Vegetation monitoring in Whanganui National Park

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ABSTRACT

This study characterised the vegetation of Whanganui National Park, North Island, New Zealand, using data from 470 temporary reconnaissance (recce) plots measured in 1986/87 and 39 permanent forest plots established between 2001 and 2006. The Whanganui forest comprises a range of plant species, but was homogenous across the area surveyed. Unlike other North Island forests, there were no strong relationships between vegetation composition and factors such as altitude or latitude, confirming earlier, qualitative descriptions. This indicates that forest composition in Whanganui varies at the local scale, and is probably driven by small changes in soil type, topography and disturbance history. Species selected by ungulates were found to be less common in the browse tier than in the canopy, which suggests that regeneration is being suppressed. Relative abundances of common species in the permanent plots differed from those in the more extensive recce plot network, suggesting that the permanent plot network was not representative. Since no distinct forest types were identified, use of a stratified sampling design will not remedy this. Instead, the number of plots should be increased. It was calculated that the number of vegetation plots in Whanganui National Park and surrounding conservation areas should be increased to at least 60 unfenced forest plots. A smaller number of exclosure plots (each paired with an unfenced plot) should be used to indicate the potential of the forest to recover if ungulates were eradicated. Targeted monitoring methods should be used for the short-term assessment of wild animal management.

Keywords: Whanganui National Park, vegetation monitoring, ungulate browse, recce plots, permanent plots, lowland forest, central North Island, New Zealand

1. Introduction

Whanganui National Park (WNP) covers 74 231 ha of lowland forest in the southwestern part of the North Island, New Zealand (DOC 1989). With adjoining conservation areas, it forms the second largest lowland forest (146 000 ha) in the North Island (DOC 2006). It lies approximately 50 km northwest of Wanganui and 30 km southwest of Taumaranui (Fig. 1). Nearly half the park is below 300 m a.s.l. and only the highest points are over 700 m a.s.l. (DOC 2006). National vegetation classifications characterise it as podocarp-broadleaf forest (Newsome 1987; Leathwick 2001; Hall & McGlone 2006).

Browsing by introduced mammalian herbivores significantly influences forest processes in New Zealand (Nugent, Fraser et al. 2001; Wardle et al. 2002). Over the past 90 years, Whanganui forests have been occupied by brushtail possums (*Trichosurus vulpecula*), goats (*Capra hircus*) and pigs (*Sus scrofa*), but there is little quantitative evidence of the latter two species' impacts on forest structure and composition. This report addresses this by summarising existing information about the Whanganui forest and recommending improvements to current monitoring methods.

1.1 IMPACTS OF BROWSING MAMMALS ON INDIGENOUS FOREST

Feral ungulates such as deer, goats and pigs were introduced to New Zealand during the late 19th and early 20th centuries, and are still spreading across the country (Fraser et al. 2000). Ungulate herbivory typically favours particular species, which can lead to changes in forest composition as the regeneration of selected species is suppressed and avoided species benefit from reduced competition (Nugent, Fraser et al. 2001). The browse preferences of feral ungulates have been determined by comparing the abundance of plant species in the browse tier with their abundance in gut or faecal pellet contents (Forsyth et al. 2002). However, palatability is not the only determinant of a plant species' response to ungulate browse, as some highly palatable species have characteristics that enable them to persist in heavily browsed communities, such as very rapid growth rates or the ability to regenerate epiphytically (Augustine & McNaughton 1998).

Fenced forest plots typically have higher densities of fast-growing, soft-leaved, palatable species, such as large-leaved *Coprosma* species, mahoe (*Melicytus ramiflorus*), pate (*Schefflera digitata*) and hangehange (*Geniostema rupestre*), and lower densities of unpalatable species, such as horopito (*Pseudowintera* spp.), small-leaved shrubs and hookgrasses (*Uncinia* spp.), than neighbouring plots exposed to browse (Jane & Pracy 1974; Allen et al. 1984; Smale et al. 1995; Bockett 1997; Walls 1998; Wardle et al. 2001; Husheer 2007). Similar responses have been found in studies relating vegetation composition to changing ungulate density over time in northern Fiordland (Stewart et al. 1987) and in the Orongorongo Valley (Fitzgerald & Gibb 2001).

Figure 1. Location of Whanganui National Park, North Island, New Zealand.
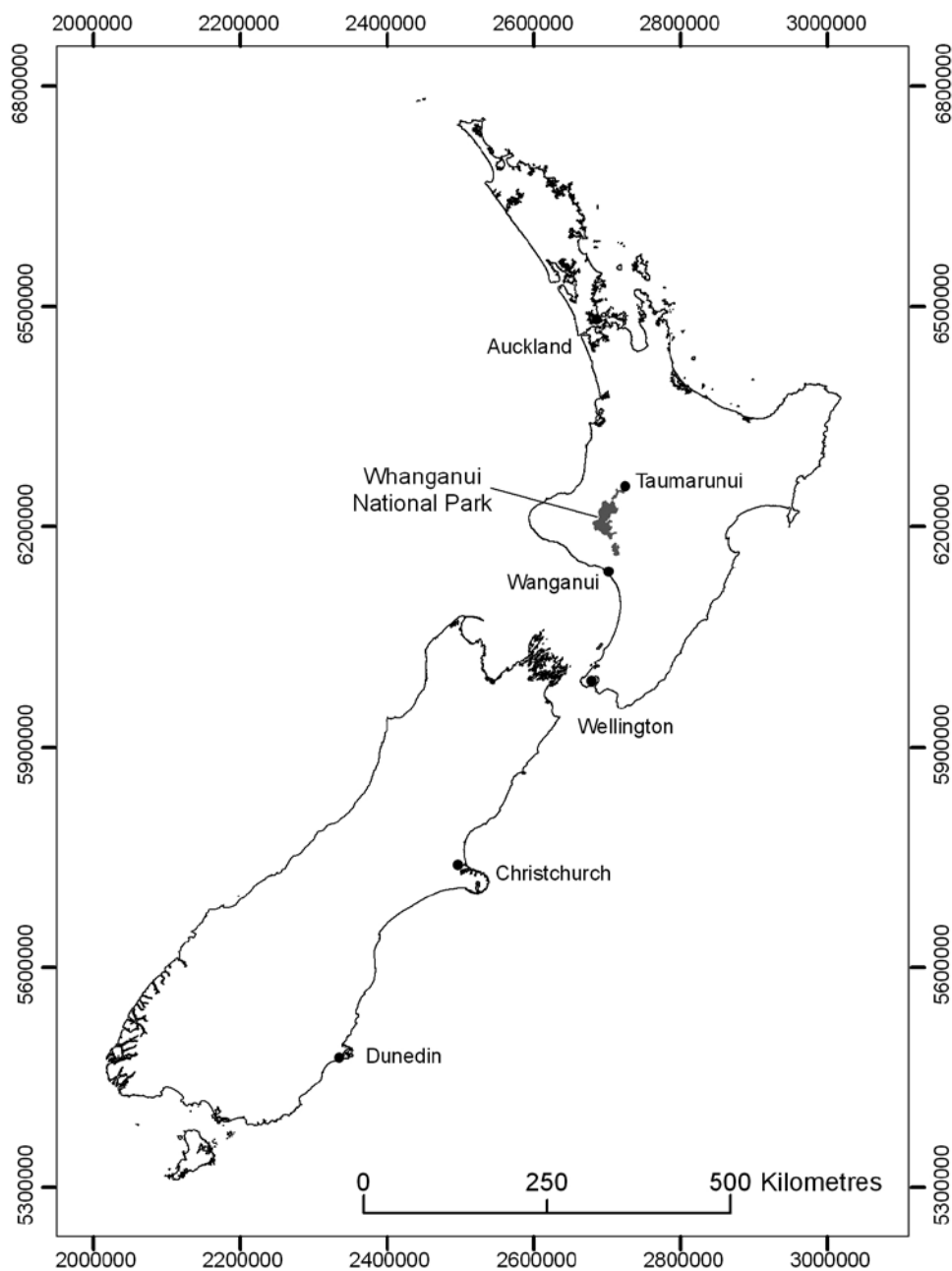
Species that are typically classified as 'not selected' or 'avoided' may also be affected by ungulate browse. For example, high deer densities apparently impede beech regeneration, even though beech is not usually considered to be a selected species (Husheer et al. 2003).

The risk of forests collapsing and being replaced by a lower scrub of browse-resistant species is greatest where ungulate herbivory is complemented by herbivory by brushtail possums (Nugent, Fraser et al. 2001). Brushtail possums can browse individual species to local extinction and may contribute to canopy collapse (Payton 2000). They reach their highest densities in diverse, low-altitude forest (Cowan 1990), such as is found at Whanganui. Conspicuous mortality followed possum colonisation in the Orongorongo Valley (Fitzgerald & Gibb 2001), Westland (Rose et al. 1992, 1993), and the southern Ruahine Range (Rogers & Leathwick 1997). Brushtail possums may also impede forest

regeneration, as fruit and flowers make up a large proportion of possum diet (Owen & Norton 1995; Nugent et al. 2000; Nugent, Fraser et al. 2001; Dungan et al. 2002) and fruit production of several species has been found to increase after possum control (Cowan & Waddington 1990; Cowan 1991). Seedlings are also directly browsed (Buddenhagen & Ogden 2003; Wilson et al. 2003), but the effect of this is probably minor relative to the effects of ungulates (Nugent, Fraser et al. 2001; Sweetapple & Burns 2002).

1.2 FOREST CLASSIFICATION

The classification of forest types allows targeted management. For instance, different forest types vary in their sensitivity to the effects of herbivores and respond in different ways to herbivore control. Environmental factors such as soil type, altitude, aspect and slope can moderate the effects of herbivores (Stewart et al. 1987; Rogers & Leathwick 1997; Husheer et al. 2003), and vegetation composition, which is often related to those factors, is also influential (Wardle et al. 1971; Stewart et al. 1987). These interactions probably reflect herbivores' differential use of habitat, and the vegetation's ability to recover from browsing and susceptibility to other forms of disturbance (Rogers & Leathwick 1997). Structural characteristics of forests also influence the recruitment of palatable species independent of browsing impacts (Bellingham & Allan 2003).

In New Zealand, vegetation classification has been carried out at different scales. National-level classifications have been created using information compiled from many surveys (e.g. Newsome 1987) or using computer modelling to predict vegetative communities based on abiotic site characteristics and known species traits (e.g. Hall & McGlone 2006). Local classifications have also been created for sites around New Zealand, using direct measurement of vegetation on systematically located plots or transects. These are used to understand the fundamental drivers of forest composition, to inform conservation management and identify priorities for further research (Clarkson 1986; Leathwick 1990; Stewart et al. 1993; Newell & Leathwick 2005).

1.3 WHANGANUI NATIONAL PARK

Whanganui National Park is in the Matemateaonga Ecological District, on an uplifted terrace of marine sediment (Baxter 1988). Dominant landforms are deeply entrenched waterways, sharp ridges and steep hillslopes (Nicholls 1956). Soils are derived from sedimentary rocks and overlying Taranaki tephra, with rich alluvium on valley floors and terraces, and skeletal soils on steep faces (DOC 1989). The average temperature is approximately 11°C. Rainfall varies from 1600 mm to over 2000 mm per year (Baxter 1988).

Early descriptions of the forest emphasised its homogeneity, but also identified some compositional trends related to topography, which is a determinant of soil depth and drainage (Levy 1923; Nicholls 1956). Levy (1923) summarised the Taranaki and Wanganui hill forests as mixed tawa (*Beilschmiedia tawa*) and kamahi (*Weinmannia racemosa*), with tawa dominating the favourable sites, and

other broadleaves such as rewarewa (*Knightia excelsa*) and hinau (*Elaeocarpus dentata*) widespread but not abundant. Nicholls (1956) made a similar description. Both authors noted that two podocarp species, rimu (*Dacrydium cupressinum*) and miro (*Prumnopitys ferruginea*), were widespread, while Hall's totara (*Podocarpus hallii*) and kahikatea (*Dacrycarpus dacrydiodes*) were found on dry ridges and fertile, poorly drained river terraces, respectively. They also identified black beech (*Nothofagus solandri* var. *solandri*) as limited to narrow ridges, cliff tops and spurs (Levy 1923; Nicholls 1956).

Baxter (1988) made a comprehensive qualitative description of indigenous vegetation in the Ecological District. He identified three vegetation types (beech and mixed beech forest, broadleaved/podocarp forest and broadleaved/kahikatea forest), and suggested that their distribution was determined by underlying rock, soils, drainage and topography, which combined to create a fine-scale mosaic of different forest types on different landforms:

- Beech (mostly *N. solandri* var. *solandri*) forest is confined to the thin, poorly developed soils on weathered sandstone ridges.

- Podocarp (largely kahikatea) dominated forests are present on poorly drained soils on lowland valley floors, river terraces and lake/swamp margins.

- Broadleaved/podocarp forest is the most common type, covering fertile ridges, spurs, hill faces, basins and swales. Within this, Baxter (1988) noted gradients in species composition driven by three factors: altitude, with kamahi and hinau replacing tawa at higher altitudes (e.g. around Mt Humphries); latitude, with tawheowheo (*Quintinia serrata*) becoming more common in the northern part of the park; and soil fertility-drainage, with kahikatea, pukatea (*Laurelia novaezelandiae*) and mahoe more common in shaded areas with moist soils, kamahi, Hall's totara and heketara (*olearia rani*) more common on exposed sites with thin, dry soils, and tawa, northern rata (*Metrosideros robusta*) and rimu likely to dominate on fertile, deeper soils.

Baxter (1998) also described several distinctive communities: cliffs and bluffs; wetlands; and regenerating forest. However, the surveys that form the basis of this report were not designed to sample these geographically limited communities.

Plant lists maintained by the Department of Conservation (DOC), which were last updated in 2006, record 304 indigenous species in the Matemateaonga Ecological District. This relatively low diversity may be partly due to botanical surveys having been limited to small areas accessed in the course of other work, but also reflects the homogeneity of environments within the Ecological District. Several threatened plants, including a five-finger (*Pseudopanax laetus*) and a shrubby daisy (*Brachyglottis turneri*), are present (Baxter 1988; La Cock 2001). Other plants reach a distributional limit in the park, including tanekaha (*Phyllocladus trichomanoides*), tawheowheo, *Lycopodium deuterodensum* and *Dracophyllum strictum* (Baxter 1988).

1.3.1 Introduced herbivore management and outcome monitoring

Brushtail possums and goats are perceived as the primary threats to forest in WNP, and are managed by DOC (DOC 2006). Pigs and red deer (*Cervus elaphus scoticus*) are also present, although the latter are uncommon.

By the 1920s, goats were widespread around Whangamomona (to the west of the Park) (Blaschke 1992; Urlich & Brady 2005). Goats have been hunted in the Mangapurua River Valley, the Whanganui River trench and the Matemateaonga Range at varying levels of intensity since the 1970s (B. Fleury, DOC, pers. comm. 2007). Between 1994 and 2005, operations were limited to the regenerating scrub of the Mangapurua and the river trench. In 2005, goat control began in approximately 10 000 ha between the Matemateaonga Walkway and the Whanganui River. Between 1700 hours and 2000 hours of hunting occurred annually in the first 3 years of this operation, and kill rates were approximately 0.5 kills/hour hunted (R. Smillie, DOC, pers. comm. 2008).

DOC has conducted possum control operations in WNP since 1995 (Mackintosh & Hawcroft 2005). The Park and adjoining conservation land were divided into management blocks of 12 000–20 000 ha, which were treated with 1080 once every 7 years (Mackintosh & Hawcroft 2005)[1]. Canopy condition is assessed by helicopter survey before each 1080 operation, 1 year after the operation and at subsequent 2–3-year intervals, using a modification of the Foliar Browse Index (Payton et al. 1999). Generally, there was an improvement in canopy condition in the first 2 years after control; stabilisation or slight improvement after 4 years; and some decline after 6 years (AH, unpubl. data). However, this aerial monitoring does not provide information about the state of the understorey, tree recruitment or mortality. Parts of the Whanganui forest were included in two long-term projects researching outcomes of possum control. In the first 2 years after possum control, browse scores on common canopy species declined relative to untreated sites, although changes in canopy density were less clear (Nugent, Whitford et al. 2001). Over the longer term, kamahi condition improved in the first 6 years after possum control, but dropped again in the following 2 years, becoming no different to the untreated site (J. Parkes, Landcare Research, pers. comm. 2006).

Blaschke (1992) used cages to study the effects of introduced herbivores on seedling growth in forest remnants near Whangamonona over 6 years. Seedling survival and growth rates were higher in the caged plots, especially for hangehange (*Geniostema rupestre*), koromiko (*Hebe stricta*) and some of the large-leaved coprosmas. The reverse was true for manuka (*Leptospermum scoparium*), rewarewa and heketara. The effect also depended on microtopography, with the greatest increases on flats and greatest decreases on convex slopes (Blaschke 1992). Blaschke did not distinguish between browsing by brushtail possums and ungulates.

There has been little monitoring of goat impacts in the Whanganui forest. Nugent, Fraser et al. (2001) suggested that ungulates are likely to be stronger drivers of forest composition and structure than possums, because of their larger size, more selective browsing and ability to supplement their diet with leaf litter.

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[1] The possum control regime for Whanganui National Park was revised in 2008, and the interval between control operations reduced to 2 years in order to benefit avifauna by reducing rodent and mustelid populations.

This research used information from permanent forest plots to relate current vegetation structure and composition to predicted ungulate impacts (reduced densities of palatable species in the browse tier).

1.4 OBJECTIVES

This research aimed to:

- Use data from New Zealand Forest Service recce plots measured in summer 1986/87 to identify and describe forest types in WNP

- Investigate correlations between the distribution of forest types and abiotic factors

- Identify which forest types are represented in the permanent forest monitoring plots established by DOC between 2001 and 2006.

- Use data from both New Zealand Forest Service recce plots and DOC permanent plots to summarise the state of the forest in terms of abundances and size class distributions of canopy-forming species, and species that are selected, not selected and avoided by ungulates

- Provide direction for future vegetation monitoring in WNP, with respect to the number of permanent vegetation plots needed, and whether the sample should be stratified by forest type


2. Methods

2.1 NEW ZEALAND FOREST SERVICE RECCE PLOTS

Recce plots are a standard field method for forest classification in New Zealand (Allen 1992), and have been widely used to derive vegetation maps (Leathwick 1990; Newell & Leathwick 2005) and to investigate relationships between forest types and environmental factors (Stewart et al. 1993).

The New Zealand Forest Service made 470 recce descriptions of vegetation in WNP during the summer of 1986/87. This survey was never formally reported and the information collected has not been accessible to conservation managers (B. Fleury, DOC, pers. comm. 2008).

Plots were located at approximately 100-m intervals along 50 randomly placed transects. Good coverage of the Park was achieved (Fig. 2), although there was some concentration around the Matemateaonga Ridge, Whanganui River and Mangapurua Stream, and less coverage in the Heao Stream catchment. In addition, up to two plots were established to the right of each transect. Plots were unbounded and described an area of homogenous vegetation. The recce protocol has been described in detail by Allen (1992). All species of vascular plants growing in mineral soil were identified, and estimates of cover were made for each recce plot in several tiers (mostly > 12 m, 12-5 m, 5-2 m, 2-0.5 m, < 0.5 m), using a six point inverse log scale (typically, 1 = 1%, 2 = 2–5%, 3 = 6–25%, 4 = 26–50%, 5 = 51–75%, 6 = 76–100%; Mueller-Dombois & Ellenberg 1974).
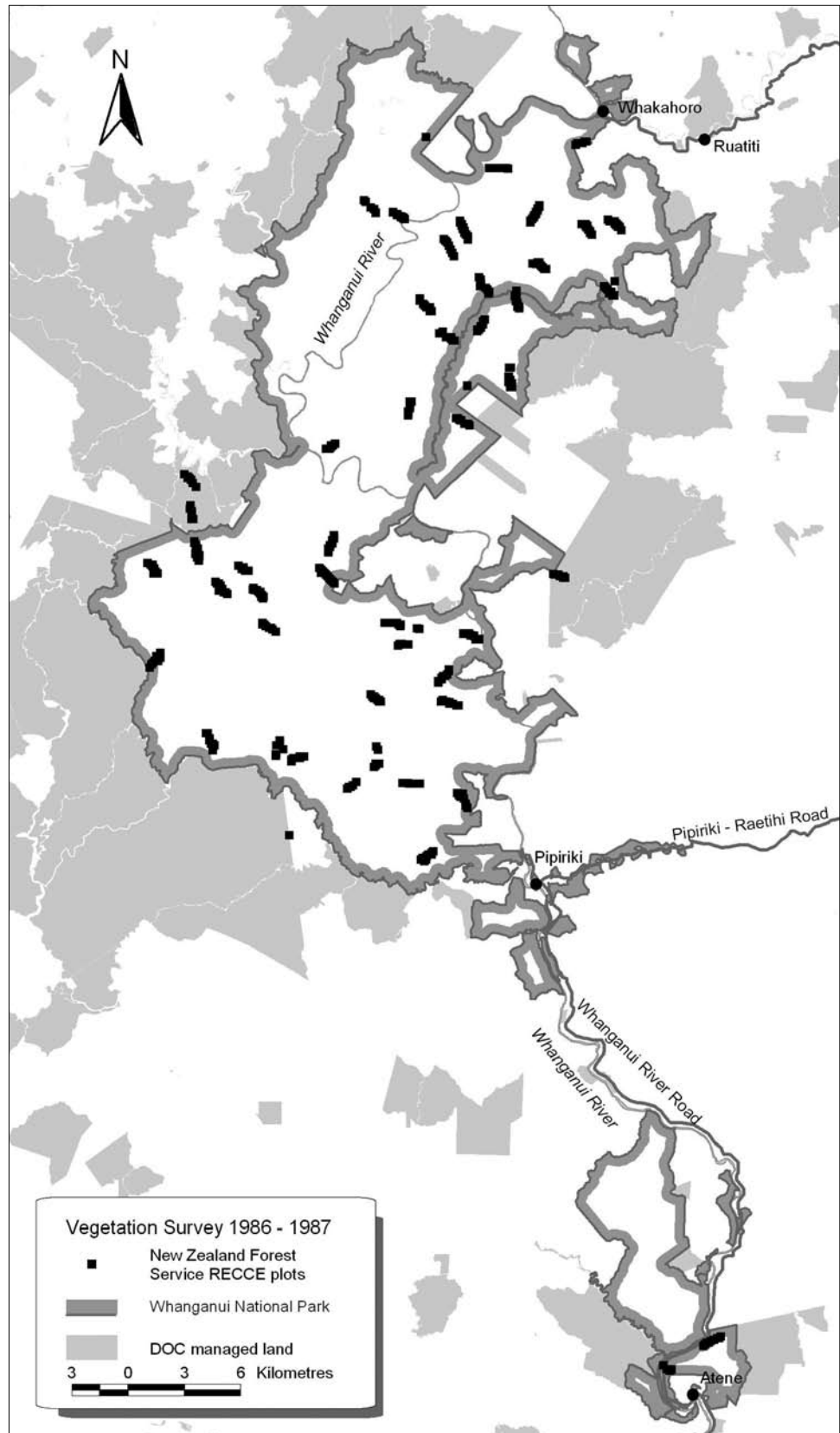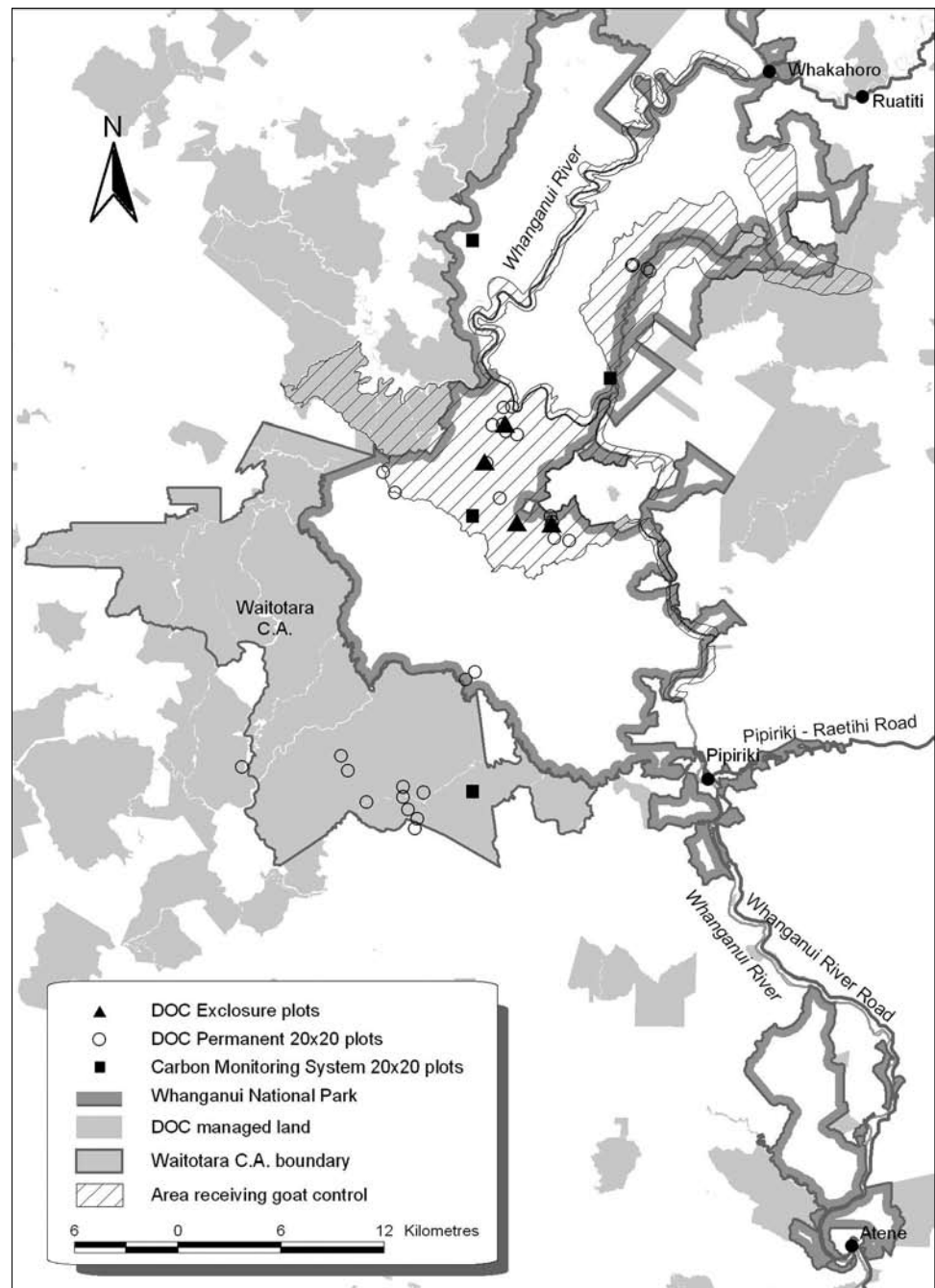
2.2 PERMANENT PLOTS

Between February 2001 and March 2006, 31 permanent 20 m × 20 m plots were established in and adjacent to forest of WNP. Plots were randomly located within 2–3 km of ten access points, to minimise access costs (Fig. 3). Four fenced exclosure plots were also established, and data from the control plots adjoining those was included in this analysis, increasing the sample size to 35. Fifteen 20 m × 20 m plots were established between 2002 and 2005 as part of the Ministry for the Environment's Carbon Monitoring System (Payton et al. 2004). Data from four of these were available at the time of analysis and were also included. Although 22 of the 39 plots are in areas receiving goat control, all represent forest without ungulate management, because data were collected either before or only 1 year after sustained management began.

Figure 3. Location of permanent forest plots and the four Carbon Monitoring System plots established between 2000 and 2006 that were used in the analysis.

Permanent 20 m × 20 m plot measurement procedures followed Allen (1993). All trees (these were generally stems over 30 mm diameter at breast height; DBH) were identified to species and the diameter over bark at breast height was measured. All saplings (individual plants > 135 cm high but less than 30 mm DBH) were counted and identified to species. Techniques for recording tree ferns were inconsistently applied (e.g. only recorded as seedlings in most plots even when recorded as > 2 m high in recce), so *Dicksonia* and *Cyathea* species were excluded from permanent plot analyses.

Within each plot, 24 understorey subplots (49 cm radius) were systematically located at 5-m intervals. All woody seedlings (15–135 cm high) were identified to species level and counted in four height classes (15–45 cm, 46–75 cm, 76–105 cm, 106–135 cm) in each subplot. For the purpose of analyses, seedling data were pooled into one height class (15–135 cm). Non-woody seedlings (e.g. *Microlaena avenacea* and *Uncinia* spp.) were not counted, making density estimates of those species a minimum based on the assumption that presence in a subplot indicated one plant. Plot location and site data were not routinely recorded for permanent plots.

2.3 DATA ANALYSIS

Extensive checking and correction of the Forest Service recce plot data was carried out as part of this research. Plot size, cover scores and tier heights did not appear to have been consistently applied or recorded, and in some cases field staff recorded cover classes as fractions (e.g. a cover class of 2.5 instead of 2 or 3). Heights specified as the division between tiers varied (e.g. tier 3 was defined as between 7 m and 10 m for some plots, but between 5 m and 12 m for others), so data for each plot were sorted into three broad tiers—seedlings (less than 1-2 m), saplings (between 1-2 m and 5–7 m) and trees (over 5–7 m)—depending on the divisions used at that particular plot. Variability in tiers and cover classes will affect the consistency of cover estimates used in analysis.

At each plot, altitude was estimated to the nearest 10 m, slope was estimated to the nearest 5° using an inclinometer, and aspect was estimated to the nearest 5° using a compass. For many plots, site data did not match vegetation data. In these instances, site data were not included in the plot summary used for analysis.

Summaries of forest composition were made using Detrended Correspondence Analysis (DCA) in CANOCO 4.0 (Ter Braak & Smilauer 1998). Importance values were calculated using tree cover scores from recce plots. Tree tier (> 5-7 m) cover scores were used to classify vegetation into six types:

- Beech: Plots where beech was present, regardless of other species present.
- Tawa: Plots where tawa had the highest cover score in the tier.
- Kamahi: Plots where kamahi had the highest cover score in the tier.
- Mixed: Plots where tawa and kamahi had the equal highest scores in the tier.

- Seral: Plots where the tree tier was dominated by any species indicative of secondary forest: wineberry (*Aristotelia serrata*), rangiora (*Brachyglottis repanda*), marbleleaf (*Caropdetus serrata*), *Coprosma robusta, C. lucida,* tutu (*Coriaria arborescens*), koromiko, hangehange, manuka, mahoe, *Pseudopanax* species, and pate (Levy 1923; Baxter 1988). Although qualitative vegetation descriptions also list 'tree ferns' as indicative of secondary forest, these were not included in the seral category because it was not certain which species were intended.

- Other: Plots where any other species (e.g. pigeonwood *Hedycarya arborea*) had the highest score. A gorse (*Ulex europeus*) dominated plot (33XT) was eliminated from DCA due to its unusual species cover scores.

These vegetation types were plotted to show DCA results.

The same data were used in Canonical Correspondence Analysis (CCA) to determine the effects of altitude, aspect, slope, physiography, latitude and longitude on tree species composition in recce plots. An automatic forward selection procedure was used in CCA using default options in CANOCO. Multiple regression in SYSTAT 10.0 (SPSS 2000) was used to explore the relationship between plot DCA axis 1 and 2 scores, the cover of common species (mean cover scores > 0.25), and plot aspect, altitude, slope and latitude ($P = 0.15$ to include and exclude in an automated forward stepwise procedure). Cover scores of important species in multiple regression (coefficients > 0.1) were then compared to DCA axis 1 and 2 scores using linear regression. Linear relationships for which $P > 0.05$ were graphically displayed (section 3.1).

To assess representation of common species in the two datasets, densities of seedlings, saplings and trees in the permanent 20 m × 20 m plots were averaged and compared with cover scores for corresponding height tiers from recce data (0.3–2 m, 2–5 m, 6–7 m, and > 5, 6 or 7 m). Species known to be epiphytes were deleted from tree tier data. Statistical tests were undertaken in SYSTAT (SPSS 2000).

Power analysis was used to investigate how many permanent plots would be needed to monitor outcomes of ungulate control. SamplePower (Borenstein et al. 2000) was used to find sample sizes required to detect hypothetical increases between 50% and 300% using a one-sample *t*-test based on the mean and standard deviation of current sapling density. The analysis used common species that were predicted to be susceptible to ungulate damage and therefore likely to increase in density as a result of control.