1	0.5	49.5
		12	90	0	0	10
		16	15	4	25	56
		17	75	0	2	23
		18	82	0.5	0	17.5
		23	45	5	5	45
		24	50	2	0	48
	Spinifex-hinarepe-*Lachnagrostis billardiereil* sandfield	6	91	0	0	9
		7	92.5	0	0	7.5
		25	95	1	0	4

[1] *Nostoc* is a genus of cyanobacteria that forms gelatinous colonies.

ANNOTATED LIST OF VASCULAR PLANTS RECORDED AT TE TUMU, 2013

Key

C = Dominates a vegetation tier in a vegetation type covering greater than 20% of the site.
S = Scattered throughout much of site, but does not achieve dominance.
LC = Common in a limited number of confined areas.
LS = Scattered through a localised area of habitat.
U = Very few individuals and not common anywhere.
R = Very uncommon e.g. less than 10 individuals or 1-2 small populations.
* = Species planted at the site.

Species		Abundance	
Scientific Name	**Common Name**	**Within Rabbit-Proof Fence**	**Outside of Rabbit-Proof Fence, Inside Stock Fence**
INDIGENOUS SPECIES			
Monocot. trees and shrubs			
**Cordyline banksii*	tī ngahere, forest cabbage tree	R	R
Dicot. trees and shrubs			
**Corynocarpus laevigatus*	karaka	R	
**Leptospermum scoparium*[1]	mānuka	R	
**Pittosporum tenuifolium*[1]	kōhuhu		R
Ozothamnus leptophylla	tauhinu	R	R
Dicot. lianes			
Calystegia soldanella	panahi, shore bindweed	S	S
Muehlenbeckia complexa	pōhuehue	C	S
Ferns			
Pteridium esculentum	rārahu, bracken	LC	U
Grasses			
Lachnagrostis billardierei	perehia; sand wind grass	S	S
Poa billardierei	sand tussock, hinarepe		LS
Spinifex sericeus	kōwhangatara, spinifex	C	C
Zoysia pauciflora		U	
Sedges			
Carex pumila		LS	LS
Carex solandri		R	
Carex testacea		S	LC
Ficinia nodosa	wīwī	C	S
Ficinia spiralis[2]	pīngao		U
Monocot. herbs (other than orchids, grasses, sedges, and rushes)			
**Phormium cookianum* subsp. *hookeri*	whararikī, mountain flax		R
Composite herbs			
Senecio biserratus		LC	LS
Dicot. herbs (other than composites)			
Oxalis rubens	sand oxalis	S	LS

[1] Planted, dead.
[2] Some planted, some natural.

Species		Abundance	
Scientific Name	**Common Name**	**Within Rabbit-Proof Fence**	**Outside of Rabbit-Proof Fence, Inside Stock Fence**
ADVENTIVE SPECIES			
Monocot. trees and shrubs			
Yucca gloriosa	yucca		R
Dicot. trees and shrubs			
Berberis glaucocarpa	barberry		R
Chamaecytisus palmensis	tree lucerne		U
Ligustrum sinense	Chinese privet	R	
Lupinus arboreus	lupin	LC	LC
**Olea europaea*	olive tree	R	R[1]
Rubus sp. (*R. fruticosus* agg.)	blackberry	U	U
Ulex europaeus[2]	gorse	LC	LC
Dicot. lianes			
Rumex sagittatus	climbing dock	U	
Grasses			
Agrostis capillaris	browntop	R	
Anthoxanthum odoratum	sweet vernal	U	U
Bromus diandrus	ripgut brome	U	U
Bromus willdenowii	prairie grass	LS	LS
Cenchrus clandestinus	kikuyu grass	LC	LC
Cortaderia selloana	pampas	R	R
Cynodon dactylon	Indian doab		R
Dactylis glomerata	cocksfoot	LS	LS
Ehrharta erecta	veldt grass		U
Festuca rubra subsp. *commutata*	Chewing's fescue		U
Holcus lanatus	Yorkshire fog	LS	LS
Lagurus ovatus	harestail	C	S
Lolium perenne	rye grass	LS	LS
Paspalum dilatatum	paspalum	R	R
Poa pratensis	Kentucky bluegrass	U	U
Schedonorus arundinaceus	tall fescue	U	U
Sporobolus africanus	ratstail	U	U
Composite herbs			
Arctotis stoechadifolia	arctotis		U
Conyza sumatrensis	broad-leaved fleabane	R	R
Crepis capillaris	hawksbeard	U	U
Gamochaeta coarctata	purple cudweed	U	
Hypochaeris radicata	catsear	LS	S
Jacobaea vulgaris	ragwort		R
Leontodon taraxacoides	hawkbit	U	U
Senecio bipinnatisectus	Australian fireweed	U	U
Senecio elegans	purple groundsel	LS	U
Sonchus oleraceus	puha, sow thistle	U	U
Taraxacum officinale	dandelion	U	U
Dicot. herbs (other than composites)			
Cakile maritima	sea rocket		R
Carpobrotus edulis	ice plant		R
Cerastium fontanum subsp. *vulgare*	mouse-ear chickweed	LS	LS
Chenopodium pumilio	clammy goosefoot		U

[1] Planted in a tyre.
[2] Five or six small infestations.

Species		Abundance	
Scientific Name	**Common Name**	**Within Rabbit-Proof Fence**	**Outside of Rabbit-Proof Fence, Inside Stock Fence**
Foeniculum vulgare	fennel	U	U
Fumaria muralis	scrambling fumitory	U	
Galium aparine	cleavers	U	
Geranium molle	dovesfoot cranesbill	U	U
Lepidium bonariense	Argentine cress	U	
Lotus pedunculatus	lotus		R
Malva neglecta	dwarf mallow		R
Modiola caroliniana	creeping mallow	U	U
Orobanche minor	broomrape		R
Phytolacca octandra	inkweed	R	
Plantago lanceolata	narrow-leaved plantain	LS	LS
Rumex acetosella	sheep's sorrel	LS	LS
Rumex obtusifolius	broad-leaved dock		R
Solanum chenopodioides	velvety nightshade	U	U
Solanum nigrum	black nightshade	U	U
Solanum tuberosum	potato	U	
Stellaria media	chickweed	LS	U
Trifolium repens	white clover	U	U
Trifolium species	clover	R	
Verbascum thapsus	woolly mullein	U	U
Verbascum virgatum	moth mullein		R

LIST OF FAUNA RECORDED AT TE TUMU, 2013

MAMMALS

Introduced (feral)

Oryctolagus cuniculus	European rabbit

BIRDS

Indigenous

Circus approximans	kāhu; swamp harrier
Haematopus unicolor	tōrea, tōrea pango, variable oystercatcher
Hirundo neoxena neoxena	welcome swallow
Hydroprogne caspia	taranui; Caspian tern
Larus dominicanus dominicanus	karoro; southern black-backed gull
Tadorna variegata	pūtangitangi; pari; paradise shelduck
Todiramphus sanctus vagans	kōtare sacred kingfisher; New Zealand kingfisher
Vanellus miles novaehollandiae	spur-winged plover

Introduced

Acridotheres tristis	common myna
Alauda arvensis	Eurasian skylark
Anas platyrhynchos platyrhynchos	mallard
Carduelis carduelis britannica	European goldfinch
Emberiza citrinella	yellowhammer
Gymnorhina tibicen	Australian magpie
Phasianus colchicus	common pheasant
Sturnus vulgaris vulgaris	common starling

REPTILES MOKOMOKO

Oligosoma smithii	shore skink

FROGS

Introduced

Litoria sp.	bell frog

LIST OF INVERTEBRATES RECORDED AT TE TUMU, 2013

Key E = Endemic
N = Native
X = Exotic

ORDER/FAMILY/SPECIES	STATUS	COMMON NAME	ECOLOGICAL NOTES
INSECTA			
Dermaptera		**Earwigs**	
Labiduridae			
Anisolabis littorea	E	Mata/seashore earwig	Coastal specialist; common here; omnivorous.
Forficulidae			
Forficula auricularia	X	European earwig	Reasonably common here; omnivorous.
Blattodea		**Cockroaches**	
Blattidae			
Drymaplaneta semivitta	X	Gisborne cockroach	Large cockroach sharing ACOs with ants; common here.
Orthoptera		**Grasshoppers/ cricket**	
Acrididae			
Locusta migratoria	N	Kapakapa/locust	Common in hind dunes - winged.
Phaulacridium marginale	E	NZ grasshopper	Flightless and small grasshopper in inter-dunes.
Gryllidae			
Nemobius bigelowei	E	Cricket	Common in dry grasslands and dunes.
Teleogryllus commodus	N	Black field cricket	Common in grasslands but not common here.
Tettigonidae			
Conocephalus bilineatus	E	North Island katydid	Common in dry grasslands and dunes.
Lepidoptera		**Butterflies and moths**	
Hepialidae			
Wiseana signata	E	Porina moth	Sand dune porina moth - larvae subterranean.
Lyonetiidae			
Bedellia psamminella	E		Larvae mining *Calystegia soldanella* leaves - common.
Elachistidae			
Cosmiotes archaeonoma	E		Larvae mine grasses.
Tortricidae			
Capua semiferana	E		Larvae feed on leaf litter.
Sperchia intractana	X		Australian species - larvae on leaf litter.
Epiphyas postvittana	X	Light brown apple moth	Green wriggly larvae on lupin and other plants.
Merophyas divulsana	X		Larvae on lotus; recent Australian species.
Merophyas leucaniana	N		Larvae polyphagous on grasses and herbs.
Crambidae			
Eudonia leptalea	E		Common sod webworm.

ORDER/FAMILY/SPECIES	STATUS	COMMON NAME	ECOLOGICAL NOTES
Eudonia sabulosella	E		Common sod webworm.
Eudonia submarginalis	E		Common sod webworm.
Orocrambus flexuosellus	E	Common grassmoth	Ubiquitous grassmoth.
Orocrambus ramosellus			Ubiquitous grassmoth.
Orocrambus vittellus	E		Ubiquitous grassmoth.
Uresiphita maorialis	E	Kowhai moth	Colourful larvae on lupin; preyed on by paper wasps.
Udea flavidalis	E	Orange triangle	Larvae on *Muehlenbeckia* and herbs.
Pyralidae			
Patagoniodes farinaria	N		Larvae bore in *Senecio* species.
Lycaenidae			
Lycaena salustius	E	Coastal copper butterfly	Green larvae on *Muehlenbeckia complexa*; common here.
Zizina otis labradus	N	Common blue butterfly	Larvae feed on clovers.
Pieridae			
Pieris rapae	X	White butterfly	Larvae on crucifers - European introduction.
Geometridae			
Chloroclystis filata	X		Larvae on flowers including *Senecio.*
Epyaxa lucidata	N		Larvae on herbs.
Epyaxa rosearia	E		Larvae polyphagous on herbs.
Epyaxa venipunctata	E		Larvae feed on *Convolvulus* and *Calystegia* species.
Helastia semisignata	E		Grassland species - larvae on herbs.
"Hydriomena" deltoidata	E		Larvae on *Plantago.*
Scopula rubraria	N		Larvae on *Plantago.*
Noctuidae			
Agrostis ipsilon	N	Greasy cutworm	Larvae polyphagous on herbs.
Aletia temperata	E		Grey and white striped larvae on *Ozothamnus* foliage.
Bityla defigurata	E		Larvae on *Muehlenbeckia complexa.*
Graphania homoscia	E		Yellow, red, and white striped larvae on *Ozothamnus* foliage.
Graphania mutans	E		Larvae on herbs.
Mythimna loreyimima	N		Larvae on *Spinifex* foliage.
Tmetolophota semivittata	E		Larvae on grasses.
Diptera			
Therevidae			
Anabarhynchus species	E		Therevid fly common on sand dunes.
Coleoptera		**Beetles**	
Scarabaeidae			
Odontria sylvatica		Chafer beetle	Larvae subterranean under shrubland and grassland.
Pericoptus truncatus	E	Sand scarab	Larvae found under drift wood in foredune - common here.
Pyronota festiva	E	Manuka beetle	Adults feed on shrub foliage - *Ozothamnus*; larvae on roots.
Tenebrionidae			
Mimopeus cf. *elongatus*	E	Darkling beetle	Under wood and ACOs.

ORDER/FAMILY/SPECIES	STATUS	COMMON NAME	ECOLOGICAL NOTES
Coccinellidae			
Coccinella undecimpunctata	X	11 spotted ladybird	Introduced common ladybird - predator.
Staphylinidae			
Several tiny species	E	Rove beetles	Predators on maggots. Under driftwood.
Cerambycidae			
Unknown species	E	Longhorn beetle	One species with larvae boring in dead branches of *Ozothamnus.*
Neuroptera		**Lacewings**	
Hemerobiidae			
Micromus tasmaniae	X	Tasmanian lacewing	Small introduced predator.
Odonata		**Dragonfly/ damselfly**	
Corduliidae			
Procordulia smithii	E	Ranger dragonfly	Larvae predatory in ponds.
Coenagrionidae		Redcoat damselfly	Larvae predatory in ponds.
Xanthocnemis zealandica	E		
Hymenoptera		**Ant, bee, wasp**	
Apidae			
Apis mellifera	X	Honey bee	Common especially in *Calystegia* flowers.
Bombus ruderatus	X	Bumble (humble) bee	Small species common on many flowers.
Vespidae			
Polisters chinensis	X	Asian paper wasp	Nests and wasp common here; seen taking kowhai moth larvae.
Formicidae			
Iridomyrmex new species	X	Australian ant	Very common under ACOs and elsewhere.
Pompilidae			
Sphictostethus nitidus	E	Spider-hunting wasp	Spider hunting wasp on sand.
Sphecidae			
Tachysphex nigerrimus	E		Hunting wasp on sand dunes.
Hemiptera		**Bugs**	
Lygaeidae			
Rhypodes species 1	E		Adults feeding on *Ozothamnus.*
Rhypodes species 2	E		Adults common on *Senecio biserratus.*
Nysius huttoni	E		Tiny adults common on bare ground in hind dune.
Miridae			Green adults on *Senecio biserratus*.
Megaloceroea recticornis	X		
Arachnida		**Spiders**	
Clubionidae			
Suppuna picta	X	Orange rock spider	Introduced Australian species - fast-moving with orange legs.
Therevidae			
Latrodectus atritus	E	Black katipo	Foredunes under ACOs and wood - not common.
Steatoda capensis	X		Introduced South African spider.
Saltidae			
Trite species	E	Jumping spider	Unidentified jumping spider.
Miturgidae			
Miturga species	E		Large unidentified spider under wood.

ORDER/FAMILY/SPECIES	STATUS	COMMON NAME	ECOLOGICAL NOTES
Lycosiae			
Lycosa species	E		Indigenous wolf spider under logs.
Opiliones		**Harvestmen**	
Unidentified species	E		Small numbers of an unidentified harvestmen in dunes.
Pseudoscorpionida		**Pseudoscorpion**	
Unidentified species	E		Small numbers of an unidentified pseudoscorpion in dunes.

APPENDIX 12

SITE PHOTOGRAPHS

Plate 1: Pīngao planted alongside the rabbit-proof fence in the south-eastern corner of the site. Wīwī and harestail,sedge-grassland (Vegetation Type 14) and kikuyu grassland (Vegetation Type 17) is present in the background (left), (wīwī)/pōhuehue-*Carex testacea* vine-sedgeland is present on the right (Vegetation Type 8). The area cleared for construction of the rabbit-proof fence is evident to the left of the planted pīngao and has been colonised by harestail and catsear (Vegetation Type 16).

Plate 2: Spinifex-pīngao sandfield (Vegetation Type 1) on the front face of the dunes outside the cattle-proof fence. Scattered to locally common lupin are present within this area.

Plate 3: Wīwī sedgeland with a patch of bracken fernland (Vegetation Type 9; foreground) borders a mosaic of pōhuehue vineland and *Carex testacea* sedgeland (Vegetation Type 8) near the centre along the southern boundary of the site.

Plate 4: Mounds of sand piled up during construction of the rabbit-proof fence support a cover of exotic grasses amongst a mosaic of pōhuehue vineland and *Carex testacea* sedgeland (Vegetation Type 8) near the western corner of the site. Wīwī/ pōhuehue-bracken-kikuyu grass vine-sedgeland (Vegetation Type 9) borders the cattle-proof fence in the background. Vegetation plot 14 is located in the centre foreground.

Plate 5: Spinifex grassland with scattered lupin (Vegetation Type 2) is present in the northeastern third of the site and grades into spinifex-pīngao sandfield (Vegetation Type 1) on the foredunes. Pīngao planted alongside the rabbit-proof fence is visible in the front background.

Plate 6: Gorse shrubland and exotic grass species grassland (Vegetation Type 21) has colonised the area between the cattle and rabbit-proof fences at the southern-western boundary of the site.

Plate 7: Shore skinks (*Oligosoma smithii*) from Te Tumu Kaituna 7B2, November 2013. The upper plate shows a gravid female.

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