A Methodology for Assessing the Biodiversity of Road Networks: a New Zealand Case Study

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An Important Note For The Reader

The research detailed in this report was commissioned by Transfund New Zealand.

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Contents

Executive Summary

The public road network makes an extensive and unique contribution to the public lands of New Zealand. It has a total area greater than our fifth largest national park (Tongariro), and connects and bisects New Zealand's towns and landscapes. While the main purposes of road construction and management are transport efficiency and safety, significant benefit can be obtained by enhancing other aspects of the road reserve, such as its biodiversity or scenic values, and reducing the negative impacts of the road and roading activities on the surrounding areas.

Objectives

- Develop a methodology for characterising the biodiversity assets and liabilities of road networks using a combination of rigorous probability sampling, modern spatial analysis, and descriptive surveys.
- Develop digital highway skeletons of the Waikato Region (North Island, New Zealand) state highway network. These skeletons depict important road attributes and environmental characteristics, and are the foundation for assessing biodiversity and other important characteristics of roads and road reserves.
- Demonstrate the methods for assessing roadside vegetation, focusing on biodiversity values and weed distributions, using these new methods of field sampling and surveying.

Methods

A hybrid methodology is employed in this research, which was carried out in 1999-2001, combining rigorous probability sampling and modern spatial analysis techniques with descriptive vegetation surveys modelled after the Protected Natural Area (PNA) survey methods. This hybrid methodology was adapted from past research by Landcare Research NZ Ltd, and has been adapted and modified to deal with the increased extent and complexity of road networks.

We developed quantitative methods for measuring roadside vegetation, including weed distributions and native biodiversity, as follows:

- Digital skeletons of Waikato Region state highways were produced by overlaying highway centrelines onto a 25-m digital elevation model. Each pixel of the road skeleton can have a number of environmental variables predicted for it, including elevation, slope, land cover, and climatic variables.
- These digital skeletons, along with the Land Cover Database (LCDB) were used to design a probability sampling scheme for roadsides, stratified by land cover.
- The probability survey visited 276 sites, and recorded vegetation cover by species at a number of plots per site, for a total of 1434 plots, 12,905 species records, and over 500 unique species. The resulting data were organised in a relational database.
- Weed and biodiversity characteristics were estimated for the overall highway network, as well as estimates of total road length and assessments of accuracy of spatial information.

- Generalised regression analysis and spatial prediction (GRASP) was used to investigate the patterns of biodiversity and weed covers in relationship to land cover and environmental variables, and to predict biodiversity indices, total weed cover and two selected weed species for the digital road skeleton and the entire Waikato Region.

Descriptive survey techniques were used to characterise the road network, describing natural areas within or adjacent to the road reserve. Additional biodiversity information was obtained from local experts, and knowledgeable field botanists. Notable areas of roadside vegetation were listed for highway segments.

Results and Discussion

- Overall, the state highway network was found to have low native biodiversity, with only slightly more cover of native species (8.7%) than of plant species considered to be environmental weeds (7.0%). This translates to 246ha of native cover. Restoration planting of 50% of the total reserve area would increase this to 1168ha.
- The Land Cover Database (LCDB) was found to have low accuracy, correctly predicting the land cover for only 59% of the sample locations, with an estimated accuracy of 68% for Waikato roadsides. However, land cover adjacent to road reserves might represent a worst-case scenario for assessing the accuracy of the LCDB.
- Roads can have both negative effects on vegetation, as well as positive benefits. In land covers such as indigenous forest or shrub, the areas immediately outside the road reserve often have a high proportion of plant species native. Nearer the road, the proportion of species native declines to less than 20%, reflecting the disturbance associated with roading activities on native vegetation. However, in urban or pastoral/horticultural areas, the areas adjacent to the road reserve have very few native species, but the road reserves can contain substantial proportions of native species.
- The proportion of species native at each site was modelled in relation to the environment and was found to increase with the elevation and slope of the site, and to be higher in areas abutting conservation reserves. This model was used to predict the proportion of species native for both the digital skeleton and the entire Waikato Region.
- Total weed cover was also modelled in relation to the environment and produced a more complicated model. This model was used to predict weed cover for the entire Waikato Region. Predictions of two species of pampas are also shown for the Waikato Region, using the same methodology but in a separate field survey.
- Some roadside vegetation represents types that have only small areas in protection, and is thus highly significant for conservation. Across the region, roadside vegetation and weed communities showed pronounced shifts in changes in composition.
- Notable roadside vegetation is described for many areas of the Waikato state highway. Roading practices detrimental to roadside vegetation are noted and recommendations for lessening these detrimental impacts are made.

Conclusions

The hybrid methodology developed in previous research was successfully adapted to road networks. This methodology has proven valuable in capturing the diverse aspects of roadside vegetation, combining quantitative and qualitative information.
Roadside reserves can provide valuable public land for conservation, but roading activities can destroy surrounding vegetation and contribute to the spread of weeds. Changes in road management can lessen these impacts, but considerable room exists for better integration of roadside management with biodiversity conservation, scenic values, and weed mitigation and control.

The approach developed here provides methods for characterising the diverse aspects of highways, but it does not address methods for delivering these in a form that is suitable for use by road managers. Ideally, systems that use this information should be developed and implemented both to influence policy, and to inform management, as well as being delivered in an appropriate form to the people driving trucks and diggers.

This could best be achieved through a unified management system that would capture information on a wide range of road properties from regional or city council surveys, or from surveys such as the one described in this report, and provide them to policy makers and roading contractors. As an overall roading agency, Transfund is ideally positioned to make this happen by wise investment in development and by a policy of unified implementation of such a system.

Abstract

The public road network makes an extensive and unique contribution to the public lands of New Zealand. It has a total area greater than our fifth largest national park, and connects and bisects New Zealand's towns and landscapes. While the main purposes of road construction and management are transport efficiency and safety, significant benefit can be obtained by enhancing other aspects of the road reserve, such as its biodiversity or scenic values, and reducing the negative impacts of the road and roading activities on the surrounding areas.

This report, researched in 1999-2001, describes a methodology for characterising the biodiversity assets and liabilities of road networks using a combination of rigorous probability sampling, modern spatial analysis, and descriptive surveys. Digital highway skeletons were developed of the Waikato Region (North Island, New Zealand) state highway network to depict important road attributes and environmental characteristics, and are the foundation for assessing biodiversity and other important characteristics of roads and road reserves. The methods for assessing roadside vegetation are demonstrated by focusing on biodiversity values and weed distributions, using new methods of field sampling and surveying.

Figure 1.1 The good and the bad of roadside vegetation.

This photo illustrates a number of assets and liabilities of the road reserve for vegetation. Here, the road reserve is acting as a refuge for native species in a production landscape; outside the road reserve, the landscape is pasture or plantation forestry, while inside the road reserve there are areas of regeneration of native vegetation. The road can also provide special habitats, such as the high banks of the road cut. However, disturbance from road construction and maintenance has created prime habitat for weeds, such as the highly visible pampas seen here, which is an aggressive weed of both production and indigenous vegetation.

1. Introduction

Roadside reserves extend along all public roads in New Zealand, and most have some sort of vegetation cover. This vegetation can be considered "good" when it contains rare or scenic native species, or used for grazing or other production purposes. The vegetation can also be considered "bad" when it contains weeds that invade surrounding farmlands or forest. It can also be considered "ugly" when roading activities are poorly designed or managed, often leaving unvegetated scarps. During 1999-2001, we developed methods for measuring and assessing the biodiversity and weed characteristics of road networks. While this report focuses on vegetation, the techniques described can easily be adapted to investigate other facets of biodiversity, or other aspects of roads, such as maintenance or safety.

Some of the beneficial and adverse effects of roads on vegetation can be seen in Figure 1.1. Roadsides can act as a refuge for native vegetation that has higher biodiversity and scenic value than the surrounding land uses, which may be dominated by exotic production species. This can be particularly important in certain lowland developed areas where little native vegetation remains. For example, in the Waikato, in areas of peat that have been drained for dairying, damp roadside drains can support relics of the original wetland/bog vegetation. In addition, roading activities can provide special habitats, such as steep banks, that can be colonised by rare or unusual species.

However, roading can also have a negative impact on indigenous biodiversity. Roading activities can destroy remnants of native vegetation or produce unsightly and highly visible spoil. The disturbance associated with roading activities can produce habitat for weeds and provide invasion conduits into relatively normal areas. Roadsides can also harbour agricultural weeds.

1.1 What if Road Reserves were a National Park?

They are not, of course. Roads and roadside reserves are designed and managed primarily for transportation. But it is interesting to consider how they might compare with national parks in their total area and other characteristics. Our estimate is that there are 90,000 km of public roads, and 140,000 ha of roadside reserve in New Zealand (not counting the road carriageway, see Section 3.2). This is greater in area than the fifth largest national park (Tongariro) in New Zealand. In the North Island, only Te Urewera National Park is larger (Table 1.1).

If the roads were a national park, they would be not only one of the largest national parks, they would also be one of the most unique. They would be a national park that ranged over the entire country, narrow but extensive. It would be a highly visible national park, and in fact some part of it would be seen almost every day by every resident and visitor to New Zealand. Furthermore, roads are predominantly in the productive lowland areas that are poorly represented in national parks. Some of these distinctive characteristics are also disadvantages. Because they are very narrow,

roadside reserves suffer heavily from edge effects. Although formal consideration of road reserves as a national park is unrealistic, the comparison highlights the large potential of these areas for their scenic and biodiversity values.

Table 1.1 The place of roadside reserves alongside New Zealand's National Parks.

National Park	Area (ha)
Fiordland	1 198 000
Mt Aspiring	359 000
Kahurangi	451 000
Te Urewera	208 000
Roadside	*140 000*
Tongariro	74 000
Whanganui	65 000

1.2 Roads & Weeds

Roads and weeds seem inevitably linked. By their very design for transportation, roads connect and divide areas. Because of these connections and the traffic and material moved along roads, they have significant potential to act as corridors for weed movement and spread, either between agricultural areas, or from agricultural areas into natural vegetation. Roads also divide areas, and can act as havens for weeds, especially if the weeds benefit from the disturbance associated with roading activities. Roadside vegetation has also been analysed in New Zealand by Wilson et al. (2000) and Ullmann et al. (1995).

1.3 Relationship to Past Landcare/Transfund Research

This research builds on previous Transfund New Zealand (Transfund) research reported in Overton et al. (2000), which is an important background to this report. Our past Transfund research pioneered techniques for the assessment of biodiversity by combining quantitative approaches with more traditional descriptive surveys. This methodology was developed on the section of State Highway 3 (SH3) between Hamilton and New Plymouth. The research reported in this present report continues this development, generalising from road segments to road networks. The assessment of networks presents several new challenges, including the need for better and new spatial information, and the overall greater length of roads involved, which necessitates less intensive sampling and survey work. Our approach is shown diagrammatically in Figure 1.2.

Figure 1.2 A hybrid approach to biodiversity assessment (*opposite page*).

Probability sampling provides plot-based measurements of roadside biodiversity condition.

Modern spatial analyses integrate measurements on small plots into regional predictions of biodiversity pattern and condition.

Descriptive surveys can integrate existing knowledge and are more likely to recognise rare species or small areas.

A Hybrid Methodology

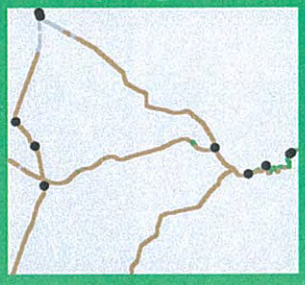
Manaaki Whenua Landcare Research

Probability Sampling and Modern Spatial Analysis

PNA Survey

Digital Road Skeleton

Define Sampling Points

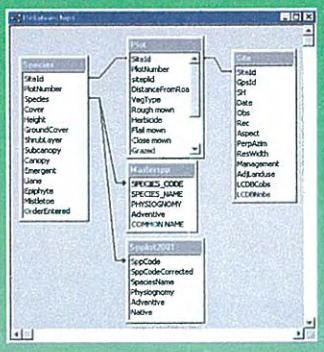


Expert Poll

Descriptive Surveys

Field Sampling

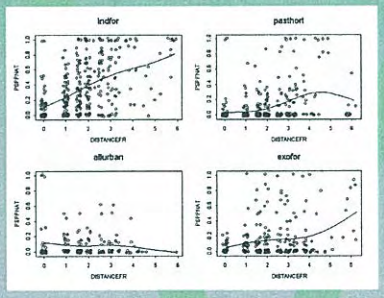
Relational Database



Generalised Regression Analysis and Spatial Prediction

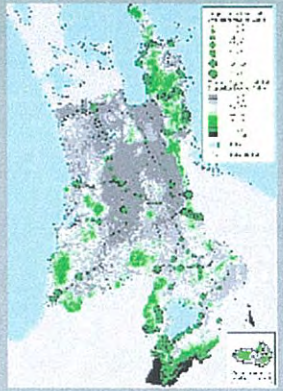
Important Species

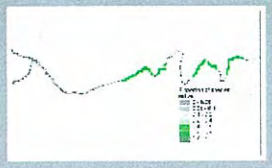
Understanding of Patterns



Significant Areas

Spatial Predictions





Combined description

Figure 1.2 A hybrid approach to biodiversity assessment (*caption on p.12*).

1.4 Probability Sampling & Modern Spatial Analyses

Probability sampling schemes are rigorous methods that allow the characterisation of an area, in this case a road network, by sampling portions, and then making estimates for the whole. This reduces the need to carry out exhaustive surveys over the entire network. These sampling schemes use a random probability that a given site will be measured. This ensures estimates for the network will be unbiased, and allows an assessment of their uncertainty. Furthermore, they provide objective information that can be repeated by other researchers.

Because probability sampling methods are rigorous quantitative methods, they can be greatly enhanced by combining them with modern database management and spatial analyses that use environmental information contained in a geographic information system (GIS). The disadvantage of these sampling schemes is that, since they do not sample the entire area, there may be small but important parts of the area that, by chance, are not measured.

1.5 Descriptive Surveys

Descriptive survey techniques can be used to characterise a road network, describing natural areas within or adjacent to the road reserve. Thus for characterising the biodiversity of a road reserve, the road is driven over, and areas along the road that have predominantly native communities are noted and described. The advantage of the descriptive survey techniques is that they give information over the entire area, incorporating existing data and expert knowledge. The disadvantages are that the survey requires exhaustive searching of the entire road network, and gives only subjective measurements subject to observer interpretation.

1.6 A Hybrid Approach

Our hybrid approach combines the complementary strengths of quantitative sampling techniques with descriptive surveys. The probability sampling scheme provides an objective, unbiased characterisation independent of previous conceptions of the actual biodiversity characteristics of the road network. This is supplemented with surveys to assess botanically the road reserve and identify vegetation communities that might have been missed by the probability survey.

Inevitably, both descriptive survey techniques and probability sampling schemes are limited by the amount of time and money invested in gathering the information. More intensive and detailed descriptive surveys will better characterise known fragments and have a lesser chance of missing important natural areas. Greater sampling intensity and more intensive sampling of plots in probability sampling schemes will reduce the uncertainty of estimates and allow more variables to be measured.

2. Probability Sampling

2.1 Methods

2.1.1 Road Skeletons

Digital skeletons of the state highways in the Waikato Region were produced using Arcview, a geographic information system (GIS) (Figure 2.1). Digital coverage of state highway centrelines for the Waikato Region was provided by Environment Waikato. These centrelines were overlain onto the national 25m digital elevation model (DEM). The digital road skeletons were defined as the pixels of the DEM that were crossed by the roads. If a road line crossed any portion of a square pixel, then that pixel was included in the skeleton. Each pixel of the road skeleton can have a number of environmental variables measured for it, including elevation, slope, land cover, and climatic variables.

2.1.2 Environmental Information

Climatic information was derived from national climate surfaces (Leathwick & Stephens 1998), and predicted for a 100m DEM. These included mean annual temperature, MAT (C); mean annual solar radiation, MAS (kJ/m*d); vapour pressure deficit (VPD); and the ratio of rainfall to potential evapo-transpiration (R2PET). Elevation and slope were obtained from the 25m digital elevation model. Land cover was provided by the Land Cover Database (LCDB).

2.1.3 Choice of Sample Locations

A stratified random sample was used to choose sample locations (Figure 2.2), stratified on land cover as predicted by the LCDB (Table 2.1). Cover classes were condensed into seven sampling categories. Target sample sizes were chosen for each cover sampling category based on the knowledge of their relative importance to roadside biodiversity developed in previous work (Overton et al. 2000). Within each sampling category, the target sample size was chosen randomly from the pixels of the road skeleton. Most sample locations were sampled, but some were skipped because of very steep terrain, reduced pedestrian safety due to narrow verges, and the constrained project budget.

Of the target locations, 20% were chosen to have paired plots to include vegetation adjoining the road reserve. By conducting paired sampling at 20% of the sites, we aimed to achieve 60 paired samples, which was considered to be sufficient for analysis purposes. These paired plots were located 50m away from the edge of the road reserve in the surrounding land cover. The paired plots had variable area, depending on the cover type, with 1x1m or 2x2m plots in low vegetation, 5x5m plots in scrub or tussock, and 10x10m or 20x20m plots in tall forest. The paired plots provided a comparison of the vegetation characteristics of the areas through which the road is passing.

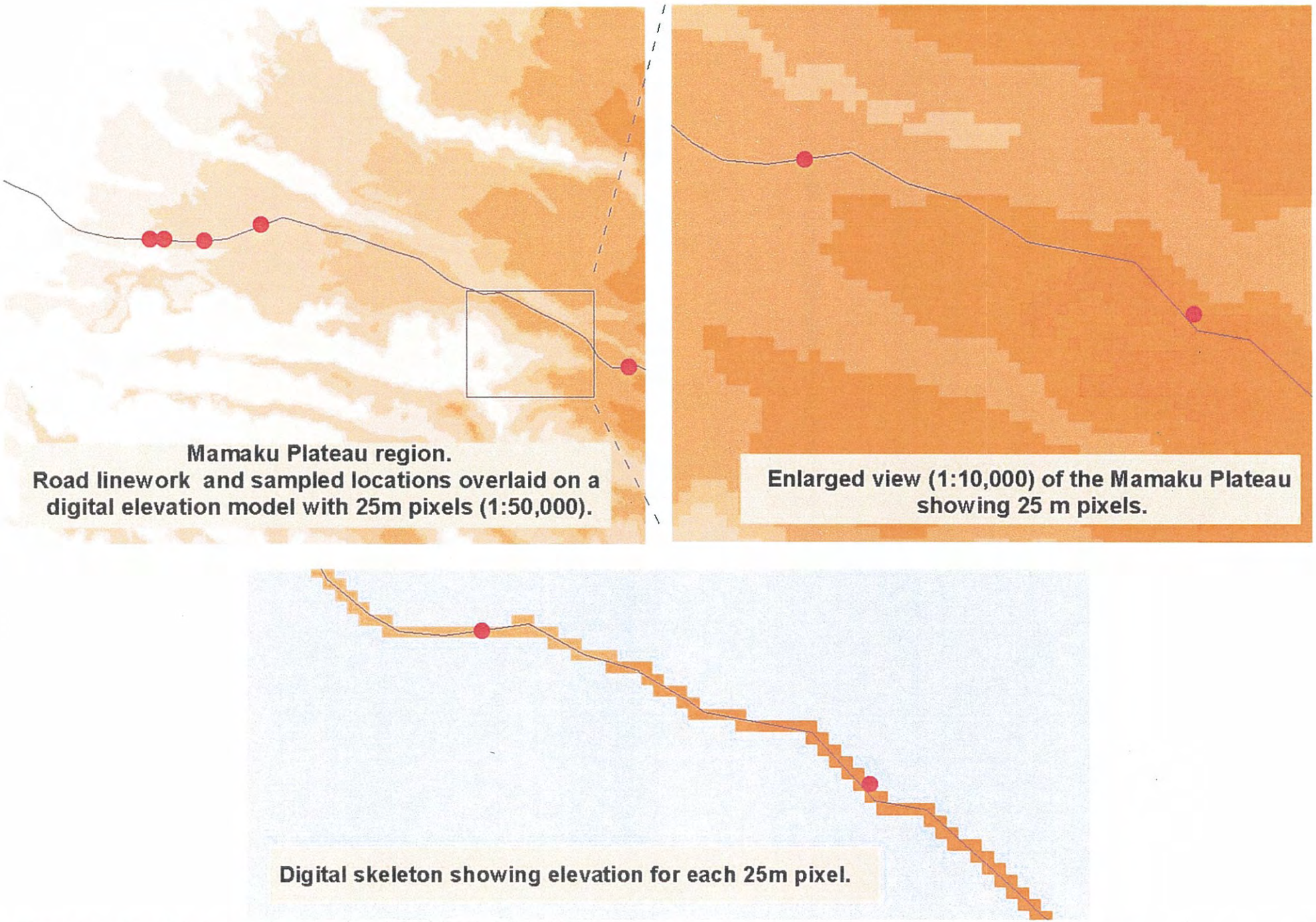


Figure 2.1 The digital road skeleton, with different attributes shown for a portion of the Mamaku Plateau where it is crossed by SH5.

The sampling weights (and the inclusion probabilities) were calculated after the sampling, based on the actual (rather than target) sample sizes. Interestingly, only 59% of the sample locations had their adjacent cover class predicted correctly by the LCDB (Table 2.3). Note that the cover category predicted by the LCDB, not the cover class observed in the field, was used to calculate the sample weights. This is a subtle but important point, and is discussed further in the discussion of accuracy of the LCDB and other spatial information.

Table 2.1 Sampling probabilities and weights for stratified sampling scheme.
Target sample sizes were chosen on the basis of past information on their relative importance. To correct for bias, less intensively sampled categories (like pasture) must have larger weights in the analyses. The sample weights can be interpreted as the number of pixels of the road skeleton represented by each sampling location.

Sampling Category	Number of Sites	Number of Pixels	Weights
All Urban	30	6834	227.8
Exotic Forestry	28	4662	166.5
Indigenous Forest	69	4290	62.2
Pasture + Horticulture	65	59 810	920.2
Shrub	44	6880	156.4
Tussock	25	855	34.2
Wetland	15	309	20.6

2.1.4 Field Sampling

The co-ordinates of the pixel were uploaded to a Garmin Etrex GPS unit. Maps were printed from the GIS showing the sample locations, and the maps and the GPS units were used to locate the sites. If the target location was off the road, because of road realignments or inaccuracies in spatial information, the point along the road closest to the target sample location was used. In all cases, an additional GPS location at the actual sample location was taken.

At each site, the following variables were recorded: landcover adjacent to the road reserve; roadside management (e.g. herbiciding, flail mowing); dominant aspect of the road reserve; aspect of the perpendicular azimuth; road reserve profile; and width of the road reserve. The edge of the road reserve was judged by either the location of a fence, or an abrupt change in land management. This judgement was often subjective, and suffered from the lack of cadastral information on the road reserve. This was not available because of the prohibitive cost of acquiring it for the entire network.

At each site, vegetation was sampled at a number of roadside plots (Figure 2.3). All plots in the road reserve were 1x1m square. The plots were located at different distances from the road edge (Figure 2.4), with the first plot on the edge of the tarseal, and subsequent plots located at increasing intervals up to the edge of the road reserve (Figure 2.4).

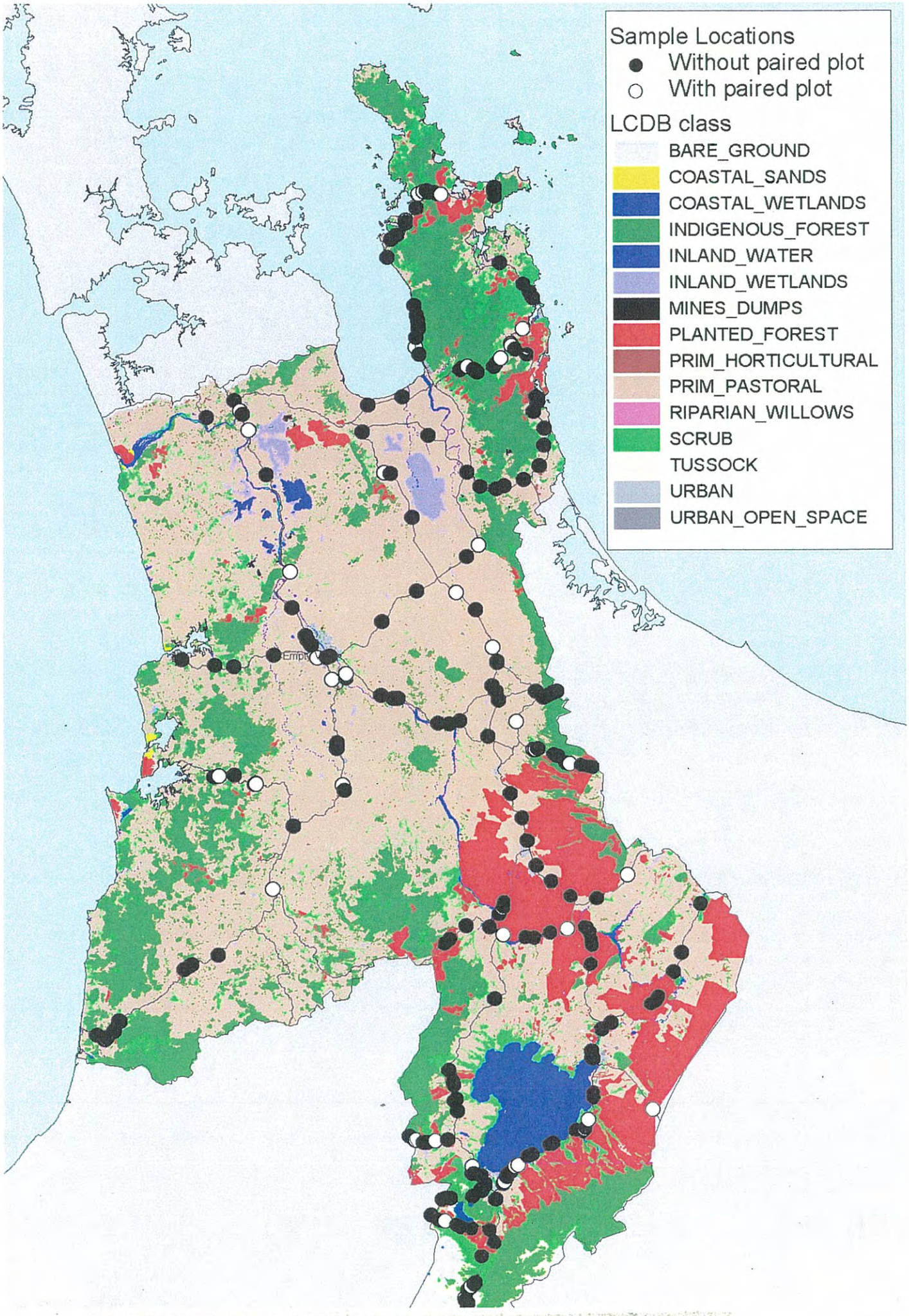


Figure 2.2 Sample locations used for the probability sample (*caption on p.19*).

Figure 2.2 Sample locations used for the probability sample (*opposite page*).

Sample locations and paired plots are shown overlain on the Land Cover Database (LCDB) for the Waikato Region.

A stratified random sampling scheme was used to choose pixels of the road skeleton (see Figure 2.1) to sample. If sampling had not been stratified, 70% of samples would have been along roads in pasture, and only 5% along roads in indigenous forest.

Paired plots were located 50m off the road at one out of every five sites to compare the road with the adjacent landscape.

For each plot, the following was recorded: distance from edge of carriageway; location on the reserve profile (e.g. berm, ditch, bank, etc.); vegetation type in plot; and for each species encountered in the plot, the species name, estimated percentage cover, and its average height in the plot. The cover of non-vegetation cover (e.g. gravel, soil, trash) was also recorded for each plot. Since there were fewer plots measured with greater distance from the seal edge compared with plots nearer the seal, the plot measurements needed to be weighted when calculating the site mean (Table 2.2).

Table 2.2 Weighting given to plot measurements when calculating the site means.
Weights represent the roadside area represented by each plot. This is equal to the spacing between plots (Figure 2.4). Without weighting, the site mean would be biased towards the plots closer to the road where plots are closer together.

Distance from road (m)	Weight
<4	1
4-10	2
10-30	4
>30	10

Figure 2.3 Roadside sampling of vegetation at randomly chosen locations.

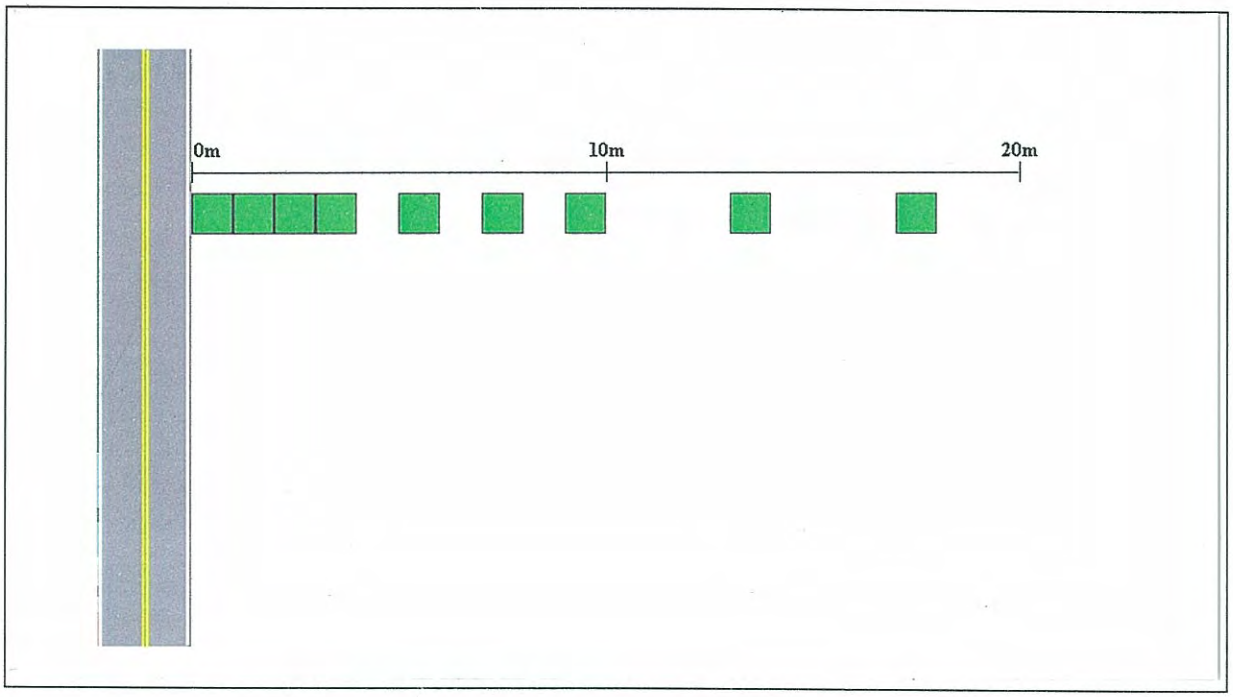


Figure 2.4 Roadside plot sampling design.

1mx1m plots were located at increasing intervals from the edge of the tarseal, up to the edge of the road reserve. To produce the site means, plot measurements were weighted (Table 2.2).

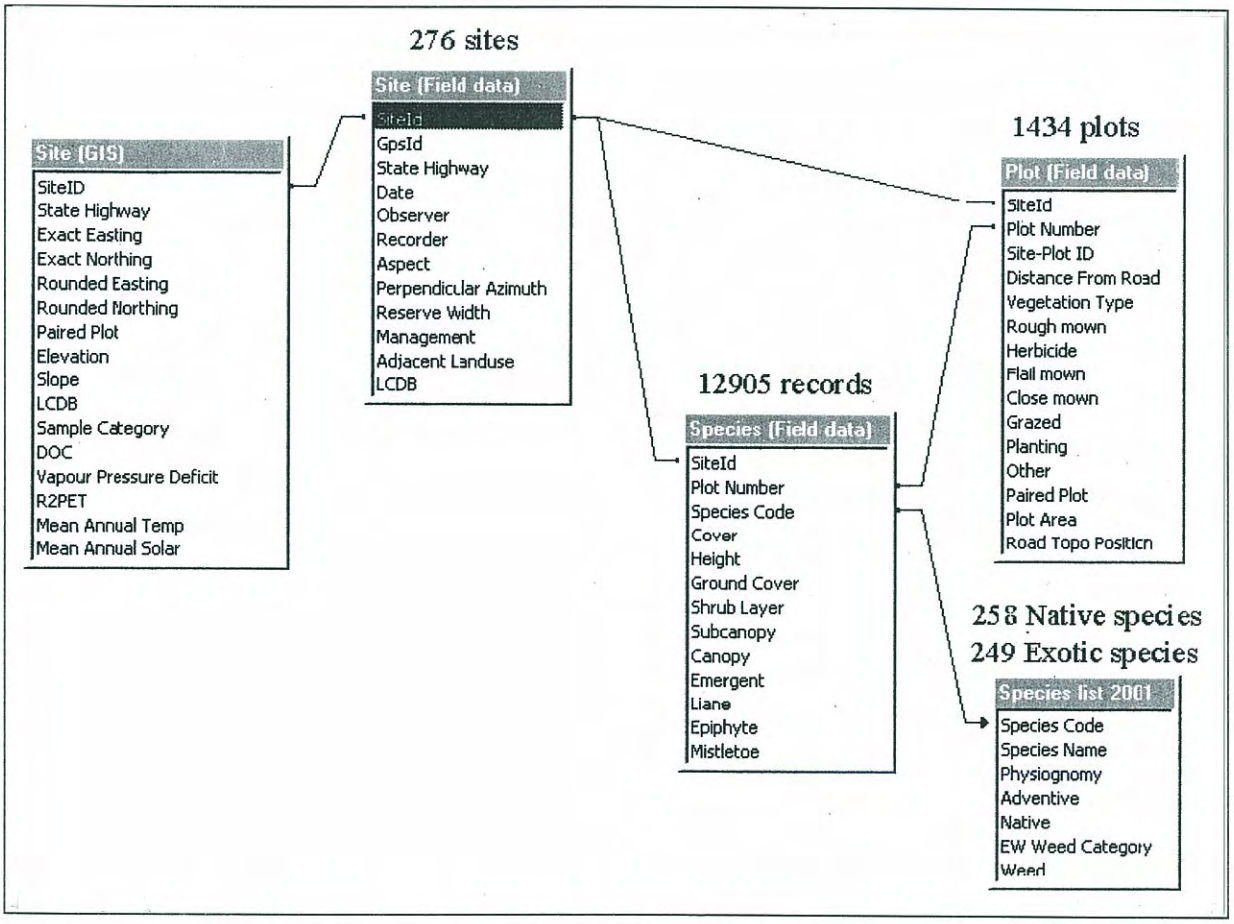


Figure 2.5 Relational database structure and sample sizes.

2.1.5 Database Development

The field data were entered into a relational database (Figure 2.5), with separate tables for the site information, plot information, and species occurrence information measured in the field. An additional table contained information about the species, such as the full scientific name, whether the species was native or exotic, and its weed status.

2.1.6 Generalised Regression Analysis & Spatial Prediction (GRASP)

For all sample locations, the points were overlaid on environmental predictors, resulting in estimates of environmental predictors for each point. Each biodiversity index was modelled by multiple regression using Generalised Additive Models (GAMs) in GRASP to model the relationships between the indices and environmental variables. The final models were chosen by backwards stepwise regression, using Akiake Information Criteria to select variables for inclusion in the models.

The final models were exported from SPlus as lookup tables. (Since GAMs are non-parametric models, they do not produce regression equations. Instead, tables are used to approximate the smoothed additive contribution of each variable.) The lookup tables were imported into the GIS package Arcview, and used to make predictions on both the 25m pixels of the road skeleton, as well as the 100m pixels of the entire Waikato Region.

2.2 Results & Discussion

2.2.1 Accuracy of Spatial Information

All spatial information used in this project, such as information on road locations, land cover, or climate estimates, has associated uncertainty. These uncertainties affect the usefulness of the information. For instance, the digital linework of the state highway network omitted SH23 north of Te Uku, and this section was therefore not included in the sampling design. The linework also has positional errors, reflecting both original accuracy of the linework, as well as systematic errors introduced for cartographic purposes.

The Land Cover Database (LCDB), which was used to stratify the sampling design, was found to have fairly poor accuracy in predicting land cover (Table 2.3). Of the sample locations, only 163 out of 276 (59%) were predicted correctly. To estimate the overall accuracy of the LCDB, the sample weights must be taken into account. When this is done, the estimated accuracy of the LCDB for predicting land cover adjacent to state highways in the Waikato Region increased to 69%. This difference between accuracy of predictions for sample locations versus accuracy for the overall region, reflects the higher accuracy of the LCDB in pastoral areas, which were less intensively sampled in our stratified design. This inaccuracy may be a result of positional inaccuracies of the road linework, as well as errors in the LCDB. However, these results may represent a worst-case scenario for the LCDB, since areas of land cover along roads can be very narrow (below the spatial resolution of the LCDB), and are often different from nearby areas.

Table 2.3 Land-cover database accuracy for predicting land cover adjacent to state highways in the Waikato Region based on field measurements.

Observed LCDB Class	Predicted LCDB Class								
	Indigenous Forest	Inland Wetlands	Planted Forest	Prim Pastoral	Shrub	Tussock	Urban	Urban Open Space	
Bare Ground				1					
Coastal Wetlands	6				1				
Indigenous Forest	46	3		1	19	2			
Inland Water	1	5		1	1				
Inland Wetlands		2			1				
Planted Forest	3		23	4	7	3			
Prim. Horticultural				2					
Prim. Pastoral	11		4	48	6			3	
Shrub	2	5	1	3	9	9			
Tussock						11			
Urban				2			20		
Urban Open Space				3			6	1	**Overall**
% Correct	66.7	13.3	82.1	73.8	20.5	44.0	76.9	25.0	**59.10%**
# Pixels in Skeleton	4290	309	4662	59778	6880	855	6211	623	**83608**
Estimated # Pixels Correct	2861.43	41	3830	44144	1407	376	4778	156	**57592**
Estimated % LCDB Accuracy for Waikato Roadsides									**68.89**

The results raise the question of the appropriate land cover to use for a site when performing these analyses: should it be 1 – the land cover predicted by the LCDB, or 2 – the actual land cover observed and recorded while at the site? The data used depend on whether the analysis aims to understand the effects of land cover, or is designed for spatial prediction. The observed land cover was used for analyses such as Figure 2.6 or Figure 2.7, for which the effects of land cover on roadside attributes are of interest.

However, when spatial prediction is required, the predicted land cover is used in analyses. This is an important point, because what is available for prediction is not the observed land cover, but the predicted land cover. To use the observed land cover in the GAM models would assume that the LCDB was 100% accurate, which we have shown that it is not. The use of the predicted land cover in the model sidesteps the need for knowledge of the accuracy of the LCDB. Uncertainty in the GAM model includes the uncertainty in the spatial prediction of land cover. Interestingly, predicted land cover (LCDB) did not enter the multiple regression for either proportion of species native or of weed cover (Figures 2.8, 2.9, 2.12, 2.13). In part this may be due to the poor accuracy of the LCDB for predicting land covers immediately adjacent to roads.

2.2.2 Estimates of National Public Road Length

To estimate the total length of public roads in New Zealand we used two digital road line databases: 1 – the national road centrelines from the NZMS260 map series obtained from LINZ (Land Information New Zealand); and 2 – similar centrelines for the Waikato Region, provided by Environment Waikato. The latter identified roads as State Highways, public roads, and other roads.

The total length of all roads in New Zealand that are mapped on the NZMS 260 map series was 125,836 km. However, this total includes a number of private roads, for example those through plantation forestry. While no nationwide information was available on which roads were public, Environment Waikato did have public road data for the Waikato Region. The proportion of all mapped roads that are public roads in the Waikato Region was 0.69. By assuming that this proportion was constant for the country, we estimated the total length of public roads for New Zealand as 86,387 km. The mean roadside reserve width for state highways in the Waikato is 8.08m (Table 2.4) on either side of the road. The estimated roadside reserve area of public roads in New Zealand (not counting the carriageway itself) is therefore 8.08 x 2 x 86,387,000m^2 or approximately 140,000ha.

2.2.3 Native Vegetation on Roadsides

These analyses of the roadside vegetation survey give important information for calculating the overall indigenous biodiversity value of the state highway network in the Waikato Region (Table 2.4). We estimate that, on average, 10% of the plant species in a 1x1m plot on the roadside will be native species. Note, however, that, for the survey overall, about 50% (258 species) of the species encountered were native. As the mean roadside reserve width for the state highway network (measured from the edge of the seal to one side of the road reserve) was estimated to be 8.08m, and there are about 1,750 km of state highways in the region, the area estimated is 2,828 ha of roadside reserve along the state highways alone.

Table 2.4 Overall biodiversity indices for the Waikato state highway network. Values are the weighted means according to the weights in Table 2.1.

Road Attribute	Weighted Network Mean
Proportion of Species Native	0.101
Native Richness (# species)	0.636
Total Vegetation Cover (%)	59.3
Total Native Cover (%)	8.70
Native Vegetation Volume Index (m*%)	22.9
Weed Cover %	6.979
Roadside reserve width (m)	8.08

While these estimates indicate a rather low indigenous value in the existing vegetation of road reserves, they also indicate a large potential for increase of biodiversity value in the roadside reserves. Of the 2828ha of roadside reserve, an estimated 59.3% is vegetated (with the remainder being gravel, bare soil, asphalt, etc.). Roadside reserves contain an average of 8.7% cover of native species, leading to an overall total area of 246ha of native cover. However, if native cover could be increased to 50% (through natural succession, restoration planting or changes in roadside management, for example), the increase would be 1168ha of native cover. This potential area of native vegetation is particularly valuable because it is highly visible and accessible to the public, and also because some occurs in landscapes that are intensively used for production purposes, and thus have very little remaining indigenous vegetation.

Figure 2.6 illustrates that roads can have both negative and positive effects on vegetation. In land covers such as indigenous forest or shrub, the areas immediately outside the road reserve have a high proportion of the plant species native. Nearer the road, the proportion of native species declines to less than 20%, reflecting the local disturbance associated with roading activities on native vegetation. However, in urban or pastoral/horticultural areas, the areas immediately outside the road reserve have very few native species, and the road reserves can contain significant proportions of native species. This effect can be seen in Figure 1.1, which shows the native species in the road reserve with pasture and plantation forestry in the land adjacent to the road reserve.

A comparison of plots in the road reserve with plots in areas immediately adjacent to the road reserve shows that the road has a significant effect on native plant species, and that this effect differs between types of land covers (Figure 2.7). Paired plots showed apparently 4-fold higher proportions of species native in the land covers of exotic forests, indigenous forests, shrublands, and tussock (with the last not statistically significant as there was only one paired plot). Pastoral/horticultural areas and wetlands showed no significant difference, and urban areas had only one paired plot. It is interesting to note, however, that both the urban and pastoral areas actually had higher means for the proportion of species native in the road reserve than in the paired plots. These differences are similar to those found by Overton et al. (2000).

Figure 2.6 The effects of distance from road edge on roadside vegetation (*opposite page*).

These graphs illustrate both the depression in native species found near roads in covers such as native forest, as well as the potential for roadside reserves to act as refuges for native species in land covers such as pasture.

For each land-cover category (as observed in the field), the proportion of species native (psppnat) is plotted against the distance from the edge of the road on a log2 scale.

These data include all plots sampled, with the paired plots (outside the road reserve) on the extreme right end of each graph.

The line on each graph represents smoothed best fit, with approx. 4 degrees of freedom.

Figure 2.6 Effects of distance from road edge on roadside vegetation (*caption on p.24*).

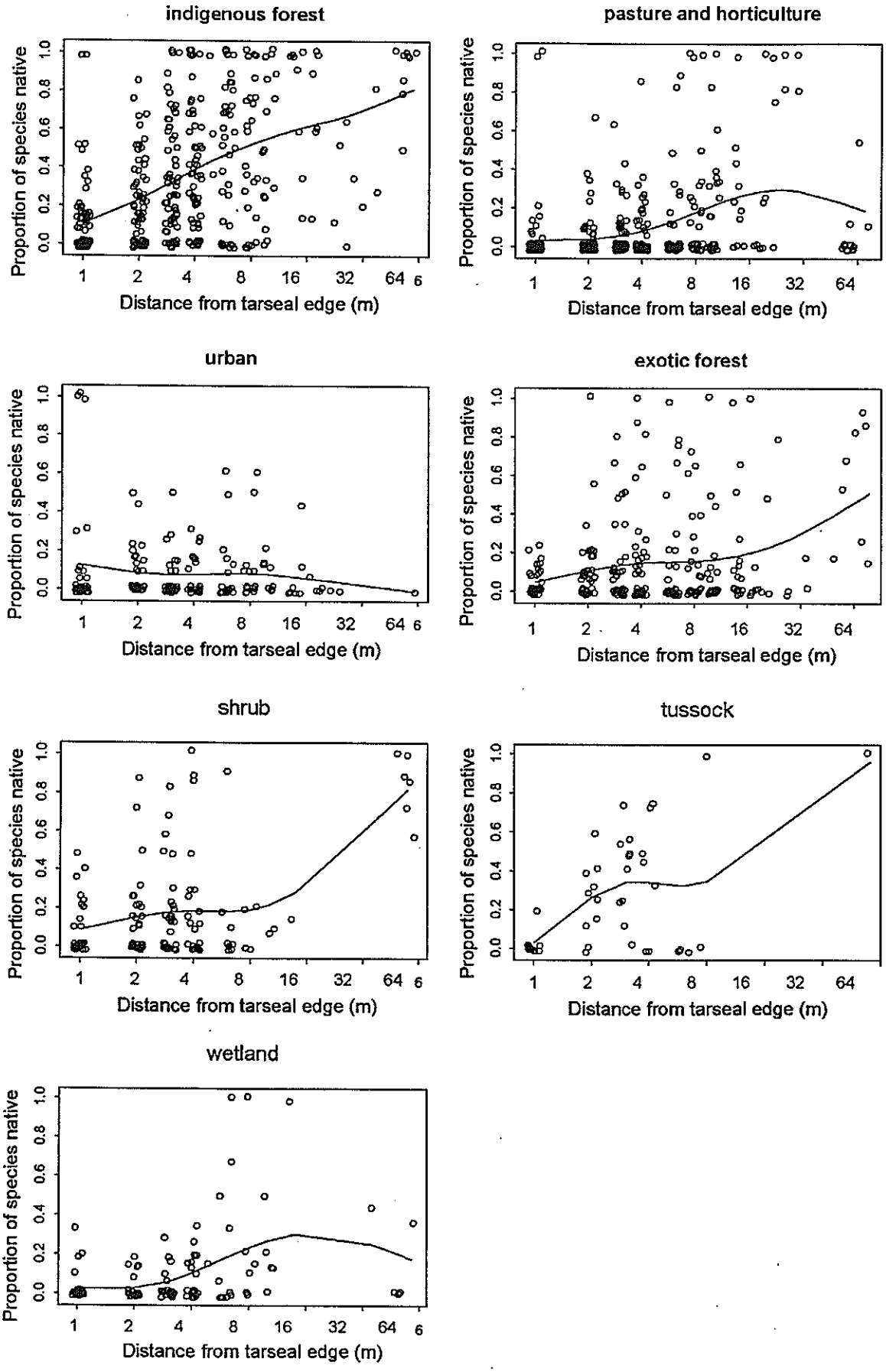


Figure 2.7 Paired plots versus roadside plots for different land covers.

For each land cover category used in sampling, the mean proportion of species native is shown for roadside plots (blue) and paired plots (red).

For the roadside plots, means were weighted according to Table 2.2. Sample sizes for each bar are indicated at the top, with asterisks for statistically significant differences.

Abbreviations for land covers:
Allurban – all urban land cover
Exofor – exotic forestry
Indfor – indigenous forestry
Pasthort – pastoral or horticultural
Shrub – shrubland
Tussock – tussockland
Wetland – wetland

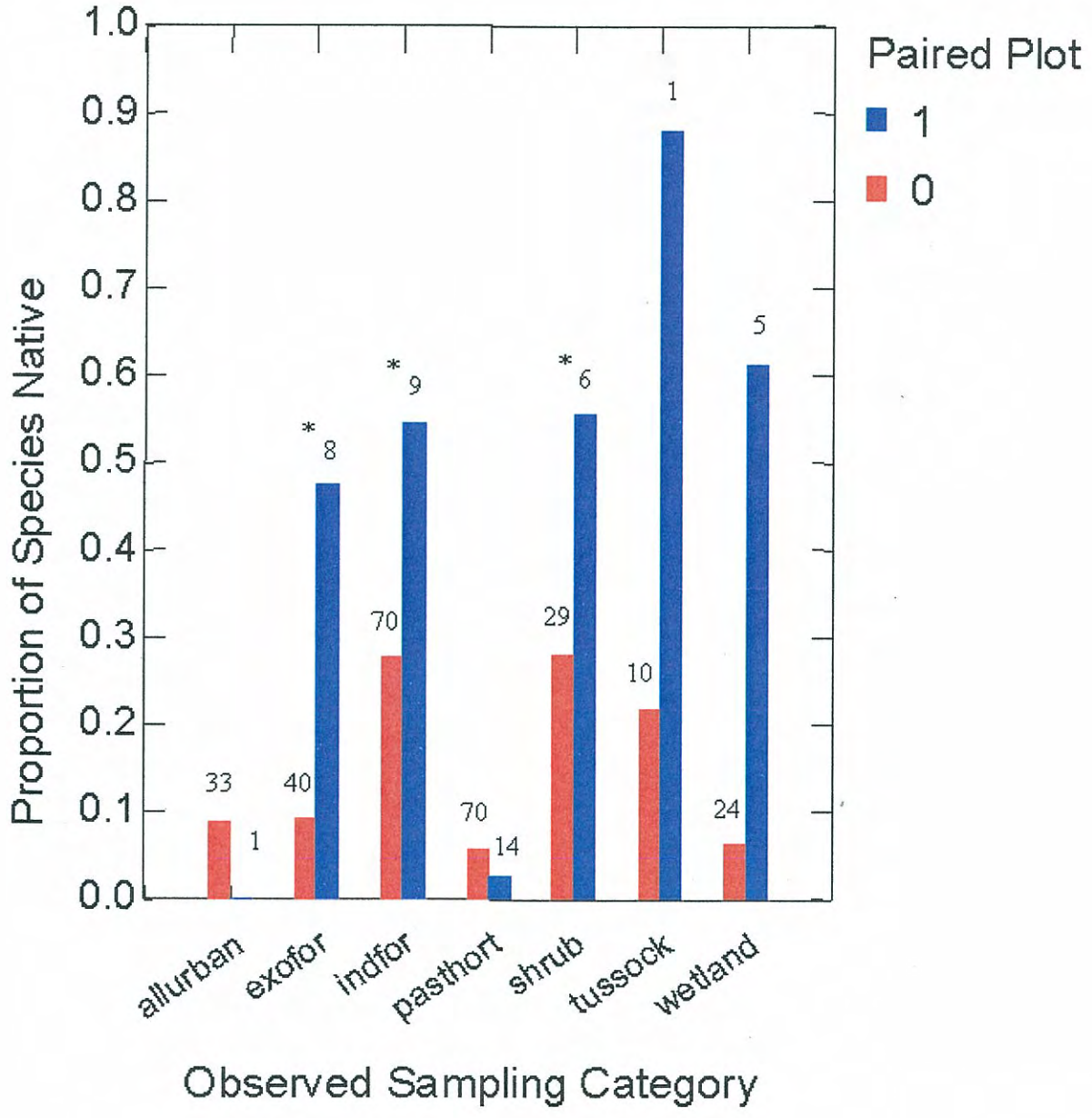


Figure 2.8 Models for the proportion of plant species native on roadsides.

Generalised additive models (GAMs) were used to model the relationship between the proportion of plant species native and environmental variables. These graphs show the partial contribution of each significant explanatory variable. The proportion of plant species native increases linearly with both elevation and slope, and is higher when the adjacent area is managed by the Department of Conservation (DOC).

This model, developed from measurements from a probability sample of roadsides, is used to make spatial predictions for the entire road skeleton (Figure 2.10) and also for the entire Waikato Region.

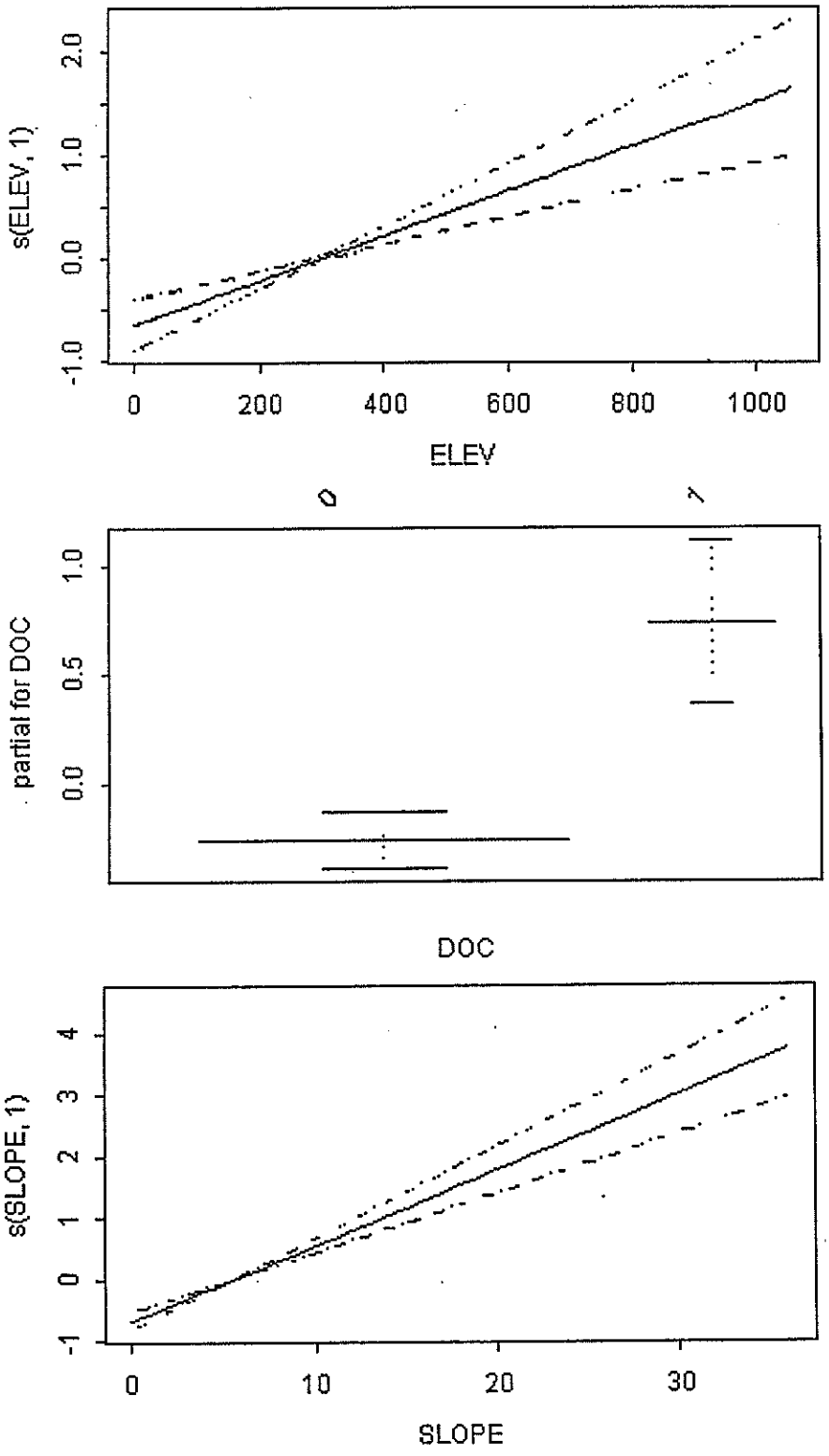
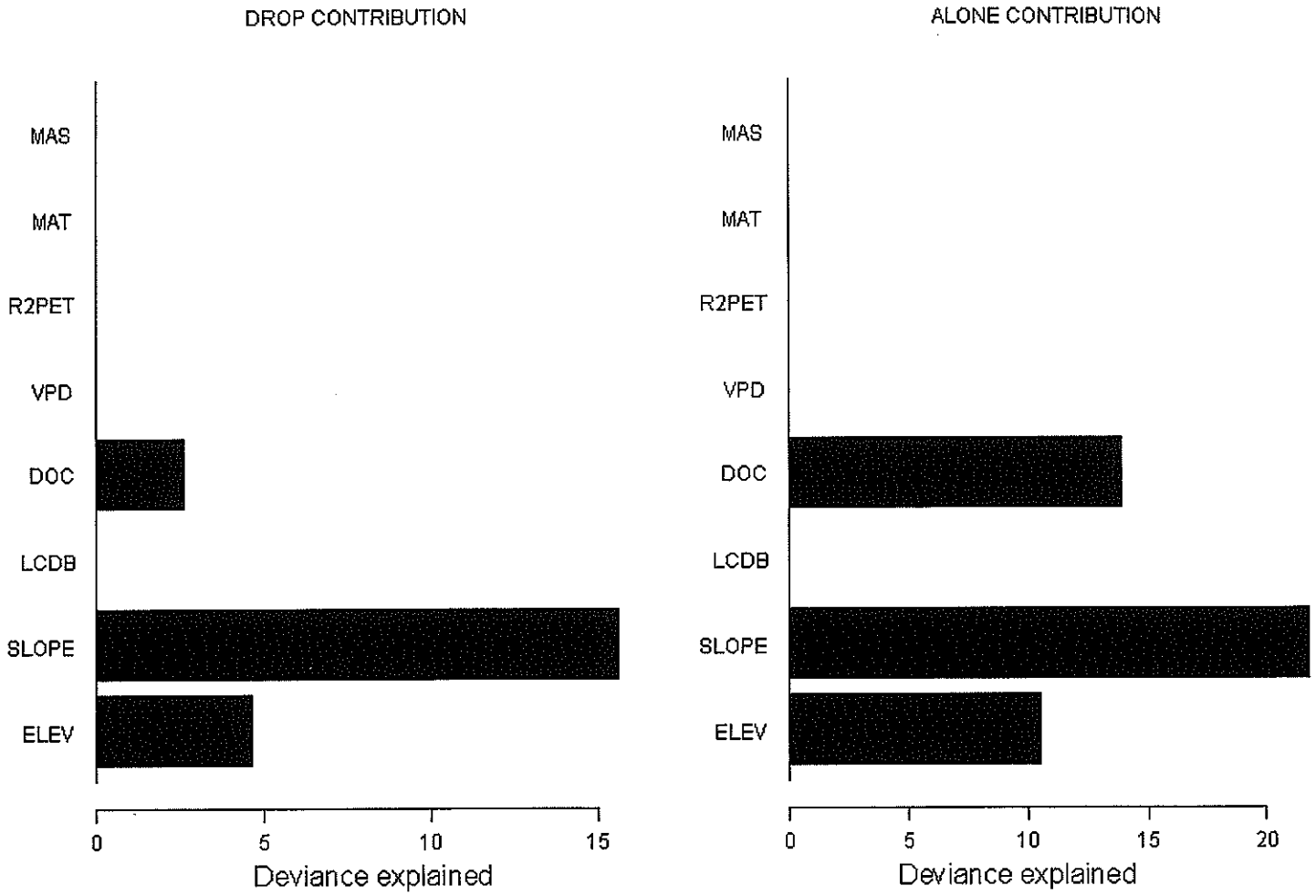


Figure 2.9 Relative contributions of the significant explanatory variables in the GAM model of Figure 2.8.

The alone contribution (right) shows the amount of deviance explained if only that variable is in the model. The drop contribution (left) shows the drop in overall deviance if that variable is dropped out of a full model with all variables in the model. Slope is the most important predictor, with elevation and DOC tenure of similar, and lesser importance.

Key:

MAS – mean annual solar radiation (kJ/m*d)
MAT – mean annual temperature (°C)
R2PET – ratio rainfall to potential evapo-transpiration
VPD – vapour pressure deficit
DOC – Department of Conservation tenure
LCDB – Land Cover DataBase
Slope – slope (°)
Elev – elevation (m)



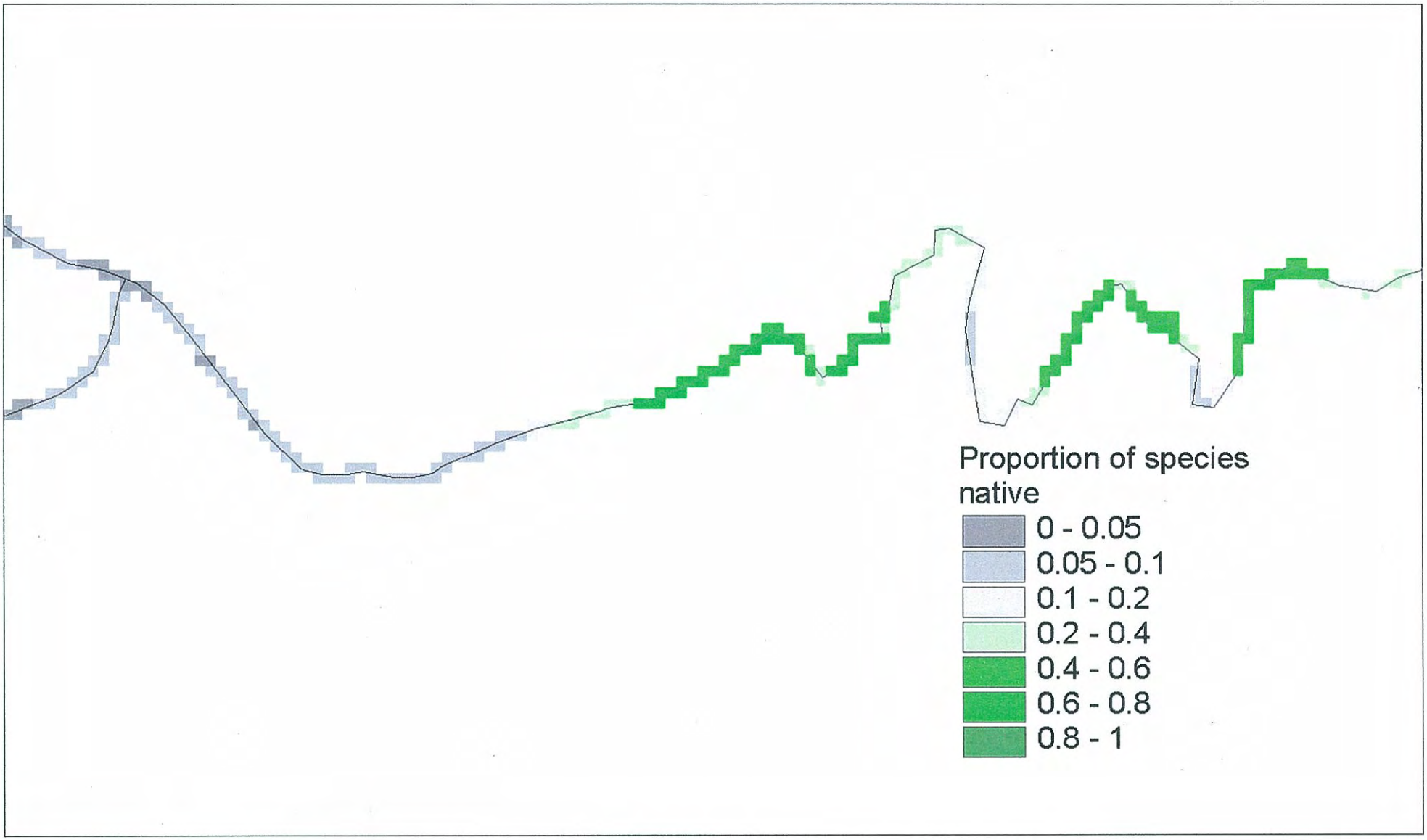


Figure 2.10 The proportion of plant species native predicted for the digital road skeleton of SH29 ascending the Kaimai Range.

The model in Figure 2.8 is used to make predictions for all the 25m pixels of the digital road skeleton. The entire Waikato Region is not shown in this Figure, because the tiny 25m pixels of the road skeleton become minuscule dots at the regional scale.

The reason for only one paired plot in urban areas was the logistic difficulties of putting plots 50m from the road in urban areas (often in someone's backyard!). The reason for the single paired plot in tussock was because of the low overall sample numbers in tussock. This is partly caused by the inaccuracies of the LCDB which meant that most of the locations to have paired plots in tussock were of some other cover type.

The proportion of species native in plots was modelled as a function of environmental and other variables using GRASP. The generalised additive model (GAM) showed that the proportion of plant species native increased with elevation and slope, and is higher when the road passes through areas managed by DOC (Figure 2.8). This model had a D^2 proportion deviance explained of 40.4%. The most important variable in the model was slope, followed by elevation and DOC tenure (Figure 2.9). This model was used to predict for all 25m pixels of the road skeleton (Figure 2.10), as well as the 100m pixels of the entire Waikato Region (Figure 2.11).

The overall mean derived from the sampling design (Table 2.4) can be compared with the overall mean of the prediction for the road skeleton prediction shown in Figure 2.10. Table 2.5 compares the mean proportion of species native derived from these two methods, with and without weighting. The overall mean for the proportion of species native was estimated from the probability sample as 0.101, which is to the third decimal place, the same as the mean of the prediction for the road skeleton, 0.101. Since the site means used to produce the GAM model were weighted as well, this similarity is not unexpected.

If the site values are averaged without weighting, the mean proportion of species native is 0.180. The difference between 0.180 and 0.101 is caused by the bias imposed by stratified sampling, and is corrected by the weights. If the GAM model is made without using weights, and then predicted as in Figure 2.10, the mean for the network is 0.130. Thus, the GRASP methodology is partially able to compensate for the biased sampling used here. While this is not needed in this study, because the weights, or inclusion probabilities, are known, it could be useful in cases where the sampling has an unknown bias. How well this works in other applications requires further research.

Table 2.5 Comparison of mean proportion of species native derived from sampling design and road skeleton prediction with and without weighting.

Means	Weighted	Unweighted
Mean of sites	0.101	0.180
Mean of prediction on road skeleton	0.101	0.130

Figure 2.11 The observed and predicted proportion of plant species native on roadsides in the Waikato Region (*opposite page*).

The sampling sites are shown, with the observed proportion of species native. These points were used in GRASP to develop the relationships between the proportion of species native and environmental variables shown in Figure 2.8. That model was then used to make the predictions for all the 100m pixels of the Waikato Region, shown here. These predictions should not be interpreted as the proportion of species native for the entire area, but rather what that proportion would be on a roadside reserve, and even more strictly on the reserve of a state highway.

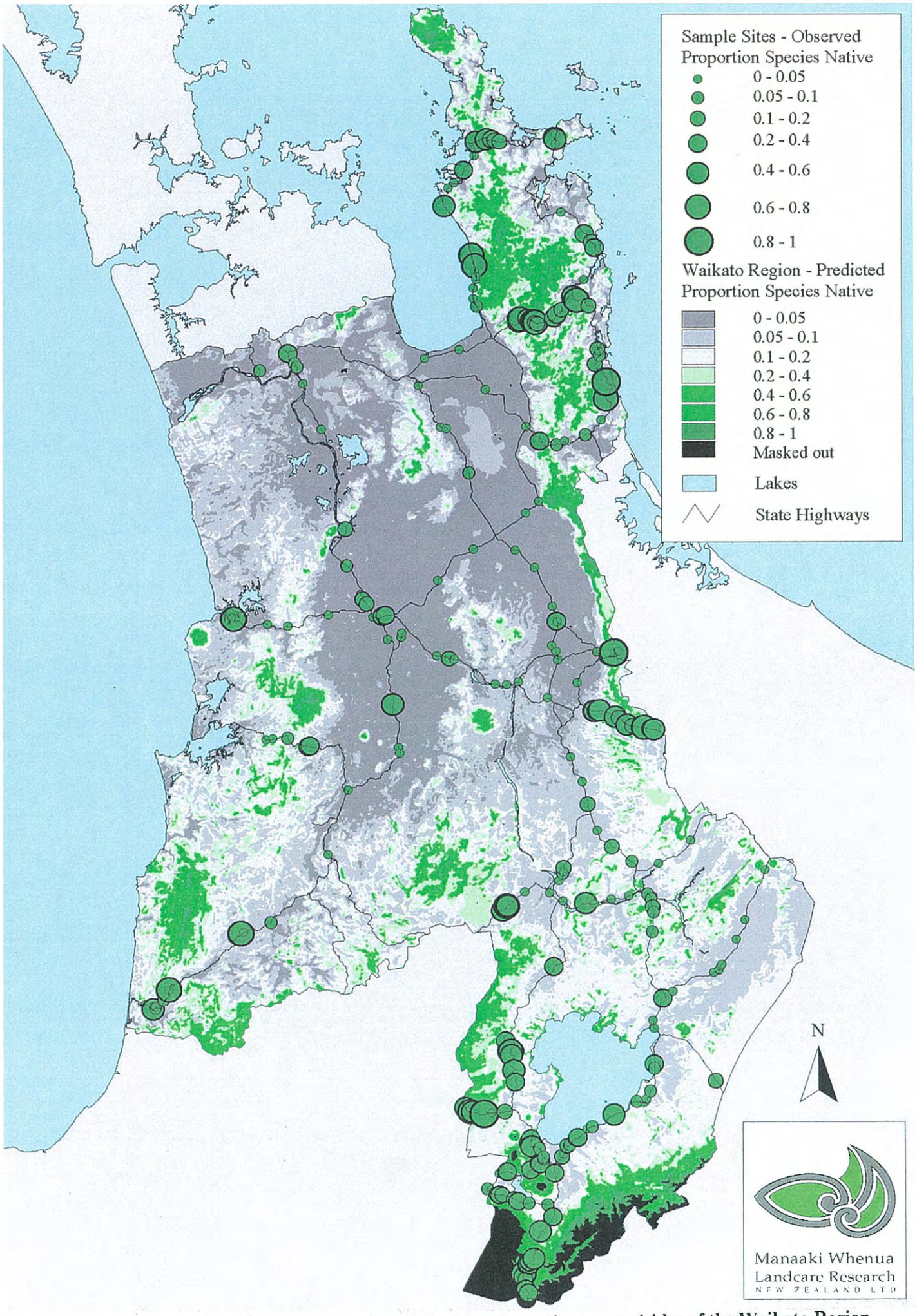


Figure 2.11 Observed and predicted proportion of plant species native on roadsides of the Waikato Region (*caption on p.30*).

2.2.4 Weeds on Roadsides

The road reserve in the Waikato contains on average 7.0% cover of species considered to be weeds (unwanted plants). This is similar to the cover of native species (8.7%) (Table 2.4).

Excluding the paired plots outside the road reserve in the adjacent land use, 32% (454 of 1434) of roadside plots, 58% (161 out of 276) of the sites had one or more weed species. Table 2.6 gives the weed species recorded during probability sampling, and their relative frequencies. There were no significant differences between road plots and paired plots in weed cover, contrary to that seen for proportion of native species in Figure 2.7. This indicates that, overall, roadsides are similar to surrounding areas in their amount of weed cover.

Table 2.6 Relative frequency of weed species recorded during probability sampling.

Latin name	Common name	Plots with Species		Sites with Species	
		Number	Percentage	Number	Percentage
Ageratina riparia	mistflower	1	0.1	1	0.4
Berberis glaucocarpa	barberry	2	0.1	2	0.7
Buddleja davidii	buddleia	8	0.6	7	2.5
Calluna vulgaris	heather	60	4.2	21	7.6
Cortaderia selloana	pampas grass	36	2.5	15	5.4
Cyperus rotundus	purple nutsedge	3	0.2	2	0.7
Cytisus scoparius	wild broom	142	9.9	55	19.9
Elaeagnus reflexa x	elaeagnus	3	0.2	1	0.4
Erica lusitanica	Spanish heath	41	0.4	21	0.7
Erigeron karvinskianus	Mexican daisy	6	2.9	2	7.6
Hedychium gardnerianum	kahili ginger	1	0.1	1	0.4
Hypericum perforatum	St John's wort	35	2.4	22	8
Ipomoea indica	blue morning glory	4	0.3	1	0.4
Leycesteria formosa	Himalayan honeysuckle	5	0.3	3	1.1
Ligustrum lucidum	tree privet	6	0.4	3	1.1
Ligustrum sinense	Chinese privet	4	0.3	3	1.1
Lonicera japonica	Japanese honeysuckle	21	1.5	5	1.8
Rosa rubiginosa	sweet briar	1	0.1	1	0.4
Rubus fruticosus agg.	blackberry	128	8.9	70	25.4
Senecio jacobaea	ragwort	34	2.4	21	7.6
Ulex europaeus	gorse	73	5.1	28	10.1

A generalised additive model of total weed cover (the sum of covers of all weed species) is shown in Figure 2.12, with contributions of the variables shown in Figure 2.13. This model had a D^2 of 25%, which suggests a weak spatial pattern picked by these analyses. The model was used to predict the weed cover of all of the 100m pixels of the Waikato Region (Figure 2.14). These analyses give an overall picture of weed cover.

However, it is interesting to consider which weed species make up this cover, especially since the suites of weed species alters across the Waikato Region (see Section 3, Descriptive Surveys). Similar analyses could be done with any particular weed species of interest. As examples, spatial analyses for both species of pampas are provided, with a different survey designed especially for those species.

Figure 2.12 Models for total weed cover on roadsides.

Generalised additive models (GAMs) were used to model the relationship between weed cover and environmental variables. These graphs show the partial contribution of each significant explanatory variable. This model is more complex than that in Figure 2.8, and contains a number of non-linear relationships. The overall proportion of deviance explained here is also lower.

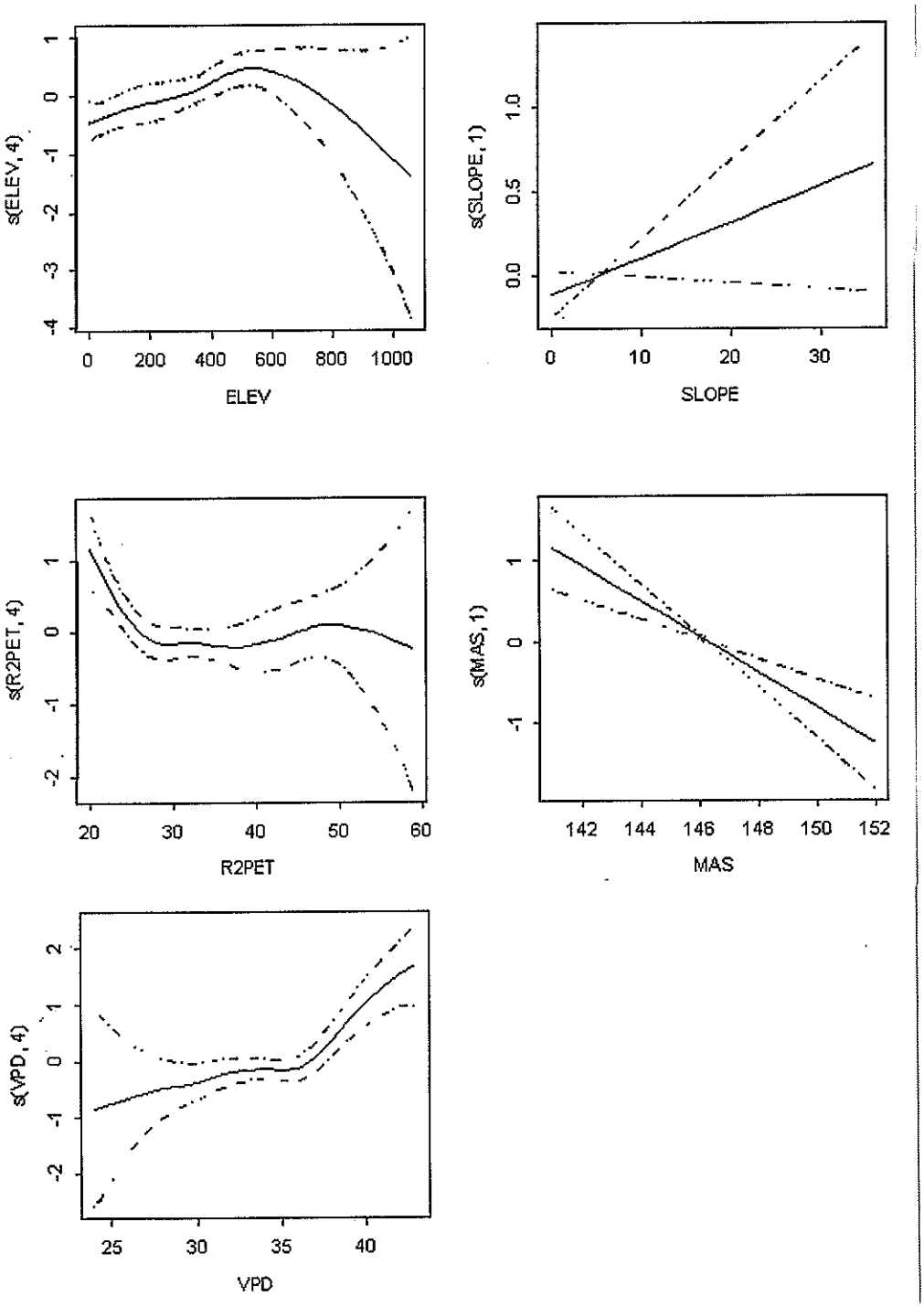


Figure 2.13 Relative contributions of the significant explanatory variables in the GAM model, seen in Figure 2.12.

The alone contribution (right) e amount of deviance explained if that variable only is in the model. The drop contribution (left) shows the drop in overall deviance if that variable is dropped from a full model with all variables in the model.
Key: same as for Figure 2.9.

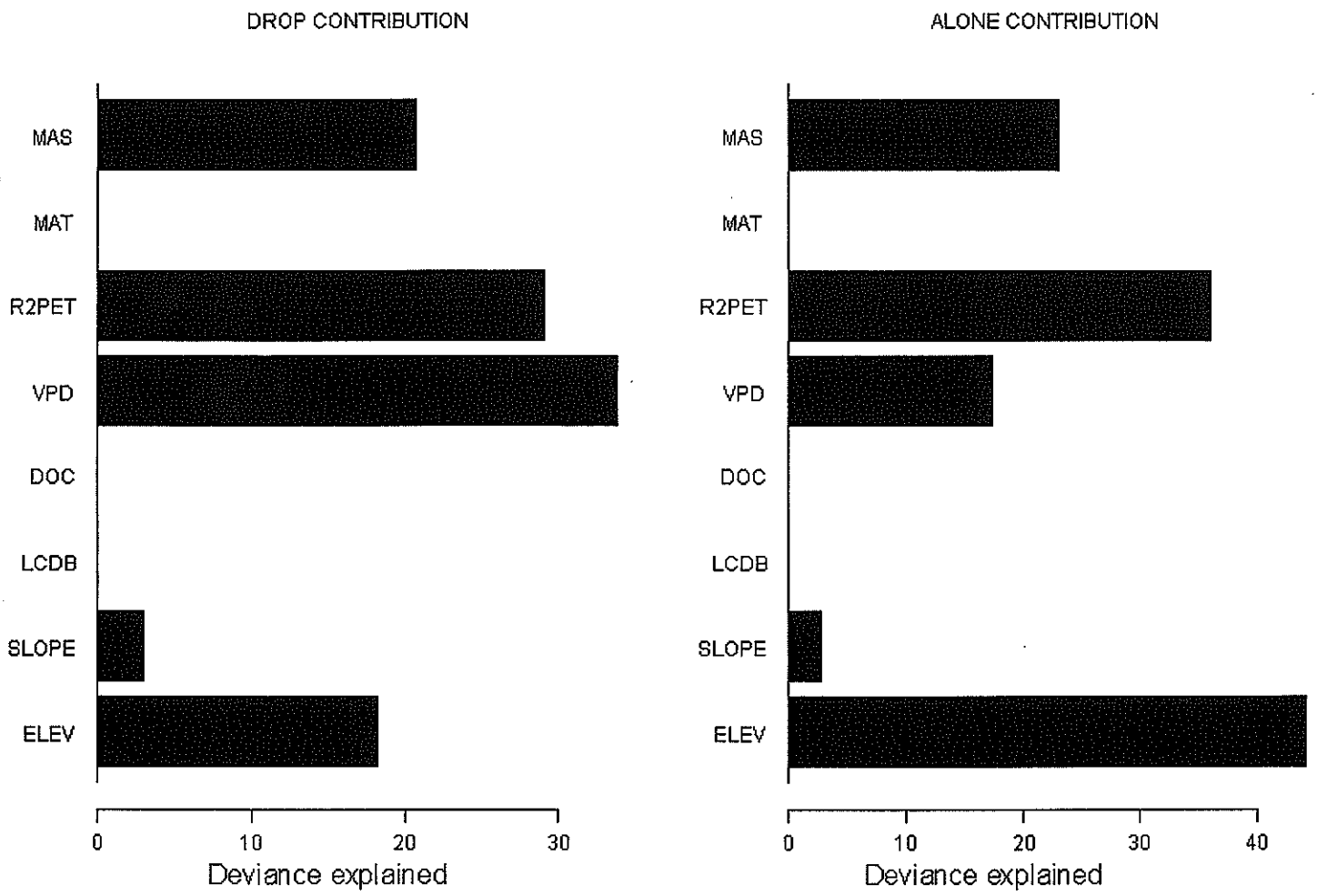


Figure 2.14 Observed and predicted weed cover on roadsides of the Waikato Region. The sampling sites are shown with the observed total weed cover. These points were used in GRASP to develop the relationships between weed cover and environmental variables shown in Figure 2.12. That GAM model was then used to make predictions for 100m pixels of the Waikato Region, shown here. Similar to Figure 2.11, these are predictions of the weed cover expected on roadsides. (*opposite page*)

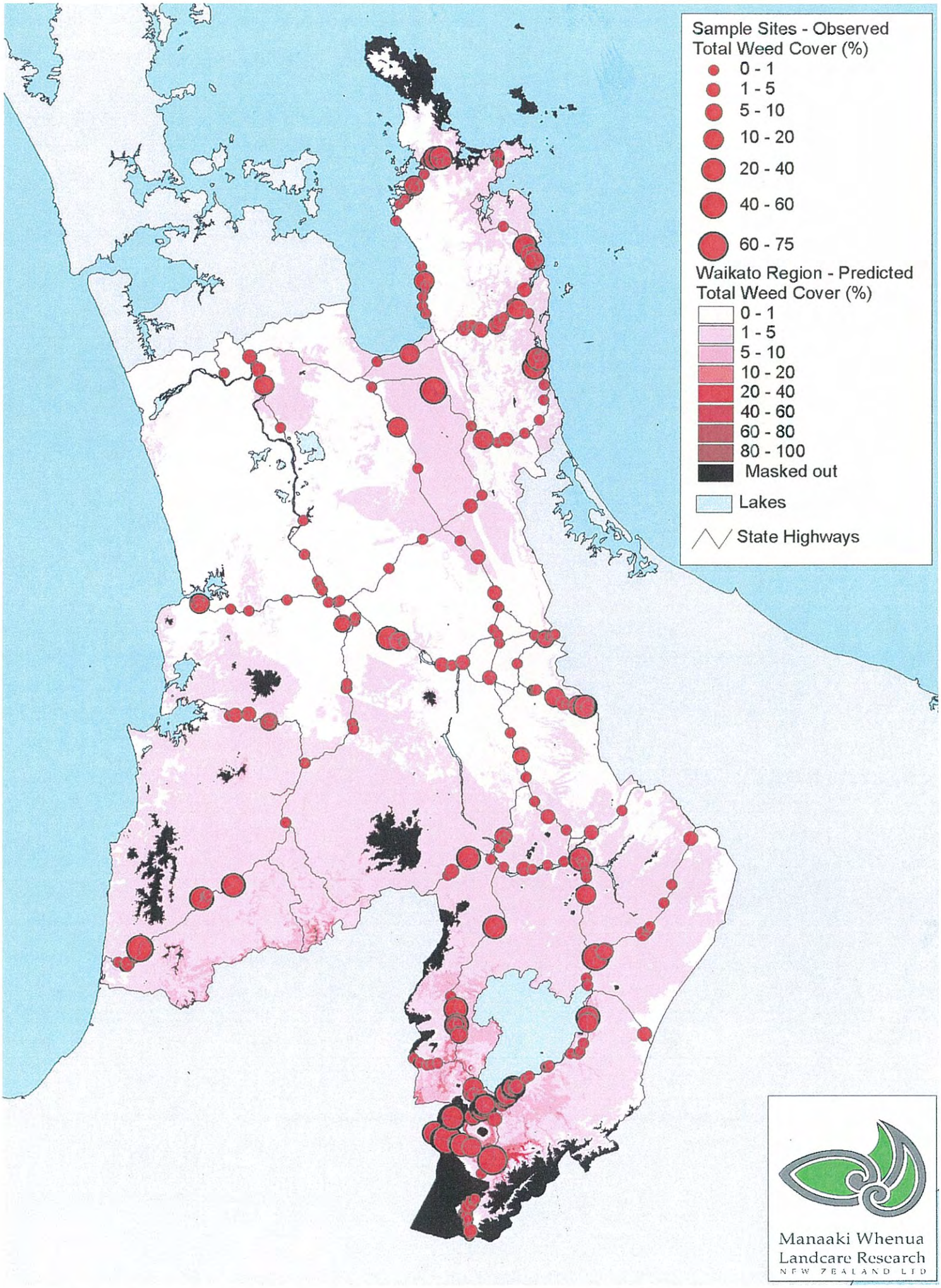


Figure 2.14 Observed and predicted weed cover on roadsides of the Waikato Region (*caption on p.34*).

2.3 Weeds on Roadsides: a Case Study of Pampas

In the Waikato, pampas is recognised as a versatile species that can withstand a wide range of environmental conditions (Environment Waikato 1998). Knowles & Ecroyd (1985) report that common pampas, imported as a useful plant in farming for its uses as winter fodder and shelter in the 1940s, has become naturalised, mainly in warmer parts of New Zealand.

Introduced pampas grasses (common pampas, *Cortaderia selloana*, and purple pampas, *C. jubata*) are serious weeds in the Waikato Region. They invade wastelands such as quarries, roadsides, and disturbed sites adjacent to residential areas, and have been recognised as a "problem weed" in plantation forestry.

Since the inclusion of pampas to the Waikato Regional Pest Management Strategy, which became operative in 1996, pampas has gained the status of a "total control weed" for parts of the Waikato Region and for all quarries and road networks. This means all forms of pampas must be controlled to prevent flowering. It is important to understand the mode of establishment and spread of pampas when considering its control status. Pampas requires disturbance to colonise, but once established remains the dominant vegetation for many years until, for example, it is overtopped by large trees. The fine seeds of pampas are dispersed well by wind, which carries them many kilometres. Thus, while some weeds are local problems, spreading into the surrounding vegetation and becoming local infestations, pampas operates at both larger and small scales. Once established, individual plants can persist for many years without spreading, while the seeds can travel for many kilometres to colonise newly disturbed areas.

2.3.1 A Roadside Survey for Pampas

A survey was performed to plot the presence and absence of pampas along most of the state highway network within the Waikato Region. The purpose was to establish what factors might limit the distribution of pampas, and to produce a prediction map based on its environmental factors that would show the probability of pampas being present at any given site in the Waikato Region. Approximately 1,389 kilometres of road were surveyed. Systematic sampling at 3-kilometre intervals was undertaken to ensure that an adequate number of sample plots was obtained on which to perform statistical analysis. A car odometer was used to measure the 3-km intervals. Plots were a 50m radius (7,854 m^2), and in nearly all cases included land adjacent to the roadside reserve. Overton et al. (2000) stated that the biodiversity attributes of the road reserve differed markedly between the environmental sectors, and showed a strong effect from the surrounding land cover. This supported the belief that the roadside might be a good indicator of the surrounding vegetation.

In each plot, several variables were recorded including location obtained from a GPS, the presence or absence of pampas by species, infestation density, whether the pampas was natural or planted, and additional comments.

Of the 463 plots sampled, 161 were found to have exotic pampas present. Five of the eight predictors used in the analysis showed significant correlations with the presence and absence of pampas; of which the two most strongly correlated were mean annual temperature (MAT) and minimum annual temperature (MINT). The other variable that showed a significant contribution was slope. The remaining two were mean annual solar radiation (MAS) and minimum rainfall to evapo-transpiration. Figures 2.15 and 2.16 show the predicted distribution of common pampas and purple pampas in the Waikato Region.

2.3.2 Common Pampas

Figure 2.15 shows that common pampas appears to be widespread, with the highest probabilities of pampas occurring in the northern and western parts of the Waikato, particularly around Kawhia, south of Piopio, Whangamata, Paeroa and Te Aroha. This is consistent with what we would expect to see in the field. The dots shown on the map in green and grey indicate the actual presence and absence of pampas as noted in the roadside survey. These correspond fairly well with the prediction.

It was interesting to note that very few presences were recorded within plots around Taupo. This corresponded well with the information from the prediction, with most of this area being coloured blue, indicating a low probability that pampas might occur. Another interesting result was the high probability of pampas occurrence predicted for Mt Te Aroha. Although no presences were recorded for nine kilometres either side of Te Aroha within the sample plots, Figure 2.15 shows that a high probability of pampas occurrence is expected on Mt Te Aroha. This prediction is confirmed as there is a dense infestation of pampas at the base of the mountain just above the township where a pine plantation was removed and the ground had been disturbed.

2.3.3 Purple Pampas

From Figure 2.16 it appears that purple pampas has a much more limited range than common pampas, and the distribution appears more concentrated, with the highest probability of occurrence in and around the Coromandel and South Auckland–Hauraki areas. This distribution may reflect the patterns of initial spread due to planting, and also climatic limitations on growth. Both species have become naturalised mainly in the warmer parts of New Zealand. It would be risky to assume that purple pampas was not capable of invading all the same habitats as common pampas. Purple pampas has become naturalised in South Africa and California, and in both places is more aggressive than common pampas (Robinson 1984).

2.3.4 Pampas on Roadsides

Given the potential for roadsides to act as major corridors for the spread of weeds, not only along the roadside but into the surrounding vegetation, the risk of pampas spreading poses two main threats. It threatens the intrinsic values of surrounding vegetation, but also the economic value of plantation forestry, because pampas can compete with pine and increase the amount of silvicultural and maintenance costs.

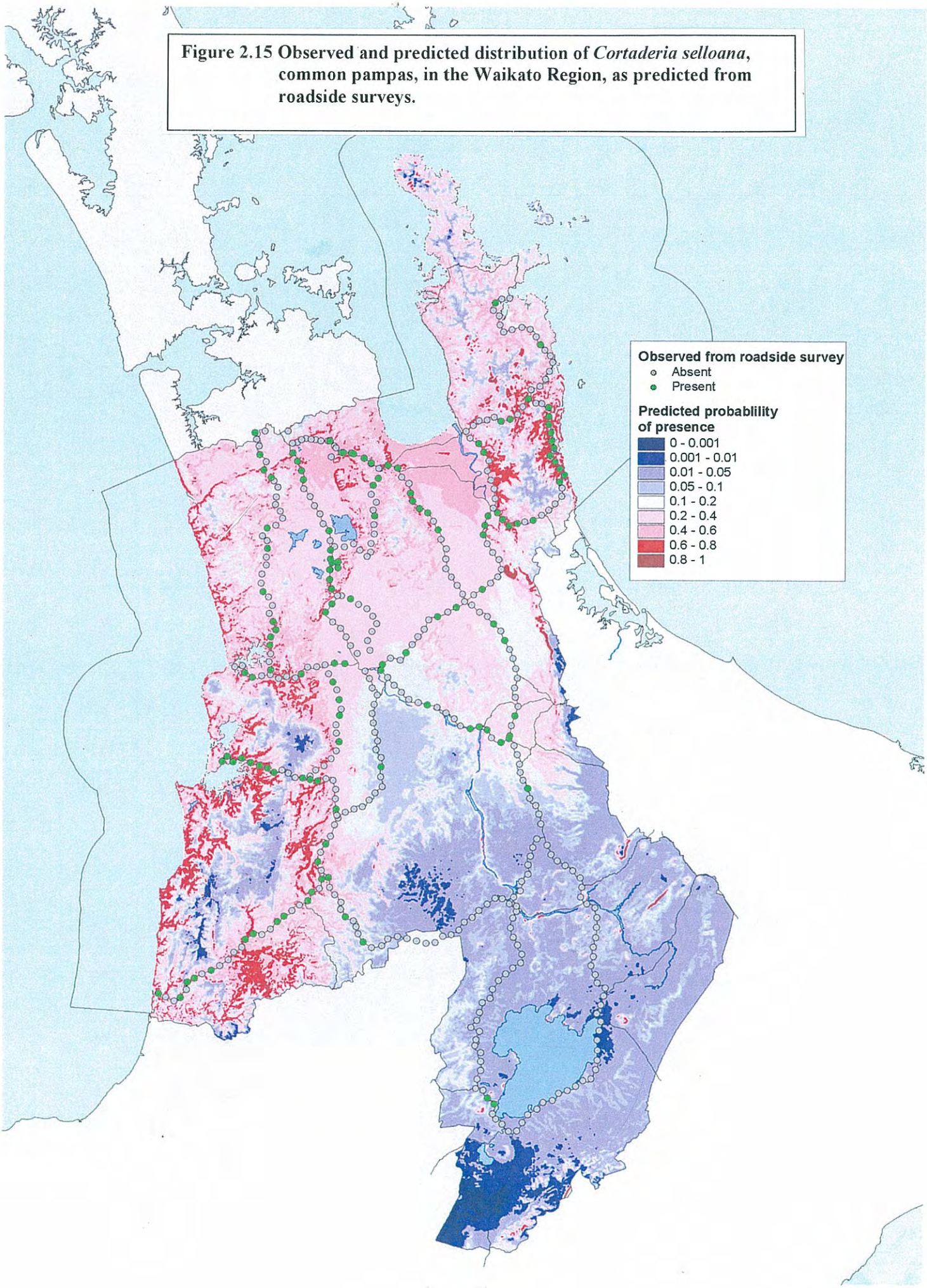
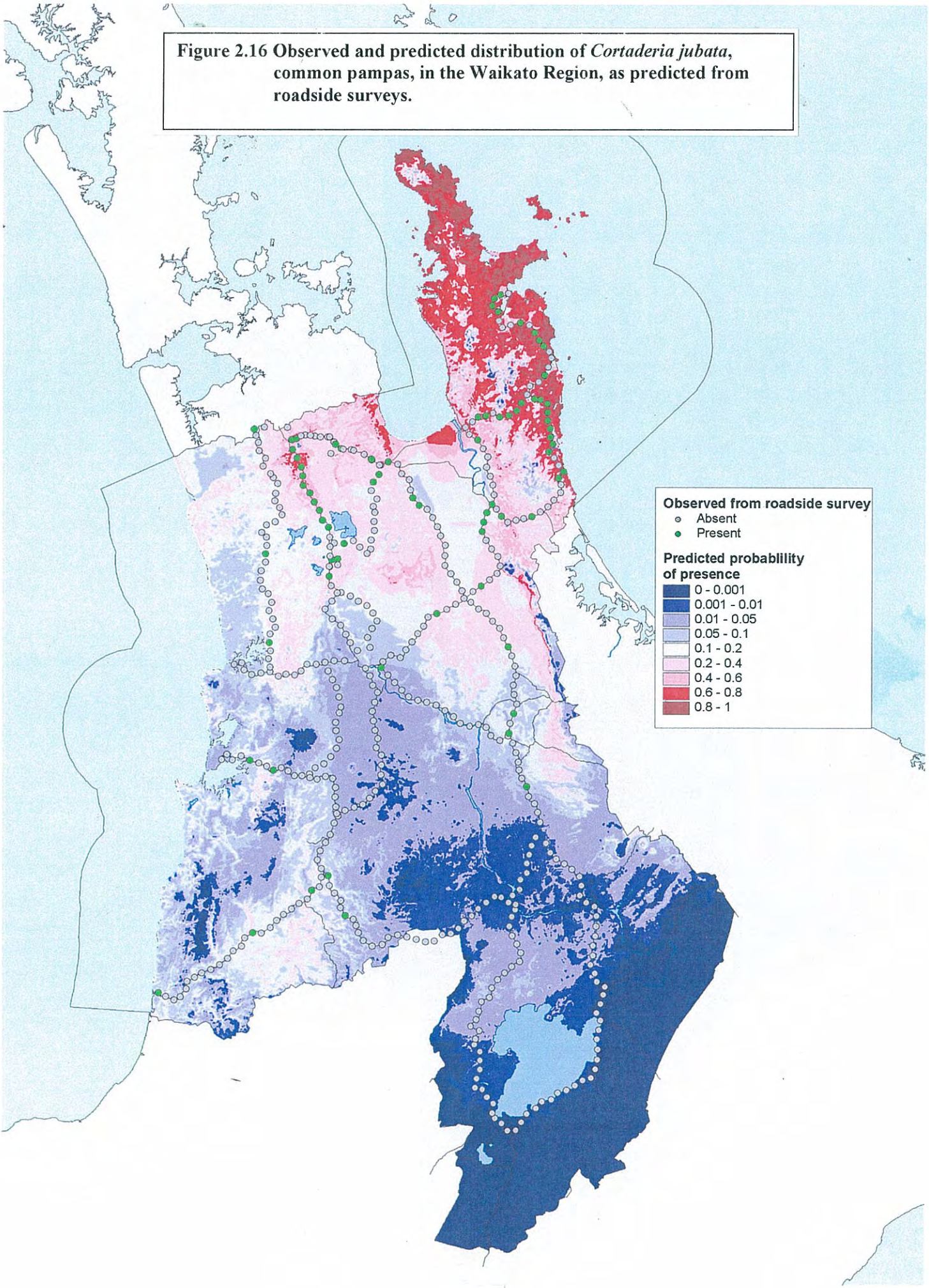


Figure 2.15 Observed and predicted distribution of *Cortaderia selloana*, common pampas, in the Waikato Region, as predicted from roadside surveys.

Figure 2.16 Observed and predicted distribution of *Cortaderia jubata*, common pampas, in the Waikato Region, as predicted from roadside surveys.



2.3.5 Management of Pampas on Roadsides

Pampas is an opportunistic weed and generally invades bare ground and disturbed sites. Because of the size of the plants, herbicide control can become fairly expensive. Up to 10 litres of spray per plant at 1% concentration of glyphosate is needed to get a satisfactory kill. Follow-up work is also required.

Where the current distribution or potential distribution of pampas is high, establishment of an appropriate ground cover may reduce the chance of pampas infestation. This may prove a cost-effective approach to control in the areas denoted by pink or red colouring in Figures 2.15 and 2.16. Where high density infestations are unlikely (indicated by the blue-coloured areas in Figures 2.15, 2.16), control of individual plants with herbicide may be both practical and potentially successful.

Pampas flowers from January through to May and is capable of setting seed at any time within this period. To avoid copious amounts of seed spreading along the road corridor, it would be most effective to spray in spring when the foliage is more susceptible to herbicide and when flowering has not begun. Plants will require a follow-up spray the following spring.

3. Descriptive Surveys

3.1 Methods

The native species-dominated vegetation of the Waikato Region state highway network, adjacent to or abutting the road reserve, was described using a combination of sources. The vegetation descriptions were based on descriptive surveying and on plot data from the random sampling, and were supplemented by existing information (e.g. DOC management strategies, scenic reserve management plans, and PNA (Protected Natural Areas) survey reports). The state highway network is divided into local segments, and descriptions relating to each are detailed below.

The methods used for the descriptive surveying of the Waikato Region SH network were developed and adapted in several ways from the methods used for the SH3 segment (Overton et al. 2000). The considerably greater extent of the regional highway compared with the SH3 segment meant surveying could not be done to the same intensity and level of detail.

All highways were driven over, and an inventory was made of the native-dominated plant communities in or abutting the road reserve. Vegetation descriptions were inevitably generalised for long stretches of highway, with limited time spent at each inspection. We also relied more heavily on existing sources of information, e.g. DOC Management Strategies. Surveying was done in the context of highway segments, rather than based on the environmental sectors used in Overton et al. (2000), a strategy which links closely with management perspectives.

3.2 Discussion

3.2.1 Significance of Vegetation

Assigning significance to each of the natural areas described throughout the Waikato Region has proved impractical because no published PNA survey reports are available for many Ecological Districts within the region. We can, however, make general statements based on our vegetation surveys and from existing data. In general, certain types of plant communities have been severely reduced by land clearance and development. These include alluvial forests, lowland forest on gentle contours, primary coastal forest, and wetland vegetation. It is likely that all intact vegetation of this kind in or abutting the road reserve will be of high significance relative to other kinds of vegetation associated with the road reserve. However, the significance of roadside vegetation must be questioned on grounds of how sustainable it is in the long term.

Examples of Significant Vegetation Types in Road Reserve
Alluvial forest
e.g. SH3 Awakino Gorge, SH22 Kahuhuru Stream valley

Lowland forest on gentle contours
Primary coastal broadleaved forest
e.g. SH25 Te Kouma Hill, remnants between Wilson and Kirita Bays, Buffalo Beach SR[1] north of Whitianga, SH31 Puti SR, Kawhia Harbour

Mangrove forest
e.g. SH25 on the margins of the Piako, Waihou, and Kauaeranga Rivers

Wetland habitats/communities
e.g. SH1 margins of Lake Taupo and where highway abuts the extensive Tongariro River Delta, SH3 Lake Serpentine, SH5 Lake Ngahewa, SH25 Waingaro Wetland, Te Rerenga

3.2.2 Changes in Suites of Roadside Plants

The Waikato Region contains a wide range of environmental conditions and habitats. Moving inland from the coast, from north to south, and from lowland to upland areas, the suite of native and/or adventive species present in the road reserve changes accordingly. Some native roadside species are present throughout most or all of the region, for example, kiokio, bracken, manuka, kanuka, mingimingi, karamu, and cabbage tree. Others have a more limited distribution and are present in only one or a few sites, or in certain parts of the region, for example, red tussock (southern uplands), tuhara (northern lowlands), kumarahou and *Pomaderris rugosa* (eastern Coromandel), haekaro (western Coromandel), and pohutukawa (coastal).

A number of exotic species are also widely distributed in the region, for example blackberry, gorse, and many common pasture grasses and herbs (e.g. hawkbit, oxeye daisy, catsear, dandelion, and lotus major) are also widely distributed in the region. Others are confined to certain areas. For example, the roadsides of the Coromandel are home to many of the invasive exotic species of warm northern New Zealand, e.g. kahili ginger, smilax, Mexican devilweed, brush wattle, and Dally pine; in the cooler southern parts of the region, weeds such as broom, buddleia, Spanish heath, heather, and mouse-ear hawkweed are prevalent.

The proximity of the road reserve to settlements and gardens appears to strongly influence the number and abundance of exotic species present, particularly those weeds that began their lives as cultivated plants, e.g. agapanthus, elaeagnus, nasturtium, and bougainvillea.

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[1] CP Conservation Park
NP National Park
SA Stewardship Area
SL Stewardship Land
WA Wilderness Area
EA Ecological Area
RR Recreation Reserve
SFP State Forest Park
SR Scenic Reserve
WMR Wildlife Management Reserve

3.2.3 Negative Impacts of Road Maintenance

Many road management and maintenance practices (e.g. widening and re-alignment, offsite dumping of material, close flail mowing, and herbiciding) have negative impacts on the natural values of the road reserve and the abutting land (Overton et al. 2000). While carrying out the sampling and surveying for this project, we observed many of the negative impacts of these practices. For example, on Whangapoua Hill and south of Kuaotunu, SH25 passes through extensive areas of native vegetation, mainly secondary and advanced secondary forest communities. Yet where realignment and widening has been carried out, the resulting bank cuttings are steep, largely smooth, and have been hydroseeded with fertiliser and exotic grasses. Little or no effort appears to have been made to integrate them biologically or aesthetically into the surrounding environment. The resulting grass cover is incomplete or sparse over most of the cuttings, with the bare substrate now available for colonisation by weed species, e.g. pampas.

Suggestions for lessening or mitigating negative impacts (see also Overton et al. 2000 for more extensive discussions) are as follows:

- direct transfer of stripped material either offsite to restore modified areas nearby or back onto the modified site;
- coppicing of trees along "new edges" before widening or realignment to provide a buffer for the vegetation behind;
- revegetation of the site with suitable eco-sourced native species;
- flail mowing further from the bank edge, to merely hedge rather than kill native plants;
- hydroseedings of new cuttings and banks, or slip faces with native species.

3.3 Notable Roadside Vegetation listed by SH Segments

3.3.1 SH1: Pokeno – Huntly

- Riparian and wetland vegetation, highly modified by crack willow and common alder invasion, occurs beside the Waikato River.
- Secondary scrub and forest dominated by bracken and mahoe, and heavily invaded in places by pampas, occurs on road cuttings and banks.

3.3.2 SH1: Huntly – Hamilton

- Riparian vegetation between SH1 and the Waikato River, highly modified.

3.3.3 SH1: Hamilton – Cambridge

- No natural areas – road reserve is narrow and bounded by pasture and litter.

3.3.4 SH1: Cambridge – Tokoroa

- Road cuttings near Lake Karapiro support a variety of native herbaceous species.
- Secondary kanuka forest occurs beside Lake Karapiro.

- Hillslope above Lake Karapiro supports secondary scrub and advanced secondary forest dominated by mahoe, wineberry, and tree ferns, with enclosed fragments of primary tawa forest (Horohoro Gorge SR).

3.3.5 SH1: Tokoroa – Taupo

- Road cuttings on Maungaiti Hill support secondary shrubland (e.g. bracken, snowberry, kiokio, manuka).
- Road cuttings and banks around Maroa support secondary scrub dominated by karamu and tutu, and secondary kanuka forest that merges into advanced secondary rewarewa-kamahi forest.
- Monoao-mingimingi frost flat abuts SH at Maroa; margins invaded by broom.
- Road margins around Oruanui support secondary scrub and young forest dominated by fivefinger, wineberry, tree fuchsia, kohuhu, and kamahi.
- Steep-sided stream gullies (dongas) north of Taupo contain bracken fernland, broadleaved forest, and occasional geothermal features.

3.3.6 SH1: Taupo – Turangi

- Raupo swamp occurs in places beside the highway between Five Mile Bay and the Waitahanui River.
- Kowhai treeland occurs on the lakeside of the same stretch of highway.
- Roadside banks and cuttings on the southern side of Hatepe (Hinemaiaia) Hill support secondary manuka scrub invaded by broom, and secondary forest dominated by kanuka, kohuhu, and fivefinger.
- Between Hatepe Hill and Waitetoke, including Hatepe Recreation Reserve (RR), Motutere SR, and Waitetoke SR, are extensive stretches of secondary fernland, scrub, treeland and forest, dominated variously by mixtures of bracken, fivefinger, kanuka, kohuhu, and kowhai on both sides of the highway. Pines have invaded in places.
- Similar secondary communities occur between Tauranga–Taupo and Motuoapa (Oruatua RR and Motuoapa SR) with local groves of young podocarps. Stands of black locust occur in places.
- Between Motuoapa and the Tongariro River, the extensive wetlands of the Tongariro Delta (e.g. raupo swamp, *Baumea* sedgeland, *Carex* sedgeland, the margins of which are heavily invaded by grey willow, blackberry, and gorse) abut the highway (including Waitaka SR). Wetland species present in drains and ditches within the road reserve include *Carex geminata*, purei, *Eleocharis acuta*, *Baumea rubiginosa*, and raupo.
- Wetlands: around the edges of Lake Taupo, e.g. harakeke-cabbage tree-*toetoe* swamps, many of which are invaded by grey willow. Wetland species present in drains and ditches within the road reserve include *Carex geminata*, purei, *Eleocharis acuta*, *Baumea rubiginosa*, and raupo.

3.3.7 SH1: Turangi – Desert Road summit

- Extensive tracts of secondary vegetation (manuka scrub–kanuka forest and fivefinger–kohuhu forest, invaded in places by pines, broom, and buddleia) occur between Turangi and Poutu Canal (including Tongariro River No. 2 SR, Waikari SR, Paurini SR and Tongariro SR).
- Extensive tracts of secondary manuka scrub–kanuka forest between the Mangahouhouiti Stream and Waihohonu River (Tongariro NP).
- Riparian mountain beech forest occurs where the highway crosses the Mangamate, Mangatawai and Makahikatoa Streams.
- Riparian silver beech-red beech forest occurs where the highway crosses the Waihohonu River.
- Extensive tracts of monoao-red tussock shrub-tussock grassland occurs between the Oturere Stream and the summit, recently burnt in at least two locations.
- Tangle fern-wire rush fernland between Te Piripiri and Wharepu Streams (Tongariro NP and Kaimanawa SFP).

3.3.8 SH2: Pokeno – Paeroa

Few natural areas remain along SH2 between Pokeno and Paeroa, with the road reserve predominantly narrow and most of the adjacent land pastoral.

- Between Pokeno and Mangatawhiri are small patches of kanuka, cabbage tree, titoki, and wheki in the road reserve, with occasional bracken in open areas and some tree privet and pampas. Also several small swampy sites support harakeke, and cabbage tree.
- East of Bell Road, along with the species listed above, totara is also present, and a small advanced secondary kahikatea treeland with harakeke.
- The road reserve abuts a swathe of restoration planting across the Waitakaruru River from the Waitakaruru SR; species planted include harakeke, tarata (lemonwood), mapou, manuka, koromiko, akeake, and rangiora (Children's Millennium Forest, Hauraki District Council).

3.3.9 SH2: Paeroa – Waihi

- Secondary totara/kanuka forest, heavily invaded by gorse and privet in places, occurs on both sides of the highway past Mackaytown. Other prominent species are mahoe and mamaku.
- Secondary broadleaved scrub–forest scrub dominated by mahoe, kawakawa and mamaku, heavily invaded by Japanese honeysuckle, occurs on hillslopes above the highway beyond Doherty's Stream.
- Secondary mahoe-dominant forest with prominent mamaku and invasion by Japanese honeysuckle and small-leaved privet abuts the highway in places in the Karangahake Gorge (Karangahake SR). It merges into primary tawa-titoki forest behind.

- Steeper slopes above the gorge support secondary manuka scrub in some places, towai forest in others, and secondary totara/kanuka-towai forest with some black wattle invasion in others.
- Towards Waikino, secondary broadleaved scrub→forest, which abuts the highway, is dominated variously by mahoe, kohuhu, towai, and mamaku, and with pine and brush wattle invasion. Groves of young totara and tanekaha occur in places within it.

3.3.10 SH2: Waihi – Waimata

- No natural areas.

3.3.11 SH3: Hamilton – Te Kuiti

Few substantial areas of predominantly natural vegetation remain within or immediately adjacent to the road reserve in this section of SH3.

- Restoration plantings around the wetland margin of Lake Serpentine, a shallow eutrophic lake with important wildlife values, abut the highway.
- Secondary short broadleaved forest dominated by kamahi, mangeao, mahoe, and mamaku occupies a sandstone slope just south of Te Kuiti.
- Secondary kahikatea stands are a feature of alluvium in the Te Kuiti Ecological District; two such stands abut the road reserve just north of the town and contain other conifers (e.g. rimu, totara) and broadleaved species such as pukatea, tawa, titoki, pokaka, tarata, swamp maire, mahoe, mapou, and kohuhu.

3.3.12 SH3: Te Kuiti – Awakino

- Tall treeland of titoki with some kahikatea occupies alluvium south of Mahoenui.
- Upstream of the Mangaparo Stream bridge is a raupo swamp with harakeke.
- Cuttings in rhyolitic tephra support shrubland of karamu, koromiko, manuka, and ferns; totorowhiti is locally present.
- Young secondary vegetation is bracken fernland; older vegetation on hillslopes comprises short broadleaved forest of lacebark, tree fuchsia, and wineberry.
- A small stand of secondary conifer forest (matai with some totara and kahikatea) occurs on footslopes near the Pangaki Stream (Paemako SR).
- Primary forest on hillslopes comprises scattered rimu and rewarewa emergent over tawa and kamahi.
- Road cuttings on mudstone support shrubland dominated by manuka, tutu, and koromiko. Young secondary vegetation is dominated by manuka, older vegetation by broadleaved scrub-short forest containing a wide range of species: kamahi, mahoe, tree fuchsia, lacebark, pate, rangiora, and karamu are common.
- Dense stands of young totara occur on mudstone just south of Totoro Road, and tall conifer/broadleaved treeland of kahikatea over lacebark, pate and putaputaweta on lower slopes nearby.

A small remnant of primary tall conifer/broadleaved forest of scattered kahikatea, rewarewa, and pukatea over tawa occurs here.

- Secondary manuka scrub on sandstone contains a range of other species, including mingimingi and *Pittosporum colensoi*. Ridges near the entrance to the Awakino Gorge carry tall hard beech forest.
- Argillite in the lower reaches of the Mangaotaki River supports secondary scrub on cuttings of tutu, koromiko, kanuka, manuka, and *Pittosporum colensoi*. Short forest on hillslopes comprises mixtures of kanuka, mahoe, lacebark, and manuka. Primary tall conifer forest in places on midslopes comprises kahikatea, rimu, totara, and matai over mahoe; and on footslopes occurs tall conifer/broadleaved forest of scattered kahikatea, totara, pukatea, and rewarewa over tawa and titoki with a mahoe subcanopy.
- Limestone faces above the Waitomo Stream support a variety of trees (e.g. mahoe, tree fuchsia), grasses (e.g. *Poa anceps*), and ferns (e.g. common shieldfern, *Pneumatopteris pennigera*). Secondary broadleaved scrub-short forest on hillslopes comprises manuka and lacebark with a range of other species. Older secondary forest is dominated by lacebark, mahoe, titoki, putaputaweta, and pate. Primary forest on hillslopes in Mangaotaki SR comprises scattered kahikatea, pukatea, and rewarewa emergent over tawa, titoki, and hinau. Matai occurs as an emergent on lower slopes.
- Remnants of primary tall broadleaved treeland-forest, degraded by logging and grazing are a feature of alluvium in the Awakino Gorge. Pukatea emerges over canopies dominated by younger pukatea, lacebark, and titoki. Kahikatea is present in places.
- Cuttings on mudstone support shrubland of manuka, karamu, totorowhiti, mingimingi, and koromiko. Secondary short broadleaved forest on lower slopes includes mahoe, pate, and kawakawa. Older secondary forest is dominated by kamahi with *Pittosporum colensoi*, mahoe and wheki.
- Sandstone is common in the lower Awakino Gorge. The original forest pattern consists of primary tall conifer/broadleaved forest dominated by tawa and kamahi on hillslopes with enclaves of hard beech forest on ridges. Rimu, rewarewa, and epiphytic puka occur as scattered emergents on upper and mid slopes; pukatea is a common emergent on lower slopes and in gullies (Arorangi SR). Miro, hinau, mangeao, mamaku, and gully tree fern are widespread canopy associates of tawa and kamahi on middle and lower slopes; puriri and karaka are also common within 8 km of the coast, but kohekohe extends a little further inland. Titoki is common on footslopes.
- Younger cuttings and slip faces are largely bare, with scattered manuka, koromiko, buddleia, and *Poa anceps*. Older ones support manuka-toetoe shrubland with some whaririki and koromiko. Bluffs carry whaririki, kohuhu, *Olearia townsonii*, manuka, mapou, and puka.
- Young secondary scrub on sandstone is dominated by manuka. Other widespread species are mamaku, mahoe, heketara, mingimingi, mapou, and karamu. *Olearia townsonii* is locally present. Older secondary short broadleaved forest on hillslopes comprises scattered rewarewa emergent over kamahi.

- A burnt sandstone ridge just inland of Awakino supports young secondary manuka scrub and older secondary short conifer forest, of scattered rewarewa emergent over dense tanekaha with some rimu. Older secondary hillslope forest here comprises kamahi and mangeao, with scattered tawa and other species.
- A small area of greywacke is intersected by the highway. Broadleaved scrub-short forest containing a range of species (kamahi, mangeao, titoki, mahoe, pigeonwood, fivefinger) occupies mid and lower slopes, and mamaku tree fernland gullies. Older secondary forest is dominated by mangeao and kamahi. Bluffs above the highway support tutu-mahoe-rangiora scrub.
- Limestone bluffs about the Awakino road tunnel support shrubland of whaririki, mingimingi, cotoneaster, and tree fuchsia in some places, with herbs (e.g. tuhara, *Poa anceps*), and ferns (e.g. common maidenhair, kiokio) elsewhere.

3.3.13 SH4: 8 Mile Junction – Tangatu

- Small gully covered with logged tawa forest and manuka/bracken scrub (Aratoro SR).
- Both sides of a main ridge, steep, covered with primary rimu/tawa forest, and *Ascarina lucida* present (Kurukuru SR).

3.3.14 SH5: Tirau – Mamaku Plateau

- Selwyn SR contains primary northern rata/tawa-rewarewa-mangeao-kamahi forest.
- Secondary rewarewa/kamahi forest occurs between Fitzgerald Glade and head of Waiohotu Stream.
- Secondary kanuka forest occurs between Fitzgerald Glade and head of Waiohotu Stream.
- Secondary fivefinger/kanuka forest occurs between Fitzgerald Glade and head of Waiohotu Stream.
- Logged northern rata/tawa-rewarewa-mangeao-kamahi forest occurs in Kuhatahi Valley.
- Primary rimu/miro-tawa-kamahi-tawari forest occurs in Waiohotu Valley.
- Primary rimu/tawa-kamahi-hard beech forest occurs in Kuhatahi Valley.
- Primary rimu-northern rata/tawa-kamahi forest occurs on plateau top.
- Logged northern rata/tawa-kamahi forest occurs on plateau top.

3.3.15 SH5: Waipa – Wairakei

- Lake Ngahewa RR, a harakeke-raupo-sphagnum wetland with sedges and manuka scrub, abuts the road near the intersection with SH38 (SSWI (Site of Special Wildlife Interest) ranking of moderate-high; Rasch 1989).
- Mosaic of manuka-kanuka shrubland and fivefinger-kohuhu forest (where Rainbow Mountain SR abuts the road).

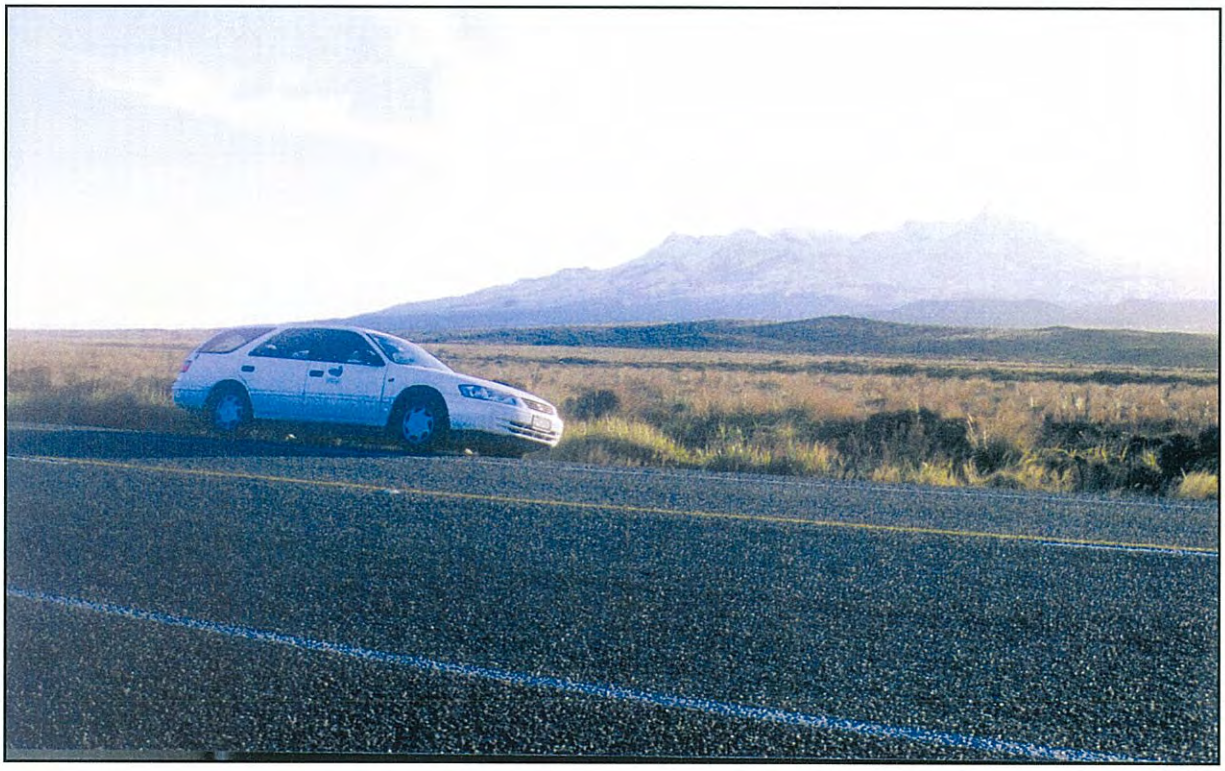

Figure 3.1 Looking west from SH1N, over red tussock grassland to Mt Ruapehu, Desert Road.
(Photo: Neil Fitzgerald)

Figure 3.2 Degraded alluvial pukatea-dominant forest in the Awakino Gorge, west of Te Kuiti, along SH3.

Figure 3.3 Kahikatea-totara forest on alluvial terraces in the Kahuhuru Stream valley, Mamaku Plateau, west of Rotorua. Restoration plantings of harakeke and cabbage tree along SH5 are in he foreground.

Figure 3.4 View north through a corridor of pohutukawa forest in Puru Scenic Reserve, between Tapu and Coromandel on SH25, west of Coromandel Peninsula.

Figure 3.5 **One of the large areas of mixed primary and secondary coastal forest north of Wilson Bay, Coromandel Peninsula, on SH25. Kauri and kanuka dominate the upper slopes and ridges, with mixed broadleaved species (kohekohe, karaka, taraire, puriri and nikau) on the mid-slopes and in the gullies.**

Figure 3.6 **The native orchid *Orthoceras novae-zeelandiae* on a roadside bank just north of Coromandel, Coromandel Peninsula, on SH25.** (Photo: Neil Fitzgerald)

Figure 3.7 Secondary vegetation between Kuaotunu and Whitianga, on SH25, Coromandel Peninsula.

Figure 3.8 Native vegetation on the roadside banks and abutting slopes around the Ngutunui Stream, west of Otorohanga on SH31.

- Manuka shrubland (where the Waiotapu SR abuts the road).
- A degraded monoao frost flat heavily invaded by broom abuts the highway west of Ohaaki.
- Roadside bank near Aratiatia supports secondary vegetation.

3.3.16 SH5: Taupo – Iwitahi

- Geothermal vegetation: roadside ditches, near intersection of SH5 and Mountain Road, support small areas of prostrate kanuka shrubland and mossfield on geothermally heated soils (Burns et al. 1995).
- Between SH1 and de Brett's Hotel, fragments of fivefinger-kanuka forest occur, degraded by wattle, buddleia, and blackberry invasion.
- In the vicinity of Mt Tauhara, bracken fernland heavily invaded by broom and blackberry occurs in and abutting the road reserve, interspersed with secondary fivefinger-kohuhu forest, bordered by tutu-koromiko scrub with heavy local pine infestation.
- At Opepe SR, secondary fivefinger-koromiko scrub invaded by broom and secondary fivefinger-tree fuchsia-kamahi forest occurs in and beside the road reserve, interspersed with pockets of primary rimu-miro/kamahi. On the eastern side of the reserve, secondary fivefinger-kanuka forest with heavy infestations of broom and blackberry occurs in and beside the road reserve.

3.3.17 SH22: Tuakau Bridge – Te Uku

- Riparian vegetation on either side of the Waikato River at Tuakau Bridge is dominated by willows and alder (particularly on the lower banks), with titoki, mahoe, kanuka, wheki, kawakawa, and the vine *Muehlenbeckia australis*.
- Small primary and advanced secondary forest remnants (kanuka-puriri-(tawa)/titoki-mahoe forest and kanuka-(puriri)/titoki-kahikatea forest) on hillslopes beside the road just south of the Tuakau Bridge.
- Degraded kahikatea-dominated forest and treeland remnants on alluvial stream terraces and lower slopes; titoki, pukatea, kanuka, totara, cabbage tree, and puka are variously present, with some invasion by willow.
- Some kahikatea remnants grade into totara treeland and forest on the ridges/road edge (e.g. Opuatia and south-facing slopes south of Waikaretu Valley Road (with rewarewa, tanekaha, lancewood, mapou, kohuhu and kanuka also present).
- Swampy ditches support *Carex geminata* sedgeland or raupo reedland.
- Totara-dominated low forest with some tawa, kahikatea, mamaku, rangiora, mapou, and *Cordyline banksii* occurs south of Naike on both sides of the highway.
- Kahuhuru Stream valley contains extensive stands of dense kahikatea and totara which abut the highway in places.
- South of Waingaro Landing Road, extensive areas of predominantly secondary vegetation (a mosaic of kanuka-dominated forest with pockets of more diverse broadleaved forest and younger scrub with gorse) abut the highway.

- North of Te Uku Landing, the highway passes through the swampy upper reaches of Raglan Harbour, abutting estuarine and freshwater communities dominated by saltmarsh ribbonwood, manuka, and raupo.
- Bracken is common along the fenceline where road reserve is narrow and surrounding land use pastoral.
- Species common on roadside banks and cuttings include kanuka, totara, mapou, titoki, cabbage tree, karamu, mingimingi, mahoe, manuka, rangiora, koromiko, kiokio, and bracken. South of Glen Murray, the countryside is more hilly, with wider cuttings and banks and larger areas of native shrubland and low forest and bracken fernland.

3.3.18 SH23: Hamilton – Raglan

- Primary, logged, rewarewa-(rimu)/tawa-kohekohe forest (Four Brothers SR), and younger kanuka forest abuts the road, with manuka, mingimingi, wheki, and bracken dominating on the cuttings.
- Wide cutting past Four Brothers SR, with rewarewa/broadleaved-treefern forest, with tawa, titoki, hinau, kahikatea, nikau, and mamaku.
- At the Waitetuna Road intersection, small fenced kahikatea-dominated remnants abut the highway.
- East of SH23-Kauroa-Kawhia Road intersection, a remnant of kahikatea-(rimu)-(rewarewa) /broadleaved forest abuts the highway.
- At the upper Okete Stream, a small patch of kahikatea-dominated treeland is on the southern side of the highway.
- *Carex geminata* is present in damp roadside ditches.
- On road cuttings and banks within and abutting the road reserve: secondary scrub with kanuka, manuka, totara, rewarewa, mahoe, mapou, wheki, cabbage tree, kawakawa, karamu, koromiko, hangehange, mingimingi, bracken, hard fern, kiokio, turutu, *Thelymitra* spp.

3.3.19 SH25: Intersection of SH2 & SH25 – Thames

- West of Back Miranda Road, the road reserve is narrow, with banks supporting bracken fernland and mixed shrublands of manuka, karamu, cabbage tree, mapou, silver fern, and mingimingi.
- East of Back Miranda Road, the narrow road reserves support bracken fernland, with raupo reedland in the deeper ditches.
- On either side of the bridges across the Piako, Waihou, and Kauaeranga Rivers, strips of mangrove forest abut the highway (some are probably in the road reserve). Some merge into raupo reedland.
- Weedy roadside banks between Kopu and Thames support mixed shrub and forest communities with kanuka, tree privet, smilax, and native broadleaved shrubs.

3.3.20 SH25: Thames – Tapu

- North of Thames, the Tararu SA (Stewardship Area) extends to the road. It contains a mixture of young and occasional large pohutukawa, kanuka, native broadleaved trees and shrubs (e.g. mahoe, mapou, cabbage tree, and fivefinger), and exotic trees such as pine, tree privet, woolly nightshade, and wattle.
- Between Tararu and Waikatete Bay, the west-facing steep banks above the highway have tall planted pines, with occasional pohutukawa, and mixed native and exotic broadleaved trees and shrubs beneath (e.g. mapou, mahoe, silverfern, kawakawa). A number of weed species are present, including brush wattle, tree privet, smilax, pampas, elaeagnus, German ivy, kahili ginger, agapanthus, and moth plant. Only scattered pohutukawa are present on the seaward side of the highway.
- From Waikatete Bay to Ngarimu Bay, the steep west-facing banks are more diverse with large pohutukawa over mixed native shrubland communities. Again only scattered pohutukawa are present on the seaward side of the highway.
- North of Ngarimu Bay, large pohutukawa are more frequent on the seaward side of the highway, often forming a scenic corridor. The vegetation on the west-facing banks is a mix of secondary and advanced secondary coastal scrub forest with primary elements (large pohutukawa and kohekohe), and pohutukawa/mahoe-kawakawa forest (Thornton Bay and Puru SR), the roadside margins of which are invaded in places by a number of weeds including woolly nightshade, nasturtium, smilax, bougainvillea, pines and tree privet.
- Between Te Puru and Tapu are long stretches of the highway where pohutukawa forest forms a scenic corridor. The pohutukawa on the seaward side has amongst it houpara, kawakawa, taupata, haekaro, rangiora, and *Astelia banksii*. On the eastern side of the highway, the pohutukawa with bracken, *Gahnia* spp., hangehange, tutu, manuka, houpara, haekaro, *Hebe* spp., manuka, and turutu beneath them, grow on steep banks and cuttings. This pohutukawa-dominated vegetation merges into manuka scrub and kanuka-dominated forest in places (Tapu-Ruamahanga SR). Pines, cotoneaster, German ivy, and smilax have invaded in parts.

3.3.21 SH25: Tapu – Coromandel

- North of Te Mata, roadside banks and cliffs on the eastern side of the highway support pohutukawa- and kanuka-dominated forests with hangehange, *Coprosma lucida*, karamu, kawakawa, rangiora, houpara, silverfern, wheki, haekaro, taupata, *Hebe* spp., bracken, turutu, arching clubmoss, *Poa anceps*, and *Thelymitra* spp. (some is included in Te Mata SR). The vegetation merges upslope or at the top of the banks or cliffs in places to secondary and advanced secondary scrub-forest communities.
- In places large pohutukawa are present on both sides of the highway forming a scenic corridor. Houpara, haekaro, taupata, and *Astelia banksii* are often present beneath the pohutukawa fringe on the seaward side of the highway.
- Harakeke flaxland is present in small damp gullies.

- Between Waikawau and Kereta the pohutukawa-dominated vegetation on the banks is more degraded, with large areas of Mexican devilweed, pampas, and smilax.
- Narrow strips of mangrove forest abut the highway on either side of the Waikowau River bridge.
- Wairotoroto shingle beach (south of Kereta) contains an area of brackish water in a hollow of shingle beach supporting a small population of the native saltmarsh plant *Suaeda novae-zelandiae*. This is the best area representative of shingle vegetation in the Thames Ecological District (Humphreys & Tyler 1990).
- North of Kereta, the pohutukawa-dominated cliff/bank communities are again more diverse (as above).
- Inland from Wilson Bay, roadside banks and cuttings support manuka- and kanuka-dominated scrub with young pohutukawa, totara, bracken, mapou, mingimingi, karamu, and *Hebe* spp.
- Between Wilson Bay and Kirita Bay, the highway abuts or bisects several large remnants of coastal northern rata/taraire-broadleaved forest. Other species present include kauri, totara, rewarewa, tawa, puriri, hinau, karaka, nikau, and kohekohe.
- North of Ohoni Stream, the highway abuts extensive areas of estuarine communities in Manaia Harbour, e.g. mangrove forest, oioi rushland, manuka-oioi shrubland, manuka-*Baumea* shrubland, and raupo reedland (Humphreys & Tyler 1990).
- Between Ahimia and north of Te Kouma are extensive areas of secondary manuka-dominated scrub, and advanced secondary kanuka- and broadleaved-dominated forest (with fivefinger, mahoe, rangiora, kohekohe, and kowhai). Older vegetation includes tanekaha, kauri, and rewarewa. Remnants of primary coastal taraire-puriri/kohekohe forest abut the highway on the Te Kouma Hill.

3.3.22 SH25: Coromandel – Kuaotunu

- East of Coromandel on Whangapoua Hill, the vegetation within and abutting the road reserve comprises secondary scrub (with manuka, *Gahnia* spp., bracken, mingimingi, and tangle fern) and advanced secondary kanuka and broadleaved communities (with mamaku, karamu, mahoe, rewarewa, hangehange, kohuhu, silverfern, and nikau), with pockets of primary forest (and occasional northern rata, rimu, tanekaha, taraire, tawa, hinau, kohekohe, and pukatea) (Kauri Block, Taumatawahine SR, and Whangapoua SA). Major realignment work has recently been carried out on this stretch of the highway (some still ongoing), creating new steep hydroseeded cuttings.
- Roadside banks through pine plantations in Whangapoua Forest support manuka-broadleaved scrub and kanuka forest, some of which are invaded by gorse, pampas, and woolly nightshade.
- At Te Rerenga, on an alluvial flat around the lower Waingaro River, the vegetation abutting the highway is a mosaic of manuka-*Baumea* rush-shrubland and raupo-harakeke reedland with some willow invasion.

- An arm of the Whangapoua Harbour containing mangrove, oioi, and raupo communities, abuts the highway east of Te Rerenga.

3.3.23 SH25: Kuaotunu – Whitianga

- The highway abuts Kuaotunu Beach (a narrow beach and dunes, some with spinifex), and rocky outcrops with planted and natural pohutukawa.
- Immediately south of Kuaotunu, the road reserve is quite narrow and bounded by pasture, but occasional banks support manuka, arching clubmoss, *Thelymitra* spp., bracken, hard fern, kanuka, karamu, mingimingi, and *Hebe* spp.
- Further south, as the terrain becomes hillier, the road reserve becomes wider, and there are extensive areas of primary/advanced secondary/secondary vegetation abutting and within it, e.g. low scrub with manuka, bracken, *Gahnia* spp., tutu, *Hebe* spp., turutu, mingimingi, *Olearia furfuracea*, and *Cordyline pumilio*, older rewarewa/kanuka forest with broadleaved shrubs amongst it (mahoe, houpara, rangiora, *Pittosporum* spp., and occasional kauri, tanekaha, pohutukawa, puriri, and nikau (Otama and Kuaotunu Block – part Coromandel CP (Conservation Park). Willow-leaved hakea and pines have invaded in places.
- North of Wharekakaho, the surrounding landscape becomes more pastoral and the highway reserve narrower, with banks supporting a similar suite of shrub and tree species as above.
- Primary forest remnant of pohutukawa/kohekohe-karaka-puriri forest with nikau and titoki on a south-east facing slope above a small stream just north of Whitianga (Buffalo Beach SR).

3.3.24 SH25: Whitianga – Hikuai

- At Mill Creek, the highway abuts an arm of the Whitianga Harbour with extensive areas of estuarine vegetation: mangrove, manuka/oioi, sea rush and oioi communities, with saltmarsh ribbonwood and harakeke also present.
- A tract of secondary manuka and mixed broadleaved scrub-forest abuts the highway just north of Mill Creek.
- A flax swamp invaded by pampas abuts the road reserve just south of the Ounuora River bridge.
- North of Coroglen, and the Waiwawa River, the highway passes a tract of secondary towai scrub-forest with pine and black wattle invasion.
- Totara is a feature of the road reserve north of the Whenuakite Stream, with kanuka, and occasional rimu and kahikatea also present.
- South of Whenuakite, on Pourewa Hill, extensive areas of secondary and advanced secondary vegetation abut the highway (Whenuakite Block (part Coromandel CP), Punaruku SR, Twin Kauri SR). They include scrub dominated by kanuka, manuka, kumerahou, and *Gahnia* spp., with rewarewa mingimingi, towai, bracken, wheki, mapou, rangiora, fivefinger, karamu, mamaku, occasional kauri and tanekaha, and the weeds gorse, needlebush and brush wattle. At the

entrance to Lynch Stream Track, advanced secondary kauri-tanekaha forest abuts the highway.

- A river terrace between the highway and the Tairua River carries a large stand of mixed native and adventive treeland-forest with cabbage tree, kanuka, mahoe, and mamaku, as well as black wattle, small-leaved privet, and willows. Pockets of flax swamp, manuka/oioi marsh, and *Carex geminata* occur in places.
- Cabbage tree-manuka/flax swamp occurs at Woody Stream.
- Hillslopes above the highway opposite Tairua Harbour support secondary scrub with *Olearia albida*, *Pomaderris rugosa*, kumarahou and older rewarewa/kanuka forest.
- Poorly drained river flats beside Swamp Stream support young manuka-kumarahou scrub invaded by gorse and black wattle on drier sites, and manuka/oioi marsh on wetter ones.
- Extensive saltmarsh and brackish freshwater wetlands of mangroves, manuka/tangle fern, manuka/oioi, and oioi occur where the road reserve abuts Tairua Harbour.
- Road fringes around the harbour support rewarewa/kanuka forest variously degraded by black and brush wattle incursion. Fragments of primary coastal forest with pohutukawa and puriri occur within it on the harbour side.

3.3.25 SH25: Hikuai – Kopu

- Roadside banks in the lower Kirikiri Valley support young secondary manuka and kanuka scrub-forest with many typical associated species (rewarewa, fivefinger, kohuhu, mamaku, silver fern, tutu, mapou, mahoe), invaded in places by small-leaved privet, pines, gorse, pampas, and Japanese honeysuckle. Similar roadside forest on the valley floor contains some kowhai and conifers (totara, tanekaha) as well.
- Road bisects the Coromandel CP, passing through logged primary forest. Road margins support a fringe of manuka and kanuka scrub-forest with rewarewa common on the eastern side and widespread invasion by gorse, Spanish heath, pampas and Himalayan fairy grass. Primary forest types (Nicholls 1976) are:
  - B3 = kauri-rimu-miro-Hall's totara-tanekaha-northern rata/tawa-hinau-rewarewa-kohekohe-puriri-towai forest below 300m asl;
  - B5 = kauri-rimu-miro-Hall's totara-northern rata/tawa-hinau-rewarewa-kohekohe-towai-tawari forest above 300m asl;
  - D2 = rimu-northern rata/tawa-hinau-rewarewa-puketea-mangeao-kohekohe forest below 300m asl;
  - D3 = rimu-northern rata/tawa-kohekohe forest above 300m asl.
- Roadside banks in the upper Fourth Branch (Tairua River) valley support secondary broadleaved scrub-forest dominated by mahoe, tree tutu, and mamaku. Young manuka scrub also occurs in places. Tuhara is common on exposed road cuttings.

- In the lower Fourth Branch valley, below Takatakahia Stream, secondary manuka and kanuka scrub-forest becomes dominant on road margins, again with associated rewarewa, kohuhu, and tree tutu, invaded locally by pines, brush wattle, gorse, Spanish heath, and pampas.
- At Fourth Branch bridge (Tairua River) is a stand of advanced secondary conifer forest with kauri, kahikatea, matai, and tanekaha (Fourth Branch SR).
- From Fourth Branch bridge to Stony Stream, road margins are dominated by young manuka scrub with much invasion by pines, gorse, Spanish heath, and Himalayan fairy grass (Fourth Branch SA and Kopu–Hikuai Road SA).
- From Stony Stream to Tramway Gully, there is young manuka scrub degraded by brush wattle and blackberry invasion (Fourth Branch SA).

3.3.26 SH25: Hikuai – Waihi

- The road reserve above Tramway Gully supports a variety of typical secondary native species (rewarewa, kanuka, towai, tree tutu, mahoe, fivefinger, akeake, mamaku) in communities heavily invaded by pines, brush wattle, and pampas.
- Between Tramway Gully and Boom Stream valley, the highway bisects a belt of secondary rewarewa/kanuka-towai forest.
- Road cuttings and banks through the Tairua Forest and south towards Whangamata have arching clubmoss in some places, tuhara in others. Patches of manuka-kumarahou scrub also occur here.
- Small patches of secondary rewarewa/kanuka-towai forest, invaded in places by brush wattle and pampas, cover roadside banks about Whangamata Harbour and above the Otahu River estuary.
- Mangrove, oioi, and saltmarsh ribbonwood/oioi communities occur in Whangamata Harbour where abutted by the road reserve.
- Fragments of primary coastal forest with pohutukawa occur between the highway and Whangamata Harbour.
- Saltmarsh ribbonwood-flax/oioi marsh occurs in the Moanaanuanu Estuary at the Wentworth River bridge.
- South of Waiharakeke, the highway bisects a tract of secondary rewarewa/kanuka-towai forest invaded by black wattle and willow-leaved hakea (Te Ramarama SR).
- Secondary rewarewa/kanuka forest with associated mahoe, fivefinger, and mamaku, with gorse and brush wattle invasion, fringes the highway in places about Whiritoa. Scattered pohutukawa trees occur within it.
- An extensive tract of secondary manuka and kanuka scrub covers the hill south of Whiritoa (some of which lies in the Te Ramarama SR and Te Ramarama SA).
- A secondary stand of tanekaha occurs within this tract on the northern edge.
- Fringes of secondary broadleaved scrub–forest containing fivefinger, mahoe, tree tutu and mamaku abut the highway further south towards Waihi (some of which lies in Maratoto East Block – part Coromandel CP).

- A patch of primary semi-coastal tawa-dominant forest abuts the highway on the northern side.

3.3.27 SH26: Hamilton – Morrinsville

- No natural areas.

3.3.28 SH26: Morrinsville – Te Aroha

- Surrounding landscape is entirely pastoral, with occasional remnants of kahikatea-dominated forest (e.g. near Waitoa), none of which are within or abut the road reserve.

3.3.29 SH26: Te Aroha – Paeroa

- No natural areas.

3.3.30 SH27: Mangatarata – Matamata

- Between Maungatarata and Kaihere, rewarewa/kanuka scrub-forest is common on road cuttings and banks; invaded locally by black wattle, Spanish heath, cotoneaster (khasia berry), pines, pampas, barberry, and privets. Kumarahou occurs in places.
- Secondary kanuka forest invaded by black wattle and woolly nightshade, and enclosing a fragment of primary tawa-dominant forest with puriri, pukatea, and rewarewa abuts the highway in Kaihere North SR.
- Kaihere SR: advanced secondary kanuka forest with prolific kahikatea regeneration.
- Alluvial terraces and banks of the Waitao River support dense secondary totara forest.

3.3.31 SH 27: Matamata – Tirau

- No natural areas.

3.3.32 SH29: Pairere – Tauranga (part)

- Logged northern rata/tawa-kohekohe-kamahi forest occurs at the head of the Rapurapu Stream.
- Logged northern rata/tawa-rewarewa-mangeao-kamahi forest occurs at the head of the Omahine Stream.
- Primary rimu-northern rata/tawa-rewarewa-mangeao-kamahi forest occurs at the head of the Omahine Stream.
- Primary miro/tawa-kamahi-tawari forest occurs at the summit of the range.

3.3.33 SH30: Atiamuri – Whakamaru

Vegetation adjacent to the road reserve is primarily plantation forest or pastoral.

- Roadside banks and cuttings support various mixtures of kiokio, karamu, kanuka, wheki, etc.

3.3.34 SH30: Whakamaru – Barryville

- Secondary tanekaha-totara/kanuka forest, invaded in places by blackberry, buddleia, and pines, abuts the road reserve at the Mangakino Stream.
- Fragments of secondary rewarewa-kamahi forest occur atop road cuttings below Pouakani SR.
- Roadside banks and cuttings support a variety of trees, shrubs and herbs, including kamahi, kanuka, rewarewa, fuchsia, hangehange, mingimingi, manuka, koromiko, snowberry, turutu, *Poa anceps*, and kiokio.
- Pouakani SR contains secondary rewarewa/kamahi forest in its lower reaches, podocarp/rewarewa/mixed broadleaved forest, and podocarp/tawa forest in its upper reaches.
- A corner of Pureora CP with coprosma (*Coprosma taylorii* and mingimingi) scrub heavily invaded by broom and blackberry abuts the highway just east of the Barryville Road intersection.

3.3.35 SH30: Tiroa – Te Kuiti (part)

- Riparian *Olearia virgata*-mingimingi scrub heavily invaded by blackberry occurs where the highway crosses a tributary of the Waimiha River.
- Herekawe SR contains logged primary tawa/hinau/rewarewa/mixed broadleaved forest.
- Secondary mixed scrub covers a south-facing cutting, east of the highway at Mangapehi.
- Secondary kamahi-dominant forest covers a steep face on the southern side of the highway just before Kopaki Junction.

3.3.36 SH31: Otorohanga – Kawhia

- West of Hikurangi Road, wide faces support a mosaic of manuka-broadleaved scrub and low forest (with mingimingi, mapou, mahoe, mamaku, mangeao), invaded by gorse and pampas.
- Broadleaved riparian vegetation, with mahoe, lacebark, wineberry, pukatea, silver fern, mamaku, and *Coprosma grandifolia*, abuts the highway where it runs parallel to the Ngutunui Stream.
- A cutting opposite the Ngutunui Stream SR (eastern end) supports broadleaved-treefern forest with lacebark, karamu, mahoe, mangeao, rangiora, pigeonwood, mamaku, pate, and koromiko.
- Cutting and hillslopes opposite the Ngutunui Stream SR (western end) support logged tawa-broadleaved forest with a similar suite of species as above.
- Broadleaved forest of mangeao, mahoe, treeferns, and rangiora occurs where the Te Rauamoa SR (tawa-dominated forest) abuts the highway.
- Mixed broadleaved forest, with mangeao, lancewood, kamahi, pukatea, rewarewa, tree fuchsia, *Cordyline banksii*, and mamaku, and a strip of manuka scrub, where Parkinson SR abuts the highway.

- Where the highway passes through Te Kauri Park SR, rewarewa/kanuka-broadleaved forest, rewarewa/broadleaved-treefern forest with hinau, kamahi, mangeao, mahoe, and nikau, and younger rewarewa/manuka scrub occur.
- Extensive areas of estuarine vegetation occur where the highway abuts Kawhia Harbour, e.g. sea rush and oioi rushlands, and eelgrass communities. The harbour is also an outstanding habitat for wildlife, wading, shore and wetland bird fauna.
- Coastal tawa-kohekohe forest abuts the highway with tutu, karamu, kawakawa, koromiko, manuka, and *Gahnia* spp. on the road cuttings (part Puti-Kawhia Harbour SR).
- A large south-east facing slope supports pockets of coastal tawa-kohekohe forest among kanuka-broadleaved forest.
- Mixed broadleaved-small-leaved scrub-low forest occupies slopes at the western end of Puti Bridge.
- Kanuka-broadleaved forest occurs around the Kawhia-Kauroa Road intersection.
- The road reserve north of Otorohanga is either narrow and dominated by exotic grasses, or has cuttings with scattered native species, gorse and Spanish heath.

3.3.37 SH32: Tokoroa – Whakamaru

- The highway passes through extensive areas of plantation forest. Road cuttings support native shrub and fern species including manuka, snowberry, kiokio, and bracken.

3.3.38 SH32: Whakamaru – Kuratau Junction

- *Gaultheria oppositifolia*, a shrub endemic to the Volcanic Plateau, occurs on road cuttings just north of the Waihaha River.
- Riparian mingimingi-*Coprosma taylorii*-koromiko scrub occurs around the Waihaha River.
- Isolated patches of secondary scrub and treeland with various mixtures of kohuhu, kanuka, fivefinger, tree tutu, and koromiko (and more locally tanekaha, kamahi, and mountain flax), and local infestations of blackberry, broom, buddleia, and pines occur on road cuttings and banks between Kuratau Junction and the Waihaha River.

3.3.39 SH41: Turangi – Kuratau Junction

- Mt Maunganamu between Tokaanu and Turangi supports secondary rewarewa/kanuka forest with local groves of pole podocarps and some pine invasion.
- Raupo and harakeke swamp communities occur beside the Tokaanu Stream between Tokaanu and Turangi.
- Extensive raupo swamps occur on both sides of the highway between Tokaanu and Waihi Road, with willow invasion in places.

- On the lower north-eastern flanks of Mt Kakaramea, the highway traverses an extensive mosaic of secondary communities dominated variously by bracken, fivefinger; and kanuka. Secondary rewarewa/kanuka forest occurs in places.
- Between the lookout and Kuratau Junction, secondary scrub and forest communities of kanuka, manuka, rewarewa, fivefinger, kohuhu, and tarata invaded in places by pines and buddleia, abut the highway.

3.3.40 SH41: Kuratau – Waituhi Saddle

- A small area of secondary scrub and forest dominated by kohuhu, fivefinger and kamahi on Mt Te Hirata abuts the highway on the southern side.
- Waituhi-Kuratau SR contains dense mixed podocarp forest in its lower reaches; a tract of monoao-mingimingi-*Coprosma taylorii-Olearia virgata*-manuka scrub with scattered mountain toatoa and local broom invasion about the upper Kuratau River; and podocarp/mixed broadleaved forest dominated by kamahi in its upper reaches.

3.3.41 SH47a: Rangipo – SH47 Junction

- Riparian vegetation around the Mangahouhounui Stream comprises secondary kanuka scrub with scattered red beech.
- Between the Mangahouhounui Stream and Papakai, road margins support extensive swathes of secondary scrub and forest dominated by kanuka and kohuhu, with heavy invasion by broom and heather in places.
- Near the Wairehu Stream, a small patch of secondary dense podocarp forest dominated by Hall's totara abuts the road reserve.

3.3.42 SH47: Junction SH46 – SH41 (Pihanga Saddle)

- Roadside wetlands in places between the SH47 junction and Otara Stream comprise *Baumea* bog, manuka/tangle fern-*Baumea-Empodisma* bog invaded by heather, harakeke-toetoe swamp and manuka-harakeke swamp.
- An extensive harakeke-toetoe swamp abuts the road reserve about the Mangamutu Stream.
- Broom-gorse shrublands north of Lake Rotopounamu contain scattered individuals and groves of kohuhu, tarata, narrow-leaved mahoe, and kanuka.
- Extensive secondary kanuka forest on the lower south-western slopes of Mt Pihanga enters the road reserve there.
- Dense conifer forest dominated by matai encloses the highway on the Pihanga Saddle. Margins created during road construction now support a fringe of secondary forest dominated by kamahi, kohuhu and tutu.
- On the northern slopes of Mt Tihia, the highway is enclosed by extensive secondary fivefinger-kanuka scrub with scattered wineberry and rewarewa, and pine invasion in places.
- Lower slopes support extensive secondary bracken fernland being invaded by fivefinger, with locally heavy infestations of gorse and broom.

4. Conclusions

The hybrid methodology developed in previous Transfund research was successfully adapted to road networks. This methodology has proven valuable in capturing the diverse aspects of roadside vegetation, combining quantitative and qualitative information.

Roadside reserves can provide valuable public land for conservation, but roading activities can destroy surrounding vegetation and contribute to the spread of weeds. Changes in road management can lessen these impacts, but considerable room exists for better integration of roadside management with biodiversity conservation, scenic values, and weed mitigation and control.

This information has a broad range of uses to improve the integration of biodiversity conservation with road management. The hybrid methodology is designed to provide the different sorts of information needed for effective protection and conservation. The regional sampling and prediction of biodiversity value allow for an overall understanding of biodiversity value of the road network, and the factors that affect this value. Descriptive surveys identify particular areas of high value or rare species in the road reserve, and their locations along the road. This knowledge can guide the protection of existing fragments, changes in road management to mitigate further effects, or the restoration of areas to higher conservation value.

The methods developed here have applications for road networks beyond the characterisation of biodiversity or weeds. Probability sampling techniques can be applied to a wide variety of important road attributes such as production of pollutants, traffic safety, highway use, highway maintenance, and weed control.

The method employed in this project could be used to assess other specific attributes measured at the sample locations. For example, traffic use could be the focus. In this instance traffic counters could be placed along highways at randomly chosen locations. Traffic use could then be related to important factors such as the time of day, day of the week, the size and type of road, and the distance to major urban centres, etc. By applying the techniques used in this report, estimates of traffic use could be made for the entire highway, or for particular segments. From these, estimates of pollution or noise production, or intervals between maintenance might be made. This approach enables predictions at large scales (regions, etc.) and the integration of a range of potentially useful factors.

This study develops methods for characterising highways, but it does not define ways of delivering this information to people who are managing roads. Ideally, systems should be in place that use this information both to influence policy, and to deliver the information, in the appropriate form, into the hands of people driving trucks and diggers. Our vision of how this could best be achieved consists of a unified information management system that can capture information from surveys (which was done here, or those done by regional or city councils) on a wide range of road

properties, and provide them to both policy makers and roading contractors. The information pyramid in Figure 4.1 shows this integrated system.

As an overall roading agency, Transfund is ideally poised to make this happen by wise investment in development and by a policy of unified implementation of such a system.

Other areas that also warrant further investigation/research include:

- a review of the impact of current maintenance and road construction practices on biodiversity and native ecosystems;
- research into hydroseeding techniques using native species, to stabilise and encourage development of native-dominated communities;
- weed occurrences and movement along road corridors, in relation to road maintenance;
- factors affecting successful amenity plantings in road reserves and around rest areas, especially for composition and width.

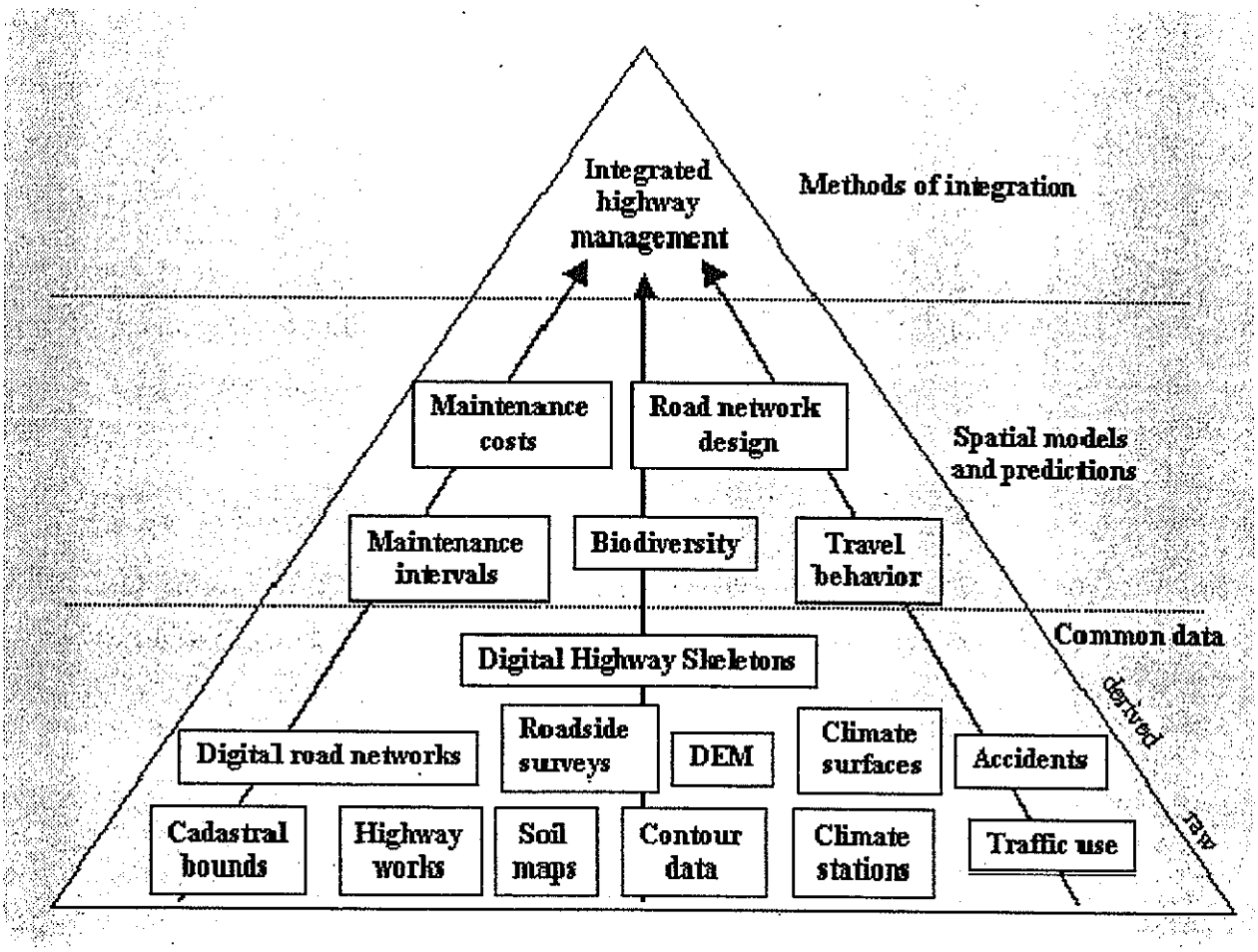

Figure 4.1 Information pyramid for integrated highway management.

The base of the pyramid consists of raw data that is derived or combined upwards into spatial predictions or indicators, as used in this study, eventually to be integrated in management decisions.

5. Glossary of Plant Names

Scientific and common names for exotic species are taken from Healy & Edgar (1980), Webb et al. (1988) and Roy et al. (1998), for wetland plants from Johnson & Brooke (1989), for trees and shrubs from Poole & Adams (1990), for monocotyledons from Moore & Edgar (1976), grasses from Lambrechtsen (1992) and Edgar & Connor (2000), and for threatened or uncommon plants from de Lange et al. (1999).

*	exotic species	spp.	species (plural)
agg.	aggregate	ssp.	subspecies
cv.	cultivar	x	hybrid
sp.	species (singular)		

Common name	Scientific name
Ferns and fern allies	
arching clubmoss	*Lycopodium cernuum*
bracken	*Pteridium esculentum*
hard fern	*Paesia scaberula*
kiokio	*Blechnum novae-zelandiae*
maidenhair fern	*Adiantum* spp.
mamaku	*Cyathea medullaris*
shield fern	*Polystichum* spp.
silverfern	*Cyathea dealbata*
tangle fern	*Gleichenia dicarpa*
wheki	*Dicksonia squarrosa*
Gymnosperms	
bog pine	*Halocarpus bidwillii*
Hall's totara	*Podocarpus hallii*
kahikatea	*Dacrycarpus dacrydioides*
kauri	*Agathis australis*
matai	*Prumnopitys taxifolia*
miro	*Prumnopitys ferruginea*
mountain toatao	*Phyllocladus asplenifolius* var. *alpinus*
*pines	*Pinus nigra, P. pinaster, P. radiata*
rimu	*Dacrydium cupressinum*
tanekaha	*Phyllocladus trichomanoides*
totara	*Podocarpus totara*

Dicotyledons

*blackberry	*Rubus fruticosus* agg.
*black locust	*Robinia pseudoacacia*
*black wattle	*Acacia mearnsii*
*bougainvillea	*Bougainvillea glabra* cv. 'Magnifica'
*broom	*Cytisus scoparius*
*brush wattle	*Paraserianthes lophantha*
*buddleia	*Buddleja davidii*
*catsear	*Hypochaeris radicata*
*cotoneaster (Khasia berry)	*Cotoneaster* spp.
*dally pine	*Psoralea pinnata*
*dandelion	*Taraxacum officinalis*
*elaeagnus	*Elaeagnus* x *reflexa*
fivefinger	*Pseudopanax arboreus*
*German ivy	*Senecio mikanioides*
*gorse	*Ulex europaeus*
*grey willow	*Salix cinerea*
haekaro	*Pittosporum umbellatum*
hangehange	*Geniostoma rupestre*
hard beech	*Nothofagus truncata*
*hawkbit	*Leontodon taraxacoides*
*hawksbeard	*Crepis* spp.
*heather	*Calluna vulgaris*
heketara	*Olearia ranii*
hinau	*Elaeocarpus dentatus*
houpara	*Pseudopanax lessonii*
*Japanese honeysuckle	*Lonicera japonica*
*kahili ginger	*Hedychium gardnerianum*
kamahi	*Weinmannia racemosa*
kanuka	*Kunzea ericoides*
karaka	*Corynocarpus laevigatus*
karamu	*Coprosma robusta*
kawakawa	*Macropiper excelsum*
kohekohe	*Dysoxylum spectabile*

kohuhu	*Pittosporum tenuifolium*
koromiko	*Hebe stricta*
kowhai	*Sophora* spp.
kumerahou	*Pomaderris kumeraho*
lacebark	*Hoheria* spp.
lancewood	*Pseudopanax* spp.
*lotus	*Lotus pedunculatus*
mahoe	*Melicytus ramiflorus*
mangeao	*Litsia calicaris*
mangrove	*Avicennia marina* var. *resinifera*
manuka	*Leptospermum scoparium*
mapou	*Myrsine australis*
*Mexican devilweed	*Ageratina adenophora*
mingimingi	*Leucopogon fasciculatus*
monoao	*Dracophyllum subulatum*
*moth plant	*Araujia sericifera*
mountain beech	*Nothofagus solandri* var. *solandri*
*mouse-ear hawkweed	*Hieracium pilosella*
*nasturtium	*Tropaeolum majus*
*needlebush	*Hakea acicularis*
nikau	*Rhopalostylis sapida*
Northern rata	*Metrosideros robusta*
*oxeye daisy	*Leucanthemum vulgare*
*oxtongue	*Picris echioides*
pate	*Schefflera digitata*
pigeonwood	*Hedycarya arborea*
pohutukawa	*Metrosideros excelsa*
pokaka	*Elaeocarpus hookerianus*
*privet	*Ligustrum lucidum, L. sinense*
prostrate kanuka	*Kunzea ericoides* var. *microflora*
puka	*Griselinia lucida*
pukatea	*Laurelia novae-zelandiae*
puriri	*Vitex lucens*
putaputaweta	*Carpodetus serratus*

rangiora	*Brachyglottis repanda*
rewarewa	*Knightia excelsa*
saltmarsh plant	*Suaeda novea-zelandiae*
saltmarsh ribbonwood	*Plagianthus divaricatus*
snowberry	*Gaultheria antipoda*
*Spanish heath	*Erica lusitanica*
swamp maire	*Syzygium maire*
taraire	*Beilschmiedia tarairi*
tarata, lemonwood	*Pittosporum eugenioides*
taupata	*Coprosma repens*
tawa	*Beilschmiedia tawa*
tawari	*Ixerba brexioides*
titoki	*Alectryon excelsus*
totorowhiti	*Dracophyllum strictum*
towai	*Weinmannia silvicola*
tree fuchsia	*Fuchsia excorticata*
*tree privet	*Ligustrum lucidum*
tutu	*Coriaria arborea*
*willow-leaved hakea	*Hakea salicifolia*
*willows	*Salix cinerea, S. fragilis*
wineberry	*Aristotelia serrata*
*woolly nightshade	*Solanum nigrum*

Monocotyledons

*agapanthus	*Agapanthus* sp.
cabbage tree	*Cordyline australis*
eel grass	*Zostera novazelandica*
gahnia	*Gahnia* spp.
harakeke, flax	*Phormium tenax*
*Himalayan fairy grass	*Miscanthus nepalensis*
mountain flax	*Phormium cookianum*
oioi	*Leptocarpus similis*
*pampas, common	*Cortaderia selloana*
*pampas, purple	*C. jubata*
purei	*Carex secta*

raupo	*Typha orientalis*
red tussock	*Chionochloa rubra*
sea rush	*Juncus maritimus* var. *australis*
*smilax	*Asparagus asparagoides*
spinifex	*Spinifex sericeus*
toetoe	*Cortaderia toetoe*
tuhara	*Machaerina sinclairii*
turutu	*Dianella nigra*
wire rush	*Empodisma minus*

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Appendix

Scenic and allied reserves that abut or are adjacent to the road reserve of the SH network within the Waikato Region

CP Conservation Park
EA Ecological Area
NP National Park
RR Recreation Reserve
SA Stewardship Area
SFP State Forest Park
SL Stewardship Land
SR Scenic Reserve
WA Wilderness Area
WMR Wildlife Management Reserve

State Highway	Section	Grid. Ref (NZMS 260 Map Series)	Reserve name	Comments
SH1	Pokeno to Huntly	No conservation land adjacent/abutting the road reserve		
	Huntly to Hamilton	No conservation land adjacent/abutting the road reserve		
	Hamilton to Cambridge	No conservation land adjacent/abutting the road reserve		
	Cambridge to Tokoroa	T15 425584	Horahora Gorge SR	32.1 ha Steep sided gorge with rocky bluffs, supports regenerating scrub and advanced secondary forest dominated by mahoe, wineberry, treeferns, with enclosed fragments of primary tawa forest.
	Tokoroa to Taupo	U18 750800	Waipouwerawera Stream CA	28.3 ha Reserve abuts SH1 north of Taupo. Contains a steep-sided stream gully, with geothermal features and vegetation: bracken fernland, fivefinger-kohuhu forest.
	Taupo to Turangi	U18 729564	Hinemaiaia SR	130 ha Reserve has conservation and scenic values; viewed from Hatepe Hill, abutting SH1 at its southern end. Vegetation includes bracken fernland, fivefinger-kohuhu forest, and kowhai-kanuka forest.

		U18 712562	Hatepe RR	19.7 ha Reserve runs between SH1 and Lake Taupo at the base of Hatepe Hill. Vegetation includes fivefinger-kohuhu forest, kowhai-kanuka forest, and exotic pines.
		T18 680535	Motutere SR	108 ha Abuts both sides of SH1 north of Waitetoko. Vegetation is all secondary/advanced secondary: bracken fernland, kanuka forest, kowhai forest, fivefinger-kohuhu forest. Dwarf mistletoe present.
		T18 647508	Waitetoko SR	75.8 ha Abuts SH1 opposite Lake Taupo, Mission Bay. Vegetation is a mosaic of manuka-manuka scrub-forest and fivefinger-kohuhu forest.
		T18 616502	Oruatua RR	33.2 ha Abuts SH1 and contains manuka scrub, kowhai-kanuka forest, and native restoration planting.
		T18 609505	Oruatua CA	80.8 ha Reserve runs between SH1 and Lake Taupo, and contains kanuka-manuka scrub, kanuka forest, fivefinger-kohuhu forest, raupo reedland, *Carex*-toetoe tussockland, and frostflat lichen field.
		T19 586480	Motuoapa SR	14.4 ha Small reserve contains kanuka forest, fivefinger-kohuhu forest, and outcrop rockland (Motuoapa lava dome has regional geopreservation significance).
		T19 563462	Waiotaka SR	29.2 ha Wetland bordering the shores of Lake Taupo. Vegetation includes *Baumea* peat bog, raupo reedland, manuka scrub, kowhai-kanuka scrub, and harakeke-toetoe tussockland.
	Turangi to Desert Rd Summit	T19 539399	Tongariro River No. 2 SR	48.9 ha Reserve lies on alluvial terraces of the Tongariro River. Vegetation includes red-, mountain- and black-beech forest, kowhai-kanuka forest, toetoe tussockland, manuka scrub, and exotic pine plantation.
		T19 534397	Waikari SR	8.9 ha Reserve runs between SH1 and the Tongariro River, and contains kowhai-kanuka forest, fivefinger-kohuhu forest, manuka and *Dracophyllum* scrub.
		T19 535395	Paurini SR	18.3 ha Reserve runs between SH1 and the Tongariro River, and contains secondary manuka scrub and kowhai-kanuka forest.
		T19 534388	National Trout Centre CA	18.1 ha Reserve adjacent to SH1. Vegetation is a mosaic of broadleaved forest, kowhai-kanuka forest, and native amenity plantings. Includes a trout hatchery and visitors centre.
		T19 545370	Tongariro River SR	160 ha Reserve lies on alluvial terraces of the Tongariro River. Vegetation includes kowhai-kanuka scrub, kanuka-manuka scrub, bracken fernland, and beech forest.
		T19 375242	Tongariro NP	24 200 ha An extensive reserve covering the cones and flanks of Mt Ruapehu, Ngauruhoe, and Tongariro – and containing a wide variety of lowland to alpine vegetation including mountain beech forest, red tussockland, monoao shrubland, manuka scrub, tanglefern-Empodisma peat bog, alpine herbfield, and alpine rockland.
		T19, T20, U19	Kaimanawa SFP	77 887 ha An extensive reserve that covers much of the Kaimanawa Ranges, and abuts SH1 around the Upper Waikato Stream. Vegetation close to the SH includes red-tussock tussockland, red-tussock-monoao scrub and manuka scrub.
SH2	Pokeno to Paeroa	S12 163332	Waitakaruru SR	13.1 ha Reserve contains regenerating podocarp and tawa forest on a steep south-facing slope.

	Paeroa to Waihi	T13	Kaimai-Mamaku SFP	
		T13	Maratoto West Block (part Coromandel CP)	c. 6600 ha Contains logged primary tawa forest (Forest Type N(D2) (Nicholls 1976) near the SH.
		T13	Owharoa Falls SR	3.3 ha Reserve contains steep hillslopes, covered with podocarp forest remnants, kanuka forest and associated shrubs. Taieri Stream, which runs through it has three waterfalls along its course.
		T13	Owharoa Scientific R	0.5 ha The reserve is an international reference site for geologists, for rock type Owharite.
	Waihi to Waimata	No conservation land adjacent/abutting the road reserve		
SH3	Hamilton to Te Kuiti	S17 138587	Lake Serpentine RR/WMR	30.3 ha A shallow eutrophic lake with important wildlife values. Restoration planting around the wetland margin.
	Te Kuiti to Awakino	R17 795991	Paemako SR	27.1 ha This reserve covers moderate to steep slopes on either side of Pangaki Stream, which has a scenic waterfall along its course. The slopes nearest the road support primary dense conifer forest dominated by matai, kahikatea, totara, and rimu.
		R17 765515	Mangaotaki Gorge SR	65.6 ha The reserve includes the remnant of forest on the western side of the highway. It has tawa forest with a fringe of manuka scrub on gentle slopes above a series of limestone bluffs. The mid-slopes are also dominated by primary tawa forest, with rewarewa, pukatea, kahikatea and titoki (lower section) amongst it. The slopes above the road have low secondary broadleaved forest of mahoe, hoheria, putaputaweta, titoki, pate, and treeferns.
		R17 594808	Arorangi SR	311.9 ha Includes two areas of steep rugges slopes above the Awakino Gorge. The west-north-west facing slopes (above SH3) are predominantly (rimu-tawa)/tawa-kohekohe-kamahi forest.
SH4	8 Mile Junction to Tangatu	S17	Aratoro SR	3.3 ha Reserve consists of a small gully covered with logged tawa forest and manuka/bracken scrub.
		S17	Kurukuru SR	56.8 ha Both sides of a main ridge, steep, covered with primary rimu/tawa forest. *Ascarina lucida* present.
SH5	Tirau to Mamaku Plateau	T16 635517	Selwyn SR	388 ha Contains primary podocarp/broadleaved forest and a large area of secondary rewarewa/kamahi-kanuka forest. Incorporates Fitzgerald Glade, a scenic forested corridor.
		T16	Mamaku Forest	Contains extensive tracts of unlogged upland rimu/tawa forest and steepland variants of it, and smaller tracts of logged upland tawa-dominant forest, upland beech-broadleaved forest, and montane kamahi-dominant forest.
	Waipa to Wairakei	U16 052153	Lake Ngahewa RR	c. 39.6 ha Reserve contains a harakeke-raupo-sphagnum wetland with sedge and manuka communities. Spotless crake and fernbird present. Water fowl breeding.

		U16 060150	Rainbow Mountain SR	438 ha Vegetation in reserve is a complex mosaic of types, many of which relate to thermal activity with subsequent cooling, and to succession after periodic burning: secondary tea tree scrub, fivefinger-kohuhu forest, kamahi forest, toatoa-rimu forest, geothermal prostrate kanuka shrubland (with rare geothermal ferns), and a *Baumea-Carex* swamp. Reserve is a renowned scenic attraction.
		U16 040100	Waiotapu SR	128 ha Reserve contains geothermal kanuka-mingimingi shrubland, manuka shrubland, secondary kamahi forest. Rare geothermal ferns present, e.g., *Cyclosorus interruptus*.
	Taupo to Iwitahi	U18 895660	Opepe Bush SR & HR	187.3 ha Reserve contains dense primary podocarp forest, secondary kamahi-kanuka forest, manuka-monoa scrub. *Thismia rodwayi* present.
SH22	Pukekawa to Te Uku	No conservation land adjacent/abutting the road reserve		
SH23	Hamilton to Raglan	S14 928728	Four Brothers SR	8.8 ha Primary logged tawa-kohekohe forest. New Zealand falcon seen in vicinity of reserve.
SH25	Intersection of Sh2 & SH25 to Thames	No conservation land adjacent/abutting the road reserve		
	Thames to Tapu	T12	Tararu SL	735.9 ha Includes steep hillslopes above Tararu, with vegetation including coastal scrub and pohutukawa forest. The area forms an environmental backdrop for local residential communities and the coastal highway, and a connecting corridor with Coromandel Conservation Park, resulting in a mountain to sea landscape. NI brown kiwi recorded.
		T12	Waihonga Private SR	No information.
		T12	Thornton Bay SR	44 ha Pohutukawa forest and secondary coastal scrub.
		T12	Puru SR	33 ha Reserve contains secondary coastal forest. Invaded by pines.
		T11	Owen Taylor Memorial SR	3.6 ha Reserve includes secondary coastal scrub, and pohutukawa forest.
		T11	Tapu-Ruamahanga SR	187.7 ha Reserve includes a steep embankment, with secondary coastal scrub and pohutukawa forest. Heavily invaded by radiata and maritime pine.
	Tapu to Coromandel	T11	Te Mata SR	0.3 ha Coastal forest and regenerating manuka-kowhai-five finger scrub. Pa site.
	Coromandel to Kuaotunu	T10	Kauri Block	48.7 ha Modified coastal forest with steep cliffs.; primary areas mapped as Forest Type B2 (Nicholls 1976) Kauri-rimu-miro-Hall's totara-tanekaha-northern rata/taraire-tawa-hinau-rewarewa-kohekohe-towai forest below 450 m a.s.l.
		T10	Taumatawahine SR	3.5 ha Secondary tea tree forest and podocarp/broadleaved forest.
		T10	Whangapoua Block (part Coromandel CP)	Contains mixed kauri-mixed podocarp-rata/mixed broadleaved forest, and secondary/advanced secondary communities in mosaic.

		T10	Matarangi Bluff SR	253.5 ha Reserve includes moderate to steep hill country and a coastal headland covered with regenerating coastal forest. Two pa sites.
	Kuaotunu to Whitianga	T10	Otama Block (part Coromandel CP)	714.4 ha Moderately steep hill country, covered with regenerating coastal broadleaved forest. NI kiwi. Pohutukawa and northern rata hybrids. Important as headwaters of Otama River and Otama estuary.
		T11	Ohuka Bush SR	0.4 ha Gully with a small stream, supports with coastal forest.
		T11	Buffalo Beach SR	4.1 ha Coastal pohutukawa-puriri treeland with kauri.
	Whitianga to Hikuai	T11	Whenuakite Block (part Coromandel CP)	771.7 ha Rolling hill country, covered with relatively unmodified coastal and semi-coastal forest, and scrub, including dense secondary stands of kauri. Fauna values include kiwi and kaka. Flora values include *Loxoma cunninghamii* and relatively unmodified coastal forest areas. Historic values include kauri timber dams and tram lines.
		T11	Punaruku SR	11.8 ha Reserve contains secondary/advanced secondary manuka- and kanuka-dominated communities, and regenerating kauri forest.
	Hikuai to Kopu	T11	Hikuai Block (part Coromandel CP)	c. 45 000 ha Includes the western side of Tairua River catchment and entire upper Hikuai River catchment; moderate to steep hillslopes and gullies with prominent pinnacles and bluffs, covered with lowland to montane forest, including kauri forest. Flora values include kauri forest, *Celmisia gracilenta, Dracophyllum patens, Marattia salicina.* Fauna values include NI brown kiwi, fernbird, kokako, long tailed cuckoo, Hochstetter's frog and long tailed bats; includes Kapowai Ecological Area and most of Motutapere Ecological Area. Historic values include the Broken Hills goldmining historic area and kauri timber logging sites.
		T12	Fourth Branch SR	19.7 ha Secondary conifer forest, dominated by kahikatea and secondary manuka scrub.
		T12	Fourth Branch SA	Reserve contain a range of secondary/advanced secondary and primary communities, including logged and unlogged rimu-northern rata/tawa forest, and dense stands of young kauri and tanekaha.
	Hikuai to Waihi	T12	Hikuai SL	
		T12	Wharekawa SL	0.4 ha
		T12	Te Ramarama SR	32.6 ha Reserve consists of four remnants of coastal primary and secondary forest.
		T12	Te Ramarama SL	12.9 ha Coastal forest.
		T13	Maratoto East Block (part Coromandel CP)	c. 6 000 ha Forest Type B3 & B5 (Nicholls 1976)

SH26	Hamilton to Morrinsville	No conservation land adjacent/abutting the road reserve		
	Morrinsville to Te Aroha	No conservation land adjacent/abutting the road reserve		
	Te Aroha to Paeroa	No conservation land adjacent/abutting the road reserve		
SH27	Mangatarata to Matamata	S13 245233	Kaihere SR	2.2 ha Small area of secondary kanuka forest.
	Matamata to Tirau	No conservation land adjacent/abutting the road reserve		
SH29	Piarere to Tauranga (part)		Kaimai-Mamaku SFP	Contains extensive tracts of unlogged upland rimu/tawa forest and steepland variants of it, and smaller tracts of logged upland tawa-dominant forest, upland beech-broadleaved forest, and montane kamahi-dominant forest.
SH30	Atiamuri to Whakamaru	No conservation land adjacent/abutting the road reserve		
	Whakamaru to Barryville	T17	Pouakani SR	71.2 ha Gently sloping land on ignimbrite, supporting mixed podocarp/tawa forest.
		T17	(Part) Pureora CP	
	Tiroa to Te Kuiti	S17 183965	Herekawe SR	234.5 ha Moderately steep hill country with sand stone bluffs on ignimbrite. Vegetation includes primary podocarp/tawa forest, scrub and cliff communities, with a small wetland. Fauna values include long tailed cuckoo. Flora values include *Monoao* and *Olearia virgata*. Landscape values of cliffs.
		S17 145956	Mangapehi SR	46.5 ha Reserve contains steep hillslopes, that support rimu/tawa forest, kahikatea forest, kamahi forest, houhere-tree fuchsia-makomako low forest, manuka scrub and bracken fernland.
		S17 190940	Mangapehi Forest SL	975 ha Reserve contains rolling hill country covered with podocarp/broadleaved forest, and swamp flats. High numbers of fernbird and spotless crake; also NZ falcon and NI robin.
SH31	Otorohanga to Kawhia	S15 942434	Ngutunui Stream SR	40.5 ha Reserve lies on moderately steep to steep hill country, that supports (rimu-rewarewa)/tawa forest, with hinau and mangeao.
		S15 915439	Te Rauamoa SR	67.8 ha Steep hillside with primary rimu/tawa forest.
		R15 880456	Parkinson SR	53.9 ha Reserve contains a limestone ridge crest and steep south-facing slopes, that support primary-advanced secondary podocarp/tawa forest. Contains kauri near its southern limit.

		R15 845446	Te Kauri Park SR	1012.6 ha This reserve consists of four parts in rugged hill country on the lower slopes of Mt Pirongia. The forest is a mosaic of ridge, slope and valley types: primary and logged rimu/tawa forest; secondary rewarewa/kamahi forest; and small kahikatea stands. Much is virgin; some has been selectively logged; some with 40 years regeneration after burning. Limestone bluffs are a major feature. Two substantial stands of kauri within the reserve are the southern-most naturally growing in New Zealand. Kawaka is also present. The reserve also contains an historic pa site, and a pristine wetland surrounded by native forest. Bitterns have been seen in the vicinity, with New Zealand falcon sighted and believed to be breeding there.
		R15 750489/ 746488	Kawhia Harbour - Puti SR	15.8 ha Eastern section: coastal tawa-kohekohe forest, with tutu, karamu, kawakawa, koromiko, manuka, and *Gahnia* on the road cuttings. Western section: large south-easterly facing slope with pockets of coastal tawa-kohekohe forest amongst kanuka-broadleaved forest
SH32	Tokoroa to Whakamaru	No conservation land adjacent/abutting the road reserve		
	Whakamaru to Kuratau Junction	T18 495750	Hingarae SR	719.5 ha Reserve covers the Otupoto Stream catchment, extending from SH32 to Lake Taupo. Vegetation includes bracken fernland, fivefinger-kohuhu forest, kamahi forest, and flax-toetoe tussockland.
		T18 452736	Waihaha SR	595.5 ha Vegetation contains monoao scrub, silver tussockland, flax tussockland, kanuka forest, fivefinger-kohuhu forest, and podocarp/broadleaved forest. Contains walking tracks along the Waihaha River. Most of Waihaha SR is situated east of State Highway 32 . The portion on the west side is managed as part of Waihaha EA.
SH39	Temple View to N of Tihiroa	No conservation land adjacent/abutting the road reserve		
SH41	Kuratau to Waituhi Saddle	T18 340545	Waituhi- Kuratau SR	1319 ha Reserve contains moderately steep to very steep slopes that support primary and logged primary-mixed podocarp-broadleaved forest, red-tussock monoao shrubland, bog-pine-mountain toatoa forest, and square sedge-*Gleichenia* wetland. *Pittosporum turneri* (conservation status 'declining'; de Landge et al. 1999) present. Kereru, kaka, long-tailed cuckoo, robin, and kakariki have all been recorded there.
	Turangi to Kuratau Junction	T19 486497	Gardiners SR	12.4 ha Reserve contains bracken fernland, kanuka-manuka scrub-forest, and fivefinger-kohuhu forest. The mistletoe *Tupeia antarctica* (conservation status 'declining'; de Lange et al. 1999) is present.
		T19 483461	Waihi Rd SR	11.99 ha Reserve contains raupo reedland, manuka scrub, and regenerating kahikatea forest. Some willow invasion.
		T19 506456	Tokaanu CA	362 ha Reserve lies either side of the Tokaanu Canal. Contains raupo reedland, *Leptocarpus* rushland, *Carex-Juncus* sedge-rushland, *Eleocharis* sedgeland, manuka scrub.

		T19 495448	Tokaanu Thermal Park RR	47.5 ha Reserve is adjacent to SH41, and includes geothermal features (geysers, hot springs, mud pools, sinter springs) and vegetation: prostrate kanuka scrub, kanuka-manuka scrub, *Leptocarpus* rushland, kanuka forest, kowhai-kanuka forest, broadleaved forest.
SH47a	Rangipo to SH47 junction	T19 375242	Tongariro NP	24 200 ha An extensive reserve covering the cones and flanks of Mt Ruapehu, Ngauruhoe, and Tongariro – and containing a wide variety of lowland to alpine vegetation including mountain beech forest, red tussockland, monoao shrubland, manuka scrub, tanglefern-Empodisma peat bog, alpine herbfield, and alpine rockland.
		T19 386345	Highway 47a CA	0.2 ha No information.
SH47	SH47a junction to SH 41 junction (Pihanga Saddle)	T19 381381	Otamangakau Wetlands CA ??	26.9 ha Vegetation includes manuka scrub and Dracophyllum scrub, with invading broom.
		T19 424399	Mangamutu CA	5.1 ha Small reserve containing mixed podocarp forest.
		T19 490380	Tongariro NP – Pihanga Block	4800 ha Reserve contains mixed podocarp/ broadleaved forest, beech-podocarp forest, subalpine scrub, alpine herb field, and *Empodisma* and *Baumea* peat bogs.
		T19 460260	Tongariro NP – Te Tatau Pounamu WA	6800 ha Reserve contains secondary kanuka and manuka scrub, podocarp/broadleaved forest, beech forest, alpine herbfield, alpine flush vegetation, and coarse tussock.