UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Waimata River Riparian Zone Description and Guidance for Restoration

Adam Forbes, David Norton and Grace Marshall

Contract Report Prepared for Gisborne District Council by the New Zealand School of Forestry

15 May 2018

Table of Contents

Table of Figures

Table of Tables

Authors:

Dr. Adam Forbes
Principal Ecologist
Forbes Ecology
PO Box 8762
Havelock North

Prof. David Norton
School of Forestry
University of Canterbury
Private Bag 4800
Christchurch 8140

Grace Marshall
School of Forestry
University of Canterbury
Private Bag 4800
Christchurch 8140

Research Associate
School of Forestry
University of Canterbury

Acknowledgements:

The work was supported by Envirolink Funding (1845-GSDC148). Dr. Murry Cave (Gisborne District Council (GDC) Principal Scientist) and GDC Land Management Officers provided client liaison and logistical support.

Cover photograph:

Aerial view of Waikereru/Longbush Reserve positioned in the riparian zone of the Waimata River, Gisborne (December 2017).

1.0 INTRODUCTION

The Gisborne District Council seeks advice and guidance on the process for evaluating the best native vegetation types for riparian margin restoration along waterways within the Gisborne District. The University of Canterbury School of Forestry was engaged to conduct an exemplar project, classifying the nature of existing riparian vegetation along an 18-km reach of the Waimata River. Based on the riparian survey data, guidance regarding restoration treatments and species can then be developed. This work then provides a framework that can be applied in other riparian settings within the Gisborne District.

1.1 Project Objectives and Deliverables

The specific objectives of the project are as follows:

1. Describe the current riparian vegetation composition, structure and condition of the Waimata River within the study area and in the context of the surrounding vegetation pattern;
2. Provide guidance regarding restoration treatments and appropriate species to be included in riparian restoration.

1.2 Approach

The Waimata River drains a large hill-country catchment north of Gisborne city, with the river joining the Turanganui River in the Gisborne CBD before discharging into Poverty Bay. This study focuses on the lower rural reaches of the catchment (above the urban limits of Gisborne). The riparian zone was defined, and a detailed survey was undertaken of the existing riparian vegetation structure and composition. The ecological condition of predominately native forest areas was assessed, which included qualitative assessments of the ecological criteria relating to ecosystem intactness, condition, and threats. The survey data was then compiled and mapped, and this provided a basis for the subsequent evaluation of appropriate restoration treatments and species to be included in future riparian restoration.

2.0 METHODS

2.1 Vegetation Survey

The study area was defined as the 18 km reach of the Waimata River located between the urban edge at Riverside Road, extending upstream to include a short reach above the end of Riverside Road. The riparian zone was defined as the land area on either bank extending from the wetted margin landwards to the foot of the main hillside. In instances where this landform arrangement did not apply, then the riparian zone was defined as extending 100 m landward of each river margin to capture vegetation areas that were riparian in nature. The variable component to the riparian zone definition was necessary to accommodate and capture the intrinsic variability in the riparian zone configuration. This resulted in a total riparian survey area of 457 ha.

Vegetation within the riparian zone was visited between November 2017 and January 2018. The following attributes were recorded:

- Vegetation structural classification (e.g., Forest, Treeland, Grassland) based on Table 9 of Atkinson (1985) (relevant classes reproduced in Table 1).
- Species composition of canopy and understorey tiers in vegetation areas, with species listed in order from most to least dominant.

Table 1. Relevant structural classes and their diagnostic criteria applicable to the survey of Waimata River riparian vegetation. Taken from Table 9 of Atkinson (1985).

Structural class	Diagnostic criteria for structural classes
Forest	Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥ 10 cm dbh. Tree ferns ≥10 cm are treated as trees.
Treeland	Vegetation in which the cover of trees in the canopy is 20–80%, with tree cover exceeding that of any other growth form, and in which the trees form a discontinuous upper canopy above either a lower canopy of predominantly non-woody vegetation or bare ground e.g., mahoe/bracken treeland.
Shrubland	Vegetation in which the cover of shrubs in the canopy is 20–80% and in which the shrub cover exceeds that of any other growth form or bare ground.
Grassland	Vegetation in which the cover of grass in the canopy is 20–100% and in which the grass cover exceeds that of any other growth form or bare ground.
Rushland	Vegetation in which the cover of rushes in the canopy is 20–100% and in which the rush cover exceeds that of any other growth from or bare ground.

Exotic communities were distinguished from native communities through application of a 50% native canopy cover criterion, meaning that vegetation areas with >50% canopy cover by native species were classed as predominantly native vegetation. Vegetation areas with <50% native vegetation cover was classed as predominantly exotic vegetation.

The successional stage and ecological condition of native vegetation areas (i.e., >50% native vegetation cover) was then assessed. Successional stage was classed as either (1) pioneer, (2) seral, or (3) old growth based on interpretation of vegetation composition and stature.

Forest condition was assessed using an abbreviated version of the Taranaki Regional Council (TRC) Forest Condition Assessment method. The TRC Forest Condition Assessment results in a numerical scoring based on the performance of Indicators, each out of a possible score of 4. A Forest Condition Index can then be calculated by taking the sum of mean Indicator scores for all Themes represented as a score out of 20 (the full method has five Themes with each Indicator scored out of 4). We adopted seventeen Indicators from three Themes of the TRC Forest Condition Assessment method (Table 2). As we used only a relevant subset of the Themes/Indicators, this resulted in a possible score of 12 (i.e., 12 represents the best case – an average score of 4 for all three Indicators) rather than 20. We therefore scaled the Forest Condition Index quality thresholds to match the total possible score of 12 to maintain overall consistency with the original quality class thresholds. This resulted in the following quality classes for the given Forest Condition Index scores: Poor = <7.7, Fair = 7.8–9.2, Good = 9.3–9.9, Very Good = 10–10.7, Excellent = 10.8–12.

Table 2. Taranaki Regional Council Forest Health Assessment themes and indicators used in the survey of the Waimata River riparian zone.

Theme	Indicator
Ecosystem intactness (Total: 5 × 4 = 20)	Size
	Shape
	Nearby forest
	Corridors
	Adjacent land use
Ecosystem condition (Total: 6 × 4 = 24)	Forest edge understorey
	Interior understorey
	Interior ground cover
	Forest edge canopy
	Interior canopy
	Interior understorey browsing
Animal threats (Total: 6 × 4 = 24)	Possums
	Deer
	Goats
	Pigs
	Stock
	Fencing

Characterisation of the extent and distribution of native cover in the catchment adjacent to the riparian zone was undertaken through a combination of field observations and interpretation of aerial photographs.

The field survey was supported with interpretation of aerial imagery and high resolution aerial photographs specifically taken from a drone for this project.

2.2 Mapping and Data Analysis

Survey data was compiled digitally in the field using ArcCollector. Vegetation boundaries and classifications were then checked on a desktop computer and spatial analysis and maps were produced using ArcGIS.

Potential associations in forest condition data were explored using orthogonal scatterplot matrices in R (R Development Core Team 2017). The association between fresh goat sign (ordinal) and understorey browse severity (ordinal) was assessed using a Spearman's rho. Correlation analysis was undertaken in R and, where plotted, a smoothing function was applied (Locally Weighed Scatterplot Smoothing; LOWESS). All plots were produced in R (R Development Core Team 2017).

Common names are used in the text and corresponding scientific names are given in Table 6.

3.0 RESULTS

3.1 Riparian Zone Analysis

A total of 457 ha of the Waimata River riparian zone was surveyed. Sixty seven percent (308 ha) of the riparian zone was forested, with exotic forest making up 78% (239.3ha) of the total forested area, the remaining 22% (68.9 ha) of forests being predominantly native (Table 3). More than half (63%) of the forested area was grazed. Treelands covered 62.5 ha and shrublands, rushlands and grasslands each formed relatively minor components of the riparian zone vegetation structure (Table 3).

Table 3. Summary statistics of vegetation structural classes by area, the percentage comprising native species, and the percentage that is grazed.

		Forest		Treeland		Shrubland		Rushland		Grassland	
		(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
% Native	0–25%	59.0	182.0	56.6	35.3	50	0.5	100	14	100	71.4
	25–50%	18.6	57.3	43.0	26.9	50	0.5	0	0	0	0
	50–75%	13.0	40.0	0.5	0.3	0	0	0	0	0	0
	75–100%	9.4	28.9	0	0	0	0	0	0	0	0
Total Vege		67.4	308.2	13.7	62.5	0.2	1	3.1	14.0	15.6	71.4
% Grazed		64.9		77.1		100		100		69.8	

3.1.1 Longitudinal Distribution of Native Riparian Vegetation

Native riparian vegetation was scarce downstream of the Goodwin Road Bridge (Fig. 1A), being limited to several areas of seral kānuka forest with exotic grasslands and forests the predominant riparian cover types. Most of the 5 km river reach from Cave Road upstream to a point 150 m below the River Road Bridge featured native dominant vegetation on at least one riverbank. This reach of semi-continuous native vegetation included a number of particularly valuable old growth forest remnants, such as Donner's Bush Scenic Reserve (Fig. 1B) and Waikereru/Longbush Reserve (Fig. 1C; Fig. 2A). These two reserves are connected along the riparian zone with stands predominantly comprising regenerating and mature kānuka. The river reaches from Goodwin Road Bridge to Cave Road, and above River Road bridge (Fig. 2B), are of a more mixed stature and composition, comprising exotic grassland and tree stands as well as regenerating and mature kānuka and broadleaved compositions.

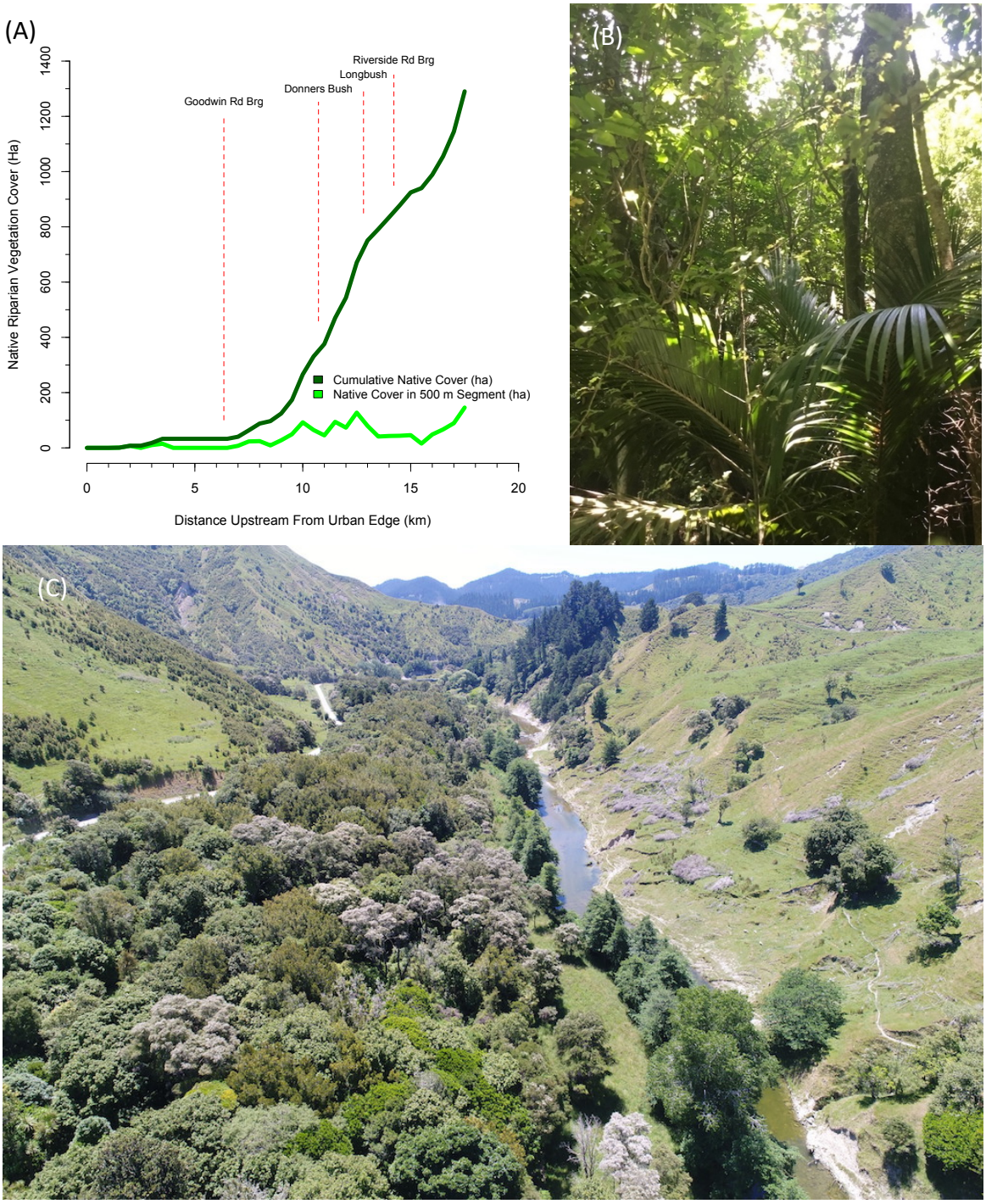

Figure 1. (A) The area (ha within 500 m long river segment) and cumulative area (ha) of native riparian vegetation cover from the Gisborne urban edge upstream to beyond the end of Riverside Road. (B) View inside Donner's Bush Scenic Reserve, and (C) view upstream of Waikereru/Longbush Reserve showing its position riparian to the Waimata River.

Figure 2. (A) View of extensive native riparian forest cover on the Waimata River valley floor between Cave Road (distant left near felled plantation) to northern extent of Waikereru/Longbush Reserve. Donner's Bush Scenic Reserve is located below the intact plantation forest. (B) Example of kānuka forest (left and centre) connecting areas of old growth broadleaved forest (top).

3.1.2 Native Vegetation Characteristics

Successional stages, species and compositions

Vegetation was classified into three successional stages: pioneer, seral and old growth. Pioneer compositions were usually mixed with exotic species such as pasture grasses or woody weeds and for this reason did not meet the criterion of >50% cover by native species to represent native dominated ecosystems.

Native seral stands were on average 1.69 ha in area (Table 4) and predominantly comprised kānuka. Seral stages of native vegetation were most numerous, with a total area of 35.5 ha held in 21 patches within the riparian zone. Old growth stands tended to be larger than seral patches on average, and a total riparian area of 33.7 ha (held in 11 patches[1]) contained old growth forest (Table 4). The characteristic canopy species occurring in old growth forest stands were kohekoke, titoki, tawa, kamahi, rewarewa, cabbage tree, ribbonwood, large-leaved kowhai, and marbleleaf.

Table 4. Riparian vegetation with >50% cover by native flora.

Successional stage	# Patches	Patch area (ha)	Total area (ha)	Grazed (%)
Seral	21	0.23–7.32, 1.69	35.51	76
Old Growth	11	0.22–9.00, 3.06	33.70	30
Seral + Old Growth	32	0.22–9.00, 2.16	69.21	61

3.1.3 Forest Condition

The overall results for forest condition indicated on average fair condition for both old growth and seral ecosystems (Fig. 3A). Thirty percent of old growth sites scored good condition and one site scored very good condition. No seral sites scored better than fair condition and average scores were centred around the boundary between poor and fair quality (Fig. 3A).

3.1.4 Ecosystem Intactness

Eighty four percent of all native patches were <5 ha, with only 10%(2) of seral patches being >5 ha. There were no native forest patches larger than 25 ha within the riparian zone. The majority of forest patches were long and narrow strips. Seral stands were mostly (62%) <20 m wide. Old growth stands were also predominantly (60%) long and narrow, and of a convoluted shape.

[1] One old growth site (of 6.05 ha in area) was inaccessible and thus was not surveyed for ecological condition or grazing status. The site was included in forest area calculations and was excluded from grazing and ecological condition analyses.

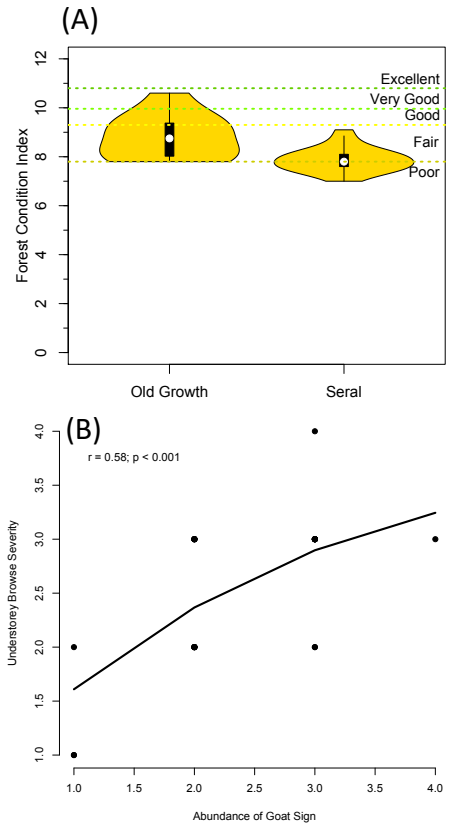

Figure 3. (A) Violin plots of the overall forest condition (sum of mean scores from assessments ecosystem intactness, ecosystem condition and animal threats) for old growth and seral successional stages. Plotted bar extents give 95% confidence intervals, box extents give interquartile range, dot indicates median value, and width represents frequency distribution of data points. (B) Positive significant association between understorey browse severity and the abundance of goat sign. Correlation calculated using Spearman's rho and line fitted using Locally Weighed Scatterplot Smoothing (LOWESS).

Most seral (67%) and old growth (70%) stands had areas of native forest >10 ha present within 50 m–1 km. In addition to good proximity of native forest habitats, 94% of all native patches had tall statured vegetation corridors (incl. exotic forests) present within 500 m. The land use type most commonly adjoining native patches was agriculture (77%), and less commonly exotic forestry (15%) and native forest (6%).

3.1.5 Ecosystem Condition

Understorey regeneration was particularly weak in seral stands at forest edges with more than half (57%) the seral stands having no understorey around the edge of the canopy. Old growth forest edges tended to have a greater amount of regeneration occurring, but only 10%(1) of old growth sites had vigorous forest edge regeneration. Only one patch (an old growth site) had a forest interior completely bare of any regeneration, and typically forest interiors featured few to moderate numbers of plants preferred by exotic herbivores within the knee to shoulder height range.

Canopy edges tended (87%) to have only small areas of localised dieback while seral (52%) and old growth (50%) interior forest canopies were sparse in some areas with canopy holes common, and some canopy dieback. Forty two percent of interior forest canopies were mostly dense with canopy holes rare and very occasional dieback.

3.1.6 Animal Threats

There was little to no sign of possums, deer or pigs within the native riparian forests. Common fresh goat sign was detected at 42% of native sites and goat sign was uncommon and often old at 45% of all sites. However, the abundance of goat sign was positively associated (Fig 3B; Spearman's rho(r_s = 0.58, p <0.001)) with understorey browse severity,

and the co-occurrence of these variables indicated that goats were likely to be impacting on the regeneration of some native forest areas. A quarter of all sites had common fresh sign of stock with occasional stock being seen or heard at those sites. In most sites (61%) stock sign was uncommon and often old or only occurred near forest edges. Forty percent of old growth sites showed no sign of stock presence.

An assessment of actual grazing activity (i.e., grazed/not grazed) showed that more than half (61%) the native sites were grazed, with more seral sites (76%) than old growth sites (30%) being grazed. Although the majority of sites (52%) were mostly fenced or required minor fencing maintenance, 30% of seral sites and 10% of old growth sites (a quarter of all sites) had no fencing/functional fencing. No seral sites were stock proof and only 20% of old growth sites were fully stock proofed. Stock exclusion is a known means of reducing the severity of understorey browse.

Figure 4. Example of browsing of a native forest edge (kohekohe), Waimata valley.

The forest condition monitoring results are contained in Appendix A.

3.2 Adjacent Catchment Analysis

3.2.1 Landscape Configuration and Connectivity

A sample of 446 patches of native vegetation covered 2 721 ha which equated to 41% native cover in the surrounding landscape (measured from a subjectively defined landscape sample area of 6 647 ha). Old growth and mature forest stands were more numerous, and on average larger, compared to seral stands (Fig. 5; Table 5). Many steep hill slopes featured kānuka regeneration from pasture (Fig. 6A), the south-east of the catchment features more pasture and less native cover (Fig. 6A), compared to areas north-east and north-west of the study area (Fig. 6B). Mature kānuka is often mixed with broadleaved canopy species such as kohekohe, titoki and tawa (Fig. 6C & D). Old growth broadleaved patches occur (Fig. 6E & F) and these stands are typically of approximately 2.3 ha in patch size. In many areas kānuka forms the pioneering and seral phases of the forest successions from exotic pasture (Fig. 6G).

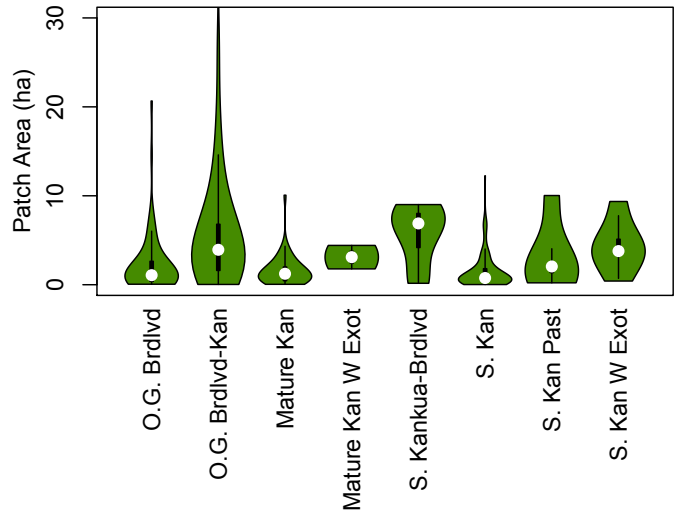

Figure 5. Areas (ha) of mature and seral vegetation compositions sampled in the portion of the Waimata catchment surrounding the riparian survey area. An outlying maximum value for O.G. Broadleaved-Kānuka forest of 84 ha falls outside of the plot area.

Landscape connectivity is good in the area sampled, with the exception of the south-east of the study area from the Whainukota Stream south towards Gisborne township.

Table 5. Summary of native vegetation cover by successional stage, patch frequency, area (ha) and combined area (ha).

Successional stage	# Patches	Patch area (ha)	Total area (ha)
Seral	199	0.02–12.25, 1.79	356
Old Growth/Mature	247	0.03–84.32,4.06	1 004
Seral + Old Growth/Mature	446	0.02–84.32, 3.05	1 361

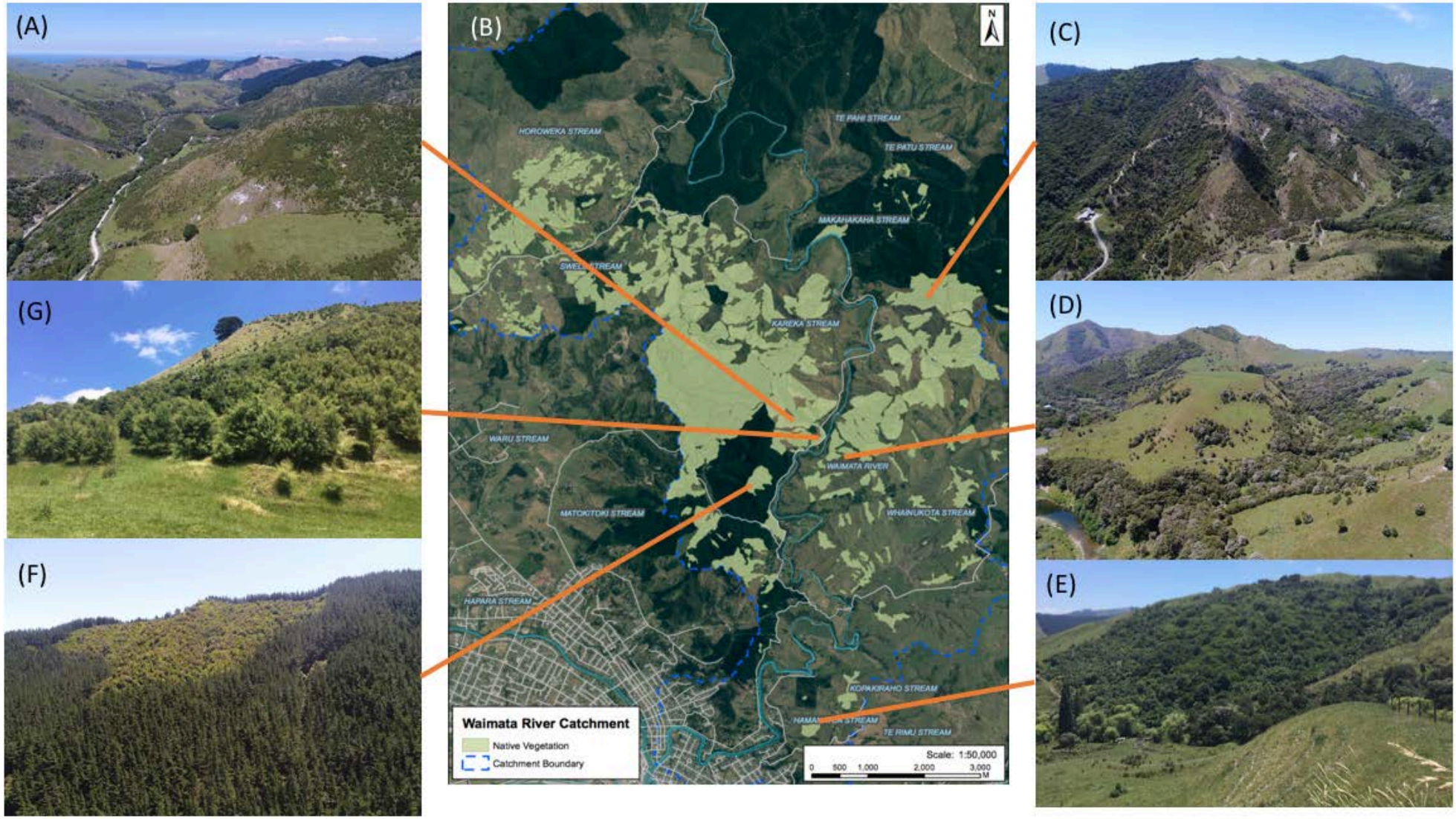

Figure 6. (A) Kānuka regeneration on steep slopes above Waikereru/Longbush Reserve and pasture predominating in the south-east extent of the catchment (distant left in photograph), (B) distribution of native cover in the landscape surrounding the riparian survey area, (C & D) broadleaved canopy species such as kohekohe regenerating in mature kānuka stands, (E & F) old growth forest patches, and (G) pioneer kānuka stand colonising exotic pasture.

4.0 DISCUSSION

4.1 Existing Forest Distributions

Forests of predominantly native composition occupy 69 ha of the 457-ha riparian study area (*ca*. 15% of the riparian study area), and these forests occur in a total of 32 discrete stands. Forests of seral (35.5 ha) and old growth (33.7 ha) successional stages were of almost equal total cover. Old growth stands were fewer in number (11) but were typically of larger area (on average 3 ha) compared to seral stands (on average 1.7 ha). We use the term 'old growth' to distinguish forests with a mixed canopy of broadleaved tree species (tawa, kohekohe, titoki etc) from seral forests, which are typically dominated by kanuka and regenerating on previously farmed sites. However, the old growth forests will have themselves been impacted by historic logging and lost the emergent podocarp component (kahikatea, tōtara, rimu, matai etc) that would have been present previously.

Between Cave Road and Riverside Road Bridge, the configuration of existing seral and old-growth forest stands provides a semi-continuous network of native riparian forest habitats (Fig. 6A). Several of the old growth stands in this reach have been protected and are undergoing restoration (i.e., Donners Bush Scenic Reserve and Waikereru). These floristically diverse old growth stands (Smale et al. 2013) serve as important sources of forest seed for the natural diversification of surrounding regenerating kānuka stands, which are the nursery sites of naturally occurring future forests. The old growth sites also provide a key reference for riparian restoration elsewhere in the study area and provide habitats for frugivorous bird species, such as tūī, korimako and kererū. These bird species would provide much of the crucial pollination and seed dispersal functions (Kelly & Sullivan 2010, Clout & Hay 1989) among the forest stands in the valley. As such, the management and enhancement of existing native forest sites is a top priority for restoration of the Waimata River riparian zone.

In contrast, downstream of Cave Road, riparian forest habitats are scarce and there is an opportunity to restore native forest habitats in these lower reaches to benefit the Waimata River and to better connect the upper reaches with Gisborne city. A similar spatial pattern in the distribution of native forest habitats occurs in the Waimata Valley outside of the riparian zone. That is, the hillslopes adjacent to the upper reach of the study area feature extensive areas of regenerating kānuka forest and patches of diverse old growth forest. But the hill country adjacent to the lower reaches of the study area, south of Goodwin Road to Gisborne city, are largely denuded of native cover. In order to strengthen the ecological connections between the Waimata River and Gisborne city, the protection of existing native forest sites (e.g., Fig. 6E) and also the retirement of land areas for the reversion to native

forests (particularly where this buffers tributary waterways and reduces soil erosion) should be encouraged in the Waimata Valley south of Goodwin Road.

4.2 Issues Affecting Existing Forest Condition

Grazing by both stock and feral goats is a significant issue for forests of the Waimata riparian zone. We found that more than half of the native forest sites were grazed by stock, with grazing of seral forests being much more common (76% of seral forests) compared to old growth forests (30% of old growth forests were grazed). Only half (52%) of the native sites were mostly fenced and no seral sites were stock proof. A positive attribute of the upper portion of the study area is that native forest sites are normally close by and rainfall and dispersal functions are both at levels were natural regeneration would be strong in the absence of stock grazing. A sign of the strong potential for natural regeneration in the Cave Road to Riverside Road reach is the advanced and diverse regeneration occurring within the understories of mature radiata pine forests (Fig. 7). Grazing is known to be detrimental to forest regeneration and the grazing of seral forests would undoubtedly be hindering forest regeneration and successional development in those stands. The retirement and fencing of seral forests is a priority for restoration.

Almost half (42%) of native sites had fresh goat sign. The positive correlation between goat sign and severity of understorey browse suggests that goats are contributing to understorey browse and are thus impacting on forest regeneration. Given the widespread occurrence of goat sign within native sites in the Waimata riparian zone, and the devastating effect goat populations have on native forests and forest regeneration, goat control and/or physical protection of native forests from goats is a high priority for restoration.

Figure 7. Native forest tree species regenerating beneath a mature radiata pine plantation opposite Donners Bush Scenic Reserve, Waimata valley.

Our results suggest that possums are not numerous, but the nature of any possum population should be determined, with this then being factored into ecological management of the Waimata forests as required. We have not assessed introduced predator presence or impacts and likewise this is another important consideration for restoration of forests and forest ecosystem health along the Waimata River.

Most native forests are narrow and long in shape, meaning the forests have high ratios of edge to interior and are subjected to modification of forest microclimate due to edge effects (Young & Mitchell 1994). Most native sites had other areas of native forests >10 ha within 0.5–1 km. Therefore, we suggest that the fragmented and narrow

configuration of existing native sites could be improved by restoring forest around the margins of narrow stands and also by connecting adjacent stands with native vegetation where possible. This might be achieved through the retirement of pasture land, encouraging kānuka regeneration and subsequent succession to mature forest compositions, or through restoration planting.

4.3 Priority Actions for Restoration

4.3.1 Protect and Enhance Existing Native Forests

The first priority action should be the protection and enhancement of existing native forest sites, including seral stands (Norton et al. 2018). However, protection needs to involve more than addressing legal tenure (reserve, covenant etc) and should include active management. The following management aspects are relevant to existing native forest sites and relate mainly to the reach of the Waimata River riparian zone between Cave Road and the end of Riverside Road:

1. Fence native sites to be stock- and goat-proof and retire native sites from stock grazing. There is a major opportunity to secure future forests (*ca*. 35.5 ha) through the retirement and protection of seral forests.
2. Enrichment planting of kānuka stands (Table 6) with mature forest canopy species in stands located *ca*. >200 m from mature native forest seed sources.
3. Retirement and buffer planting to widen narrow sites and to connect discontinuous forest areas or to create additional stepping-stone habitats between distant sites to improve connectivity.
4. Assess and control possums and predators as resources allow, focusing on the larger more diverse forest sites as a first priority.
5. Implement straight-forward and repeatable monitoring of restoration sites using a set of photo-point monitoring stations[2].

[2] For the method and guidance, see
http://www.nzpcn.org.nz/page.aspx?conservation_monitoring_photo_points

Along the Waimata River, forests in early stages of succession are usually grazed (Fig. 8A) and this will be limiting regeneration and succession to more advanced stages of forest development. Kānuka is the main native nurse species in the study area and young kānuka stands represent sites of potential future forest. The existing kānuka stands within the study area are often lacking species that will grow to form a longer-lived mixed forest canopy (Fig. 8A). For this reason, retirement of existing kānuka stands from grazing and protection from goats, coupled with low-density underplanting with mature forest canopy species in artificial gaps (Tulod et al. 2018), are both important management actions to secure future forests and direct successional development. Ultimately these actions will improve the ecological value of these existing forest stands. Underplanting of kānuka can be monitored easily and at a low cost though use of fixed photo-point monitoring techniques.

Figure 8. (A) Example of grazed kānuka stand riparian to the Waimata River near River Road. (B) Example from Hawke's Bay of underplanting a mature kānuka stand with tītoki and tōtara, two long-lived mature forest canopy species.

4.3.2 Create New Native Forests

The second priority is to create additional native riparian forests through restoration treatments (Table 6) which commence forest regeneration and ultimately improve riparian functions and ecological connectivity both along the Waimata River and within the wider catchment. These treatments generally relate to the river reach downstream of Cave Road, where existing native forests are scarce both within the riparian zone and in the adjacent catchment areas. The treatments may also be applied where revegetation is required to expand existing native forest sites.

1. Restorative planting of nursery-raised native seedlings[3].
2. Laying seed-bearing mānuka/kānuka slash 30–40 cm deep to provide 80–95% soil cover[4].

[3] See Davis and Meurk (2001) for a detailed guide to the restoration planting process.
[4] See Porteous (1993; p. 99) and Boffa Miskell (2017; p. 48).

3. Establishment of a drought resistant and low-cost exotic nurse crop (such as tree lucerne[5]) to provide initial shelter followed by native enrichment planting with native conifer and broadleaved canopy species.

Planting of nursery-raised native seedlings would be the primary revegetation method and is particularly suited to revegetation areas that are distant from adjacent native seed sources. Revegetation using laying of mānuka/kānuka brush is a useful tool for treating relatively small areas and is a good treatment when diverse native seed sources are close, such as around forest margins or between adjacent forest stands. The exotic nurse treatment (tree lucerne followed by native enrichment planting) provides an opportunity to create favourable conditions over larger riparian areas at less cost than traditional revegetation planting with native species. This treatment should be deployed in a trial manner to refine the optimal spacing and timing of the treatment.

However, before restorative plantings can be undertaken, the current factors that limit native forest establishment and growth at these sites need to be addressed (Norton et al. 2018). First, grazing animals (livestock and goats) need to be removed from any sites that are to be planted. Even one goat, can result in the total loss of the full restoration investment up to that point and a deer fence is a cheap solution to this problem. Secondly, the exotic grass sward and weedy plant species (e.g. pampus grass, blackberry, wandering dew) need to be controlled so that plantings are able to establish and grow. Finally, there needs to be consideration to a public engagement programme with the local community, so people understand the importance of these plantings.

[5] See Porteous (1993), p. 101.

Table 6. Target species and treatments for forest restoration. The symbols ● and ○ denote pioneer and enrichment phases (respectively).

Species name		Revegetation treatment			
Common	Botanical	Planted native seedings	Kānuka underplanting	Mānuka/Kānuka slash	Exotic nurse crop
Cabbage tree/ti kōuka	*Cordyline australis*	●			○
Five finger	*Pseudopanax arboreus*	●	○		○
Hīnau	*Elaeocarpus dentatus*	○	○		
Houhere	*Hoheria sextsylosa*	●			○
Kahikatea	*Dacrycarpus dacrydioides*	○	○		○
Kaikōmako	*Pennantia corymbosa*	●	○		○
Kamahi	*Weinmannia racemosa*	○	○		○
Kānuka	*Kunzea robusta*	●		● (slash)	
Karamū	*Coprosma robusta*	●	○		○
Kohekohe	*Dysoxylum spectabile*	○	○		
Koromiko	*Veronica stricta*	●			
Māhoe	*Melicytus ramiflorus*	●			○
Mānuka	*Leptospermum scoparium*	●		● (slash)	
Māpou	*Myrsine australis*	●			○
Mataī	*Prumnopitys taxifolia*	○	○		
Miro	*Stachopitys ferruginea*	○			
Ngaio	*Myoporum laetum*	●			○
Nīkau	*Rhopalostylis sapida*	○			
Northern rātā	*Metrosideros robusta*	○	○		
Pigeonwood/porokaiwhiri	*Hedycarya arborea*	●	○		○
Pūriri	*Vitex lucens*	○	○		
Rewarewa	*Knightia excelsa*	●	○		○
Ribbonwood	*Plagianthus regius*	●			○
Rimu	*Dacrydium cupressinum*	○	○		
Large-leaved kōwhai	*Sophora tetraptera*	●			○
Tawa	*Beilschmiedia tawa*	○			
Tītoki	*Alectryon excelsus*	○	○		○
Tōtara	*Podocarpus totara*	○	○		○
Tree lucerne	*Chamaecytisus palmensis*	●			●
White maire	*Nestegis lanceolata*	○	○		
Wineberry/makomako	*Aristotelia serrata*	●			○

References

Boffa Miskell. (2017). The mānuka and kānuka plantation guide. Retrieved from http://www.gw.govt.nz/assets/Manuka-plantation-guide-landcare-April2017.pdf

Clout, M., & Hay, J. (1989). The importance of birds as browsers, pollinators and seed dispersers in New Zealand forests. *New Zealand Journal of Ecology*, (12),27–33.

Davis, M., & Meurk, C. (2001). *Protecting and restoring our natural heritage: A practical guide*. Christchurch: Department of Conservation. Retrieved from http://www.doc.govt.nz/documents/conservation/native-plants/motukarara-nursery/restoration-guide-complete.pdf

Kelly, D., & Sullivan, J. (2010). Life histories, dispersal, invasions, and global change: progress and prospects in New Zealand ecology, 1989–2029. *New Zealand Journal of Ecology,34*(1), 207–217.

Norton, D., Butt J., & Bergin D. (2018). Upscaling restoration of native biodiversity: A New Zealand perspective. *Ecological Management and Restoration*, 19:S1.

Porteous, T. (1993). *Native forest restoration: A practical guide for landowners*. Wellington: Queen Elizabeth the Second National Trust.

R Development Core Team. (2017). R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.r-project.org/

Smale, M., Overton, J., & Price, R. (2013). *Longbush Ecosanctuary: Assessment of baseline flora and vegetation by landform*. Hamilton: Landcare Research. Retrieved from http://envirolink.govt.nz/assets/Envirolink/1277-GSDC108-Longbush-Ecosanctuary-assessment-of-baseline-flora-and-vegetation-by-landform.pdf

Tulod A., Norton D., & Sealey C. (2018). Canopy manipulation as a tool for restoring mature forest conifers under an early-successional angiosperm canopy. *Restoration Ecology* 26, in press.

Young, A., & Mitchell, N. (1994). Microclimate and vegetation edge effects in a fragmented podocarp-broadleaf forest in New Zealand. *Biological Conservation, 67*(1), 63–72.

Appendix A

Forest condition themes, indicators, and scoring criteria as applied to seral, old growth and combined native riparian vegetation in the Waimata River study area. Scores for seral and old growth (O.G.) successional stages are represented with percentage followed by the number of patches in brackets.

Theme	Indicator	Score (1–4)	Seral	O.G.	Seral+O.G.
1.0 Ecosystem Intactness	1.1 Size	1) 0–5 ha	90,(19)	70,(7)	84,(26)
		2) 5–25 ha	10,(2)	30,(3)	16,(5)
		3) 25–100 ha	0	0	0
		4) >100 ha	0	0	0
	1.2 Shape	1) Narrow long strip, sometimes can look through from one side to other – may be <20 m in width	62,(13)	20,(2)	48,(15)
		2) Some wider areas but still long/narrow/convoluted in shape	38,(8)	60,(6)	45,(14)
		3) Mostly in compact shape w/out extensive exposed strips	0	10,(1)	3,(1)
		4) Extensive and compact, approximately round or square area	0	10,(1)	3,(1)
	1.3 Nearby forest	1) No native forest areas over 10 ha in size within 5 km	0	0	0
		2) Closest areas of forest >10 ha are 1–5 km away	24,(5)	0	16,(5)
		3) Areas of forest >10 ha present within 50 m–1 km	67,(14)	70,(7)	68,(21)
		4) Large continuous areas of forest within 50 m	10,(2)	30,(3)	16,(5)
	1.4 Corridors	1) Patch is isolated from other tall stature vegetation for >1 km	0	0	0
		2) Vegetation corridors are present within 500 m–1 km	10,(2)	0	6,(2)
		3) Vegetation corridors are present within 500 m	90,(19)	100,(10)	94,(29)
		4) Extensive vegetation corridors incl. exotic forest & vegetated waterways extending from boundary to native forest >10 ha	0	0	0
	1.5 Adjacent land use	1) Mostly urban/residential	0	0	0
		2) Mostly agriculture	86,(18)	60,(6)	77,(24)
		3) Mostly exotic forestry	10,(2)	30,(3)	16,(5)
		4) Mostly native forest	5,(1)	10,(1)	6,(2)

2.0 Ecosystem Condition	2.1 Forest edge understorey	1) Understorey completely absent around the edge of the canopy	57,(12)	30,(3)	48,(15)
		2) Some understorey present & occasional seedlings/saplings	33,(7)	50,(5)	39,(12)
		3) Considerable understorey & many seedlings/saplings	10,(2)	10,(1)	10,(3)
		4) Vigorous, abundant understorey with a range of seedlings/saplings spreading well below the canopy	0	10,(1)	3,(1)
	2.2 Interior understorey	1) Understorey completely bare of all species	0	10,(1)	3,(1)
		2) Very few plants preferred by deer/goats/stock present in knee–shoulder height range, scattered seedlings of other species	76,(16)	20,(2)	58,(18)
		3) Moderate plants preferred by deer/goats/stock are present in knee to shoulder height range, other species relatively abundant	24,(5)	50,(5)	32,(10)
		4) Abundant plants preferred by deer/goats/stock & other species may also occur	0	20,(2)	6,(2)
	2.3 Interior ground cover	1) Bare soil/rock/gravel covers >20% of ground, eroding soil common, ground vegetation absent–very uncommon	0	0	0
		2) Scattered bare soil & rock, eroding soil uncommon, ground vegetation covers <20%	14,(3)	0	10,(3)
		3) Bare soil, rock absent or very uncommon, no eroding soil, ground vegetation covers 20–50%	62,(13)	70,(7)	65,(20)
		4) No bare soil, rock or eroding soil, ground vegetation abundant, covering 50–100% of the ground	24,(5)	30,(3)	26,(8)
	2.4 Forest edge canopy	1) Major dieback in canopy, dead standing trees	0	0	0
		2) Areas of significant dieback, but all trees live	10,(2)	0	7,(2)
		3) Small areas of localised dieback	86,(18)	90,(9)	87,(27)
		4) Canopy without dieback	5,(1)	10,(1)	7,(2)
	2.5 Interior canopy	1) Foliage very sparse, many large holes, dieback covers >25%	0	0	0
		2) Sparse in some areas, canopy holes common, some dieback	52,(11)	50,(5)	52,(16)
		3) Mostly dense, only occasional sparse areas, canopy holes rare, very occasional dieback	48,(10)	30,(3)	42,(13)
		4) Foliage abundant & dense over whole canopy, no canopy holes or dieback	0	20,(2)	7,(2)
	2.7 Interior understorey browsing	1) Severe browse. 75–100% of stems of deer/goat/stock preferred species are browsed, understorey may be completely bare	0	0	0
		2) Moderate–heavy understorey browse: 25–75% of deer/goat/stock preferred species are browsed	0	0	0
		3) Light understorey browse: 1–25% of stems of deer/goat/stock preferred species are browsed	5,(1)	0	3,(1)

		4) No understorey browse	95,(20)	100,(10)	97,(30)
3.0 Animal Threats	3.1 Possums	1) Abundant fresh sign (droppings, runs, bark scratching/biting)	0	0	0
		2) Common fresh sign but some scattered	0	0	0
		3) Sign uncommon, often quite old	0	10,(1)	3,(1)
		4) Sign very rare or non-existent	100,(21)	90,(9)	97,(30)
	3.2 Deer	1) Abundant fresh sign (droppings, tracks & hoof prints)	5,(1)	0	3,(1)
		2) Common fresh sign	0	0	0
		3) Sign uncommon & often old	0	10,(1)	3,(1)
		4) No sign	95,(20)	90,(9)	94,(29)
	3.3 Goats	1) Abundant fresh sign, goats commonly heard/seen	5,(1)	0	3,(1)
		2) Common fresh sign, occasional goats heard/seen	48,(10)	30,(3)	42,(13)
		3) Sign uncommon, sign is often old	48,(10)	40,(4)	45,(14)
		4) No sign	0	30,(3)	10,(3)
	3.4 Pigs	1) Abundant fresh sign	0	0	0
		2) Common fresh sign, occasional pigs heard/seen	0	10,(1)	3,(1)
		3) Sign uncommon, sign is often old	0	0	0
		4) No sign	100,(21)	90,(9)	97,(30)
	3.5 Stock	1) Abundant fresh sign, stock heard/seen throughout the area	0	0	0
		2) Common fresh sign, occasional stock heard/seen	33,(7)	10,(1)	26,(8)
		3) Sign uncommon & often very old, only near edges	66,(14)	50,(5)	61,(19)
		4) No sign	0	40,(4)	13,(4)
	3.6 Fencing	1) No fencing/fencing no longer functional	29,(6)	10,(1)	23,(7)
		2) Partially fenced or major maintenance required	14,(3)	30,(3)	19,(6)
		3) Mostly fenced or minor maintenance required	57,(12)	40,(4)	52,(16)
		4) Fully stock proofed	0	20,(2)	7,(2)