New Zealand's remaining indigenous cover: recent changes and biodiversity protection needs

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Cover: Remnant of beech forest cut and burned in the 1920s–1930s, Huiarua Station, Tokomaru Bay. *Photo: P. Morrison (1974).*

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CONTENTS

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ABSTRACT

There has been substantial loss of indigenous habitat in New Zealand's coastal, lowland and montane environments—and what does remain has little legal protection. We define five categories of environments that contain indigenous biodiversity most at risk of loss due to land clearance; risk was determined based on the level of legal protection and past habitat loss. Land clearance and loss of indigenous habitats continues across New Zealand, and highest rates of loss are occurring in the most threatened environments. Moreover, ecosystems in these most threatened areas support a disproportionate percentage of New Zealand's most threatened species and habitats. Thus, this pattern of clearance will exacerbate threats to biodiversity. We recommend that the Land Environments of New Zealand database (LENZ) be used to identify environments that are most threatened by land clearance. The Land Cover Database will need to be updated regularly to monitor progress in halting biodiversity declines.

Keywords: indigenous cover loss, at risk biodiversity

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1. Introduction

This work has four objectives, addressing the current status of New Zealand's indigenous cover and change, and the consequences of the latter:

- To explain the likely consequences for indigenous biodiversity of historical (prehuman to 2001/02) changes in indigenous land cover
- To identify New Zealand's terrestrial environments (as defined in the Land Environments of New Zealand database (LENZ); Leathwick et al. 2003b) that are most vulnerable to biodiversity loss
- To calculate the area of unprotected indigenous cover, identified in the national Land Cover Database (LCDB), in threatened land environments by local authority district
- To estimate the change in indigenous land cover from 1996/97 to 2001/02 in land environments, and the consequent likely change in risk to remaining biodiversity, in each local authority district and Department of Conservation (DOC) conservancy and area

1.1 BIODIVERSITY PATTERN AND PROCESS AT RISK OF LOSS

The persistence of biodiversity requires the protection of both biodiversity pattern (the 'full range' of biodiversity from genes to species, communities, habitats and ecosystems, and landscapes) and the ecological and evolutionary processes that sustain it (Margules & Pressey 2000; Moritz 2002).

Both pattern and processes are under threat in New Zealand. Indigenous biodiversity *pattern* is under threat from 'insufficient and fragmented habitat', while *processes* are under threat from 'introduced invasive species which damage their habitat and important ecosystem processes'.

1.2 RISK OF LOSS OF BIODIVERSITY PATTERN

The first objective of *The New Zealand Biodiversity Strategy* (*NZBS*) (DOC & MfE 2000: 41) regarding biodiversity on land addresses the threat posed to biodiversity pattern by insufficient and fragmented habitat. Specifically, Objective 1.1 for biodiversity on land is to:

- Enhance the existing network of protected areas to secure a full range of remaining indigenous habitats and ecosystems.
- Promote and encourage initiatives to protect, maintain and restore habitats and ecosystems that are important for indigenous biodiversity on land outside of protected areas.

Priority actions associated with this objective require New Zealand agencies to work to protect and maintain habitats and ecosystems important for indigenous

biodiversity that are not represented in the existing protected area network or at significant risk of irreversible loss or decline.

National databases can assist agencies to identify places where biodiversity pattern is at significant risk of loss or decline. In this work, we combine databases describing land environments, land cover and protected areas to determine the extent of past habitat loss and legal protection within land environments. We use past habitat loss and the legal protection status of land environments to indicate places where the risk of irreversible biodiversity loss or decline through land clearance (and the combined effects of fragmentation, pests, weeds and other pressures) is likely to be greatest.

Specifically, this work suggests that indigenous habitats remaining in land environments that have been much reduced in the past (much reduced environments) are likely to support some of New Zealand's rarest biodiversity today. Further loss of these indigenous habitats would be a major setback to the goal of maintaining a full range of biodiversity, and could result in disproportionate loss of species (see below). Effects of habitat fragmentation are also likely to increase the risk of biodiversity loss in much reduced habitats. Indigenous habitats remaining in land environments with little of their land area legally protected for conservation purposes (poorly protected environments) are also likely to contain biodiversity at high risk of loss. This is because indigenous habitats that are not legally protected are more likely to be cleared for future land development than legally protected habitats. Unprotected indigenous habitats are also less likely to be fenced against stock, and/or to receive regular pest and weed control to maintain biodiversity.

Work to protect, maintain and restore unprotected indigenous habitats in much reduced and poorly protected environments would, therefore, make a major difference to the security of a full range of New Zealand's biodiversity.

1.3 LIMITATIONS OF THE WORK

This work directs attention to places that are vulnerable to loss of biodiversity *pattern* only. Specifically, it identifies places where biodiversity is vulnerable because remaining habitats and ecosystems are likely to be at high risk from land clearance and vulnerable to the effects of fragmentation, and where the costs of further clearance to biodiversity could be disproportionately high.

The persistence of biodiversity requires protection not only of pattern but also of essential ecological and evolutionary *processes*. Therefore, agencies with responsibilities for biodiversity must allocate their resources to maintain both. This work does not identify places where biodiversity is vulnerable to pressures that damage ecosystem processes (e.g. predators, weeds, pollution, fire, drainage and/or extractive land uses such as selective logging and extensive grazing). These pressures threaten biodiversity processes in all environments in New Zealand, not just in those environments that are much reduced and poorly protected. Many indigenous species survive today only in relatively intact, extensive and well-protected environments, depend upon ecosystem attributes and processes that have been lost from more fragmented landscapes, and remain vulnerable to ubiquitous pests, weeds and extractive land uses that continue to degrade them.

Accordingly, this work does not suggest that indigenous habitats in much reduced and poorly protected land environments are the only places that require biodiversity protection. Nor do we suggest that maintaining indigenous habitats in relatively intact and well-protected environments is superfluous to the goal of halting biodiversity decline. We simply indicate that more intact and better-protected environments will tend to support biodiversity that is less threatened by direct land clearance and the effects of fragmentation than biodiversity in much reduced and poorly protected land environments.

Unfortunately, national, spatially explicit measures and estimates of process disruption are not yet available to reveal how risks to biodiversity processes are distributed across the landscape. Although the magnitude of impacts of pattern and process loss cannot be objectively compared at this time, we may be sure that their combined effect is considerably greater than loss of pattern (i.e. habitat loss) alone. Therefore, our assessment of threat to remaining indigenous biodiversity in environments on the basis of habitat (pattern) loss and legal protection will considerably underestimate actual threat.

2. Background

2.1 PAST LOSS OF BIODIVERSITY AND THE THREAT OF EXTINCTION

Historically, protection for New Zealand's indigenous biota has largely been opportunistic, expedient and ad hoc (Kelly 1980). As a consequence, the national network of protected areas is strongly skewed towards higher, wetter, mountainous environments, and there is little protection of habitats and ecosystems in productive lowland and montane environments. There has also been differential concentration of human impacts and loss or removal of indigenous biodiversity across New Zealand's environments. In general, environments of the alpine and upper montane zones remain dominated by indigenous cover, while environments of the warmer lower montane and lowland zones contain only traces of indigenous communities, as a consequence of more intensive land-use activities.

Similarly uneven patterns of protection and loss are evident in most nations in the world (see Pressey et al. 1993; Pressey 1994; Stewart et al. 2003). Worldwide, the consequences include increased loss and extinction of indigenous species in those habitats and ecosystems where indigenous habitat loss has been greatest, and where the proportion of land set aside for protection is smallest (e.g. Heijnis et al. 1999; Heydenrych et al. 1999; Gaston et al. 2002).

Direct (or 'active') clearance for human land use (e.g. ploughing, felling, planting in exotic forestry trees) is the principal cause of loss of indigenous cover in New Zealand. Some additional loss also occurs through attrition and the deterioration of fundamental processes (or 'passive' clearance; e.g. dieback of forest edges may be caused by browsing). The consequences of habitat loss for biodiversity are perhaps most plainly illustrated by the distribution of threatened plant species,

which is strongly skewed towards lowland environments (e.g. Rogers & Walker 2002). For example, of New Zealand's 278 Acutely and Chronically Threatened vascular plant species—the two highest categories of extinction threat in the New Zealand threat classification system of Molloy et al. (2002)—20% are coastal, 37% occur in the lowland zone and a further 31% in the montane zone, while the subalpine and alpine zones contain only 7% and 5%, respectively (de Lange et al. 2004). The concentration of threatened species at low elevations is also seen at the regional scale. For example, Lee & Walker (2004) report that 80% of the Acutely and Chronically Threatened vascular plants of the inland Central Otago District occur in the lowland and montane zones.

2.2 THE VULNERABILITY PRINCIPLE

It is recognised in New Zealand (e.g. in *NZBS* (DOC & MfE 2000: 41, Objective 1.1a, above)) and internationally (Margules et al. 1988, 2002; Rouget et al. 2003) that there is an urgent need to establish more representative networks of protected areas if much of today's biodiversity is to survive into the future. However, some species, habitats and ecosystems are less likely to persist under current and future land-use trends and pressures than others[1]. Therefore, over time, realistic opportunities for the protection of biodiversity are reduced, by incremental or rapid loss, to a subset of the full range. This subset will typically contain only those elements of the full range that are safest from clearance, pest invasion and other pressures (Pressey & Taffs 2001a, b; Rouget et al. 2003).

Because realistic opportunities for the protection of biodiversity decrease over time, achieving representativeness becomes less likely. If representativeness is to be achieved, priority for protection must be given to the most vulnerable elements of the full range of biodiversity pattern, i.e. those ecosystems, communities and/or species for which there is the greatest likelihood of imminent loss or degradation (World Resources Institute 1992; Pressey 1994; Pressey & Taffs 2001b).

This vulnerability principle ('priority for protection must be given to the most vulnerable elements of the full range') is emphasised in the *NZBS* (DOC & MfE 2000). For example, the first Priority Action (Objective 1, Biodiversity on Land, Action b) states that priority for addition to public conservation lands should be given to those 'habitats and ecosystems important for indigenous biodiversity that are not represented within the existing protected area network, or that are at significant risk of irreversible loss or decline'.

These two characteristics—poor legal protection and risk of loss—are two components of vulnerability.

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[1] For example, The *NZBS* (DOC & MfE 2000: 34) highlights a number of examples of imminently threatened 'scarce habitats' that remain largely unprotected and vulnerable to ongoing decline because of the pressure to clear land for intensive use (e.g. agricultural development, urbanisation) and/or the pressures imposed by introduced weeds. In contrast, most alpine and forest environments are comparatively safe from direct clearance, since they are largely legally protected, and are either unsuitable for human use or remote from human-induced pressures

2.3 LAND ENVIRONMENT UNITS

LENZ provides a national spatial framework of units ('land environments') to assess the vulnerability of remaining indigenous habitats and ecosystems. We use the measures 'poor legal protection' and 'susceptibility to biodiversity loss' (SBL), respectively, to represent the two components of vulnerability within land environments.

2.4 INDICATING POOR LEGAL PROTECTION

New Zealand is an island with an unusual evolutionary history of prolonged isolation, and its indigenous biodiversity is distinctive and particularly vulnerable to introduced herbivores, predators and weeds (e.g. Atkinson & Cameron 1993). These ubiquitous pressures reduce the viability and persistence of biodiversity across the landscape (including legally protected areas), and active ongoing intervention is generally needed to secure biodiversity (Perley et al. 2001). The combination of innate vulnerability with extreme habitat loss in lowland environments has resulted in New Zealand having one of the worst records of biodiversity loss of anywhere on earth (DOC & MfE 2000: 4). In Australia and other Commonwealth nations, legal protection of 15% of original ecosystem extent has been adopted as a pragmatic (and arbitrary) target for conservation planning purposes (e.g. Pressey & Taffs 2001a). However, to sustain biodiversity in New Zealand, it is probably necessary to retain and actively manage indigenous biodiversity across greater proportions of the original ecosystem than in most other nations.

Accordingly, we suggest that in New Zealand a safety net of legal protection covering at least 20% of the original area of each land environment is desirable to retain a full range of biodiversity (see Lee & Walker 2004; Walker & Lee 2004; Walker et al. 2004). Support for this suggestion is also drawn from the species–area relationship (see section 2.5.1), which indicates that indigenous biodiversity decreases particularly rapidly once less than about 20% of original habitat remains (but as we note in section 2.5.2, the onset of rapid decline may occur earlier owing to isolation, co-extinction and other associated factors).

2.5 INDICATING RISK OF LOSS (SBL)

Generalisations from ecological research suggest that risk of future biodiversity loss is related to the extent of past loss of natural habitat. Below we give synopses of two relevant generalisations from ecological science: species–area relationships and fragmentation effects[2].

[2] The species–area relationship and fragmentation effects are the basis for various international predictions of extinction risk related to habitat loss (see for example Brooks et al. 1997, 1999; Fahrig 1997, 2002; Thomas et al. 2004).

2.5.1 The species–area relationship

Characteristics of the species–area relationship

The generalised species–area relationship describes the relationship between area of habitat and that habitat's species richness (i.e. the number of species) (Rosenweig 1995) (Fig. 1). The relationship between the extent of an area (A, being the proportion an area relative to a reference area) and the number of species (S, being the proportion of species relative to a reference number of species) that it holds is not linear, but a curve, usually described by the generalised power function ($S = A^z$ where $z < 1$). That is, the number of species contained in any area (be this a quadrat, a paddock, a lake or a mountain range) will be more than half the number of species in an area twice that size.

The species–area relationship is derived from the sampling of areas of different size and is a consequence of the manner in which species are distributed along environmental and geographic gradients. The shape of the species–area curve depends on body size and life history and, therefore, differs for different biotic groups (e.g. vertebrates, plants, micro-organisms). It also varies across different habitats, ecosystems and landscapes. Nevertheless, the general shape of the curve remains the same (Fig. 1).

The species–area relationship predicts that any loss of part of the area occupied by an ecosystem, habitat or community will lead to the loss of some species associated with it. With initial decreases in area (upper right portion of the curves in Fig. 1), the rate of species loss may be relatively low. The plants and animals most likely to be lost from a habitat at this early stage of habitat loss include large-bodied, host-dependent, and/or habitat-specialist species with a narrow range, as well as those dependent on large, contiguous habitats.

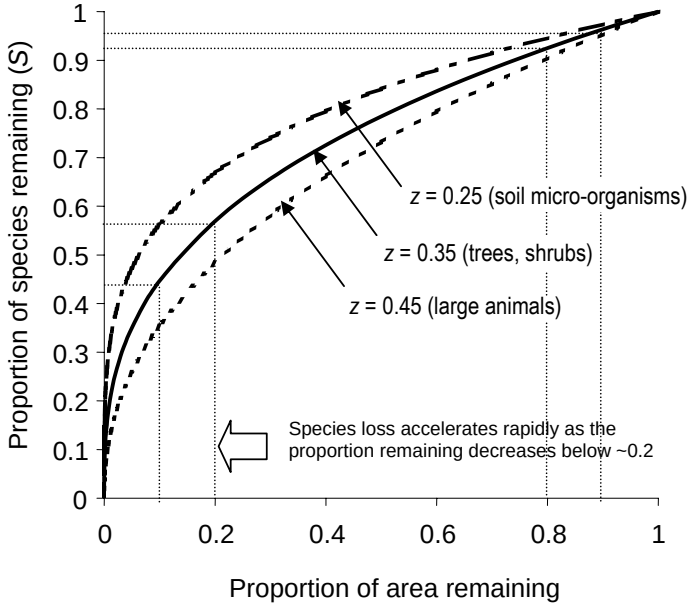

Figure 1. Generalised species–area relationship applied to the proportion of indigenous habitat remaining (A), showing curves for biota of different body size (z = 0.25, 0.35 and 0.45). The vertical and horizontal lines are interpreted in the text.

As habitat area is further reduced, the rate of species loss increases, and biota in smaller size classes also become affected (middle portion of the curves in Fig. 1) together with more wide-ranging, generalist species. As the area of indigenous habitat decreases, each increment of further loss results in a greater magnitude of loss of remaining biodiversity (lower left portion of the curves in Fig. 1). However, because of the nature of the relationship between area and richness, the last indigenous remnants in an environment are predicted to still contain a proportion of the biodiversity associated with that environment.

Indicating SBL using the species–area relationship

A species–area relationship with an exponent (z) of 0.35 (see Fig. 1) may be an appropriate 'average' to apply to biodiversity protection in New Zealand. This exponent represents the end of the range of 0.25–0.35 suggested for islands (Rosenweig 1995) and is most appropriate for prominent components of vegetation, which are readily recognised (including by remote sensing), and is often pragmatically used as a surrogate for other elements of indigenous biodiversity.

The curve of the species–area relationship with an exponent $z = 0.35$ predicts that a 10% change from 90% to 80% remaining habitat (i.e. a change in the proportion remaining from 0.9 to 0.8) will remove 3.9% of the original full complement of species and 4.0% of those remaining in an area, but a 10% reduction from 20% to 10% remaining habitat removes 12.3% of the original full complement of species and 21.5% of the species remaining. (These different rates of loss are indicated by the distances between each pair of horizontal lines in Fig. 1.)

We refer to this increasing rate of loss as habitat loss proceeds as 'susceptibility to biodiversity loss' or 'SBL'. It can be quantified as a function of the proportion or area of habitat remaining, being the derivative of the generalised species–area relationship (i.e. the slope, or instantaneous rate of change at any point; Fig. 2).The mathematical expression to calculate SBL is based on a generalised species–area relationship with an exponent of 0.35:

$$\text{SBL} = 0.35 \times (\text{proportion remaining indigenous cover}^{(0.35 - 1)}).$$

SBL ranges from 0.35 in an intact habitat to infinity when habitat area remaining is negligible (Fig. 2).

In this work, we use SBL to indicate the relative impact of any increment of further habitat loss within an environment, based on the loss that it has undergone in the past.

2.5.2 Fragmentation effects

The species–area relationship and SBL indicate the likely non-linear consequences of loss of habitat area for remaining biodiversity. However, in biological systems, habitat loss and fragmentation also alter the *nature* of habitat, with negative consequences for biodiversity beyond that due to the loss of habitat area alone.

Some fragmentation effects, like area effects, are also non-linear. In other words, as with the species–area relationship, their effects increase more rapidly in severity as habitat loss advances. For example, Andrén (1994) demonstrated that there is a rapid increase in the average distance between habitat patches (isolation) as the proportion of habitat in a landscape decreases below about 0.3 (or 30%) (Fig. 3).

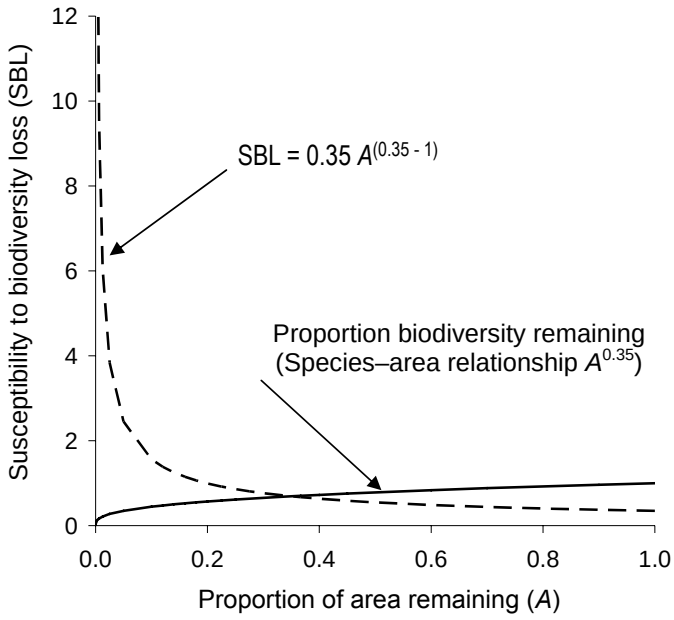

Figure 2. Susceptibility to biodiversity loss (SBL) v. the proportion of species remaining for each land environment (*A*). SBL is the instantaneous rate of change at any point of the species–area curve where $z = 0.35$.

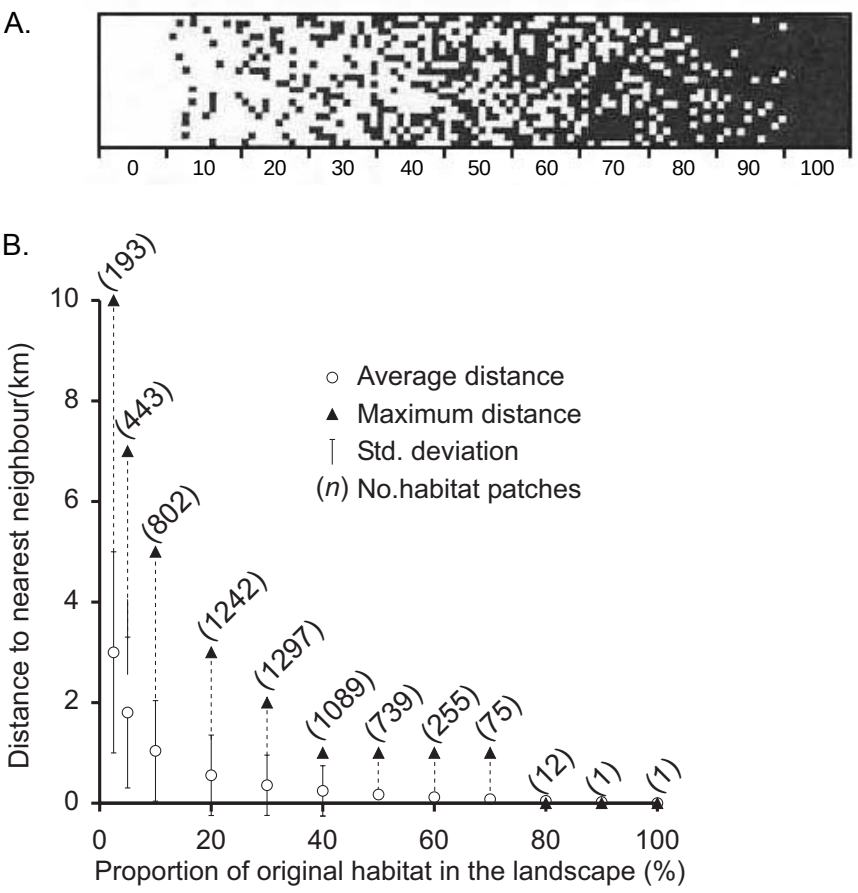

Figure 3. Average and maximum simulated isolation (distance to nearest neighbouring habitat) in relation to the proportion of habitat remaining based on simulations of habitat fragmentation (redrawn from Andrén (1994)). A: One possible configuration of fragmentation of habitat (black pixels). B: Average and maximum isolation of remaining pixels derived from multiple random spatial configurations of fragmentation for different proportions of remaining habitat.

Increased distance between habitat patches can: limit species' access to key resources; restrict the potential of migration for species and populations (for example, as climate change progresses); and prevent the exchange of genetic material between populations. Resulting inbreeding then lowers long-term viability and limits resilience (i.e. ability to survive extremes or adapt to change). For a New Zealand example, see Berry et al. (2005). Andrén (1994, 1996) suggested that increased isolation may lead to sharp population declines once a threshold of loss (generally between 10% and 30% habitat remaining) is exceeded. As with the species–area relationship, this threshold is likely to vary across different landscapes and biotic groups.

The ratio of fragment edge to fragment interior area also increases exponentially as the average habitat patch area decreases with increased habitat loss. Small fragments in modified landscapes may be largely or entirely edge habitat (i.e. they have little or no buffered interior). The adverse physical and biological consequences of high edge-to-interior ratios include increased exposure to desiccation and climate extremes, and increased penetration by weeds and pests (Harrison & Bruna 1999).

Effects of fragmentation may contribute to more rapid biodiversity loss, and higher risk to remaining indigenous biodiversity, than would be predicted by habitat area loss alone. Consequently, the onset of rapid loss of biodiversity is likely to commence earlier, and declines may be more rapid than suggested by the species–area relationship and measures such as SBL that are based on it.

2.5.3 Limitations of the SBL measure

The SBL measure indicates the relative risk to remaining indigenous biodiversity within any land environment, based on the species–area relationship. Our application of the index is straightforward: environments are treated as individual units, and no attempt is made to account for relationships among environments (e.g. the effect of habitat loss within one environment on biodiversity within another, adjacent or similar environment). The index does not quantify actual biodiversity either within or across environments; this is because understanding of potential and actual biodiversity patterns is still too rudimentary to allow us to do so. It is very likely that more sophisticated measures of risk to indigenous biodiversity across landscapes will be developed in the future, based on a deeper and more detailed understanding of actual and potential biodiversity pattern within and across environments.

2.6 THREAT CATEGORIES FOR NEW ZEALAND'S LAND ENVIRONMENTS

We propose a classification of threat to the remaining indigenous biodiversity in New Zealand's land environments based on the two components of vulnerability (likelihood of loss): poor legal protection and risk of loss.

We use the past level of habitat loss (represented by percentage remaining indigenous cover) as the primary threat criterion. Based on the above principles (species–area relationships and fragmentation effects), remaining indigenous biodiversity within environments with less than 30% indigenous cover is

considered 'threatened' by land clearance (Table 1). Indigenous biodiversity is classified as 'At Risk' in environments where 20–30% of indigenous cover remains, and 'Chronically Threatened' in environments where 10–20% indigenous cover remains. When less than 10% of indigenous cover remains, indigenous biodiversity is considered to be 'Acutely Threatened'. We have chosen the terminology for these three threat categories to be consistent with the national system for classifying species according to threat of extinction (Molloy et al. 2002)[3].

Two further threat categories are erected to take poor legal protection into account (Table 1). Environments that have more than 30% indigenous cover remaining and are poorly protected (i.e. they have less than 20% of their area under legal protection) are categorised as 'Critically Underprotected' if less than 10% is protected, and 'Underprotected' if 10–20% is protected.

For convenience, we refer to environments within any of these five categories as 'threatened environments'.

Environments that have been less preferred for intensive land uses in the past, and have a fifth or more of their land area protected against future loss, fall into a sixth category that we name 'Less Reduced and Better Protected' (more than 30% indigenous cover remains, and over 20% of it is protected). This name reflects that biodiversity within these environments is not entirely secure; rather, it remains vulnerable to future loss should land-use patterns change, and to ubiquitous pests and weeds. Vulnerable elements of the full range of biodiversity (e.g. large-bodied, host-dependent and/or habitat-specialist species with a narrow range, and those dependent on large, contiguous habitats) will be lost from environments well before loss of 70% of original habitat has occurred. Therefore, environments that are less reduced and better protected today support indigenous species that can survive only in relatively intact, extensive and well-protected environments. Their persistence will depend on the maintenance of extensive areas of native cover, and of healthy, functioning ecosystem processes that have been lost from the more fragmented landscapes represented in threatened environments.

TABLE 1. THE SIX RECOMMENDED LAND ENVIRONMENT CATEGORIES, AND DEFINING CRITERIA.

NO.	CATEGORY	CRITERIA
1	Acutely Threatened	< 10% indigenous cover remaining
2	Chronically Threatened	10–20% indigenous cover remaining
3	At Risk	20–30% indigenous cover remaining
4	Critically Underprotected	> 30% indigenous cover remaining, < 10% legally protected
5	Underprotected	> 30% indigenous cover remaining, 10–20% legally protected
6	Less Reduced and Better Protected	> 30% indigenous cover remaining, > 20% legally protected

[3] The New Zealand threat classification system was designed specifically for taxa that occur in New Zealand. Three higher-order categories and seven classes of threat are recognised, in order of increasing threat: At Risk (Range Restricted and Sparse classes), Chronically Threatened (Serious Decline and Gradual Decline classes), Acutely Threatened (Nationally Critical, Nationally Endangered and Nationally Vulnerable classes).

3. General methods

3.1 DATA SOURCES

Five sources of spatial data in digital format (GIS shapefiles and grids) were used in the analyses.

3.1.1 Land Cover Database

Three versions of the Land Cover Database are available:

- LCDB 1_2 (derived from satellite imagery acquired in 1996/97, second version, released in 2001, 14 cover classes)
- LCDB 1C (corrected version, derived from satellite imagery acquired in 1996/97, released July 2004, 43 classes)
- LCDB 2 (derived from satellite imagery acquired September 2001–March 2002, released July 2004, 43 classes) (Terralink 2004)

We used LCDB 1C as the principal data source defining the status of indigenous cover in New Zealand in the summer of 1996/97. LCDB 2 was used to represent land cover in 2001/02. Note that in this report LCDB 1C is referred to as 'LCDB 1' and that LCDB 1_2 data are presented only in section 4.6.

The 43 classes of land cover within LCDB 1 and LCDB 2 were assigned to indigenous (22 'natural' LCDB 2 cover classes) and non-indigenous (21 'exotic' LCDB 2 cover classes) categories (Appendix 1). A third category (non-indigenous cover recently disturbed, 'NIRD') was developed for LCDB 2 and represents areas that had been classified as 'Non-indigenous' in 1996/97 that had changed by 2001/02 to one of the following LCDB 2 classes: 10, Coastal Sand and Gravel; 11, River and Lakeshore Gravel and Rock; or 12, Landslide. Because NIRD areas do not represent recovery of indigenous vegetation, and are unlikely to revert to indigenous cover over time, we assigned them to non-indigenous cover.

As stated previously, past level of habitat loss was to be our primary threat criterion, so the percentage of indigenous cover remaining in an environment in 2001/02 (based on indigenous cover classes of LCDB 2) was used to estimate the risk to remaining biodiversity within that environment, i.e. its SBL. Change in the percentage of indigenous cover remaining in an environment between 1996/97 and 2001/02 was used to estimate the change in the risk to indigenous biodiversity within an environment.

3.1.2 LENZ

The LENZ classification (Leathwick et al. 2003b) identifies the diversity of New Zealand's terrestrial environments, based on climate, soil and landform. Because these factors are major drivers of the patterns of living organisms, it is reasonable to assume that each different environment supported a unique assemblage of ecosystems, habitats and species in the past—not different in all respects, but in important features, from that in other environments. LENZ can, therefore, be used as a surrogate for the potential 'full range' of terrestrial ecosystems, habitats and biodiversity once found across New Zealand.

Land environments are classified at four different national scales: Level I (20 land environments, A to T), Level II (100 land environments, A1 to T1), Level III (200 land environments, A1.1 to T1.1) and Level IV (500 land environments, A1.1a to T1.1a). Each level is nested within higher levels.

Because LENZ is not a map of ecosystems or vegetation, but a map of abiotic environments; the boundaries often divide environmental gradients that are generally not visible on the ground. Because environmental gradients are often gradual rather than sharp, and because the land cover seen on the ground today is the product of both history and environment, current vegetation patterns are most unlikely to ever match LENZ boundaries. Even at the finest level of LENZ (Level IV), each land environment is likely to contain a variety of native habitats and ecosystems that grade continuously into habitats and ecosystems of adjacent environments. Loss and protection statistics for a land environment are an average taken across the different native habitats and ecosystems contained within it.

3.1.3 Protected areas

We used the 'protection' dataset compiled for MfE, DOC & LGNZ (2004), comprising land managed by DOC, and covenants administered by the Nature Heritage Fund, Nga Whenua Rahui and Queen Elizabeth II National Trust. Limitations and methods relating to these data are described by Rutledge et al. (2004). Note that council-protected lands are not included in this dataset.

The percentage area of land and/or indigenous cover of a land environment that is protected (i.e. set aside for biodiversity conservation purposes) is a useful index of how well the ecosystems, habitats and biodiversity associated with that environment are protected from further loss (Leathwick et al. 2003a; Lee & Walker 2004).

3.1.4 Districts, regions, DOC conservancies and areas, and pastoral leases

To define political districts and regions, we used national GIS databases delineating 73 local authority districts and cities, and 16 local authority regions. We did not split political districts where they spread across more than one political region (e.g. Franklin District, which spreads across Auckland and Waikato regions, was kept distinct) (Table A2.1). DOC supplied spatial data showing its conservancy and area boundaries in August 2006. To define the spatial extent of the 304 pastoral leases in the South Island high country, we used a spatial database of lease boundaries supplied by DOC in January 2004.

3.1.5 Land-use capability

Eight classes of Land-use capability (LUC) were used from the NZLRI (New Zealand Land Resource Inventory; held by Landcare Research). The NZLRI is a spatial database of 100 000 polygons (land parcels) covering the whole of New Zealand. The characteristics or attributes (e.g. rock, soil, slope, erosion, vegetation, LUC) of each parcel of land is described. LUC is an assessment of the land's capacity for sustained productive use taking into account physical limitations, soil conservation needs and management requirements. 'Class' is the most general unit of LUC, categorising land into eight classes, from Class I (the most versatile and productive class with the highest value for agricultural production) to VIII (the class with most limitations to use and, therefore, the lowest value for agricultural production).

All shapefiles were converted to 25-m grids for analysis. The spatial database and analysis methods were based on, and described by, Rutledge et al. (2004).

3.2 DATA ANALYSIS

3.2.1 Identifying threatened environments

Using LENZ, LCDB 2, and the protection dataset, we calculated (1) the total area of each land environment and (2) the area of each land environment within an indigenous cover class (hereafter referred to as 'indigenous cover remaining'), and (3) the area of each land environment that was legally protected. Then, for each of the five environment threat categories, we calculated the number of land environments, the total area of the environments, and the total area of indigenous cover.We then assigned each land environment to one of six categories, based on the criteria in Table 1. This analysis was performed twice, with categories determined at Levels IV and II of LENZ, respectively.

To provide an overview of the distribution of threat categories across New Zealand's land environments, we (1) calculated the number of Level IV land environments in each threat category within each Level I land environment, and (2) mapped the national distributions of threatened environments.

3.2.2 Indigenous cover not protected

We calculated the area of each land environment that was under indigenous cover and not within legally protected land (indigenous cover not protected, hereafter 'INP') in 2001/02. We then calculated the area of indigenous cover not protected in the first five land environment categories referred to as 'threatened environments' (hereafter 'INPTE'). Next, we calculated the area of INPTE in each of New Zealand's 73 district councils in DOC conservancies and areas, and in each threatened environment category. We also calculated the area of INPTE within the boundaries of the 304 pastoral leases remaining in the South Island High Country. Again, each of these analyses was performed twice, with land environment threat categories determined at Levels IV and II of LENZ, respectively.

3.2.3 The appropriate LENZ level to assess threatened environments

Next, we compared the effectiveness and efficiency of threat categories determined at Level II and Level IV. First, we illustrated effectiveness and efficiency by examining variability of protection and land clearance, of biodiversity pattern, and of current land cover types across Level IV environments within a given Level II environment (F1).

We then quantified, across all land environments, land areas affected by two issues arising from threat classification at Level II, rather than Level IV. First, we quantified the *less effective* protection that would arise because the areas are assigned to a lower category of threat, or to the 'Less Reduced and Better Protected' category. Second, we quantified the *less efficient* protection resulting from areas of indigenous cover being classified as 'threatened' when in fact they were less reduced and/or better protected.

3.2.4 Land-use capability in areas under indigenous cover, but not protected, in threatened environments

We calculated the area of indigenous cover not protected (INP) in each of eight LUC classes and each of the six land environment categories. This analysis was performed twice, with land environment categories determined at Level IV and Level II of LENZ.

3.2.5 Changes in indigenous cover from 1996/97 to 2001/02 and subsequent risk to remaining biodiversity

By comparing LCDB 1 and LCDB 2, we quantified the total change and net loss of indigenous cover from 1996/97 to 2001/02 by environment threat category and indigenous cover class. We calculated the rate of loss of indigenous cover from 1996/97 to 2001/02 in each land environment as a percentage of LCDB 1 (i.e. 1996/97) indigenous cover. We then calculated the change in SBL for each Level IV land environment from 1996/97 to 2001/02, based on the total area (and hence proportion) of indigenous cover remaining at each date.

We compared these changes across land environment threat categories determined at LENZ Level IV only. We quantified the contribution of each of the 73 council areas, and each DOC conservancy and area, to change in indigenous cover, and to summed change in SBL across New Zealand's land environments from 1996/97 to 2001/02, by threatened environment category.

3.3 DATA LIMITATIONS

Existing national large-scale environmental, biological and protection databases are surrogates for the pattern of environments, biota and protection across New Zealand. They all have limitations for application on the ground at the scale of individual properties and areas. Particular concerns, and some implications, are noted below.

3.3.1 Environmental information

LENZ is based on 15 environmental variables with known relevance (e.g. trees, ferns, land snails) for biodiversity pattern. It does not contain all of the environmental variables that affect biodiversity pattern. It is of limited use in identifying small-scale ecosystems and habitat types that are controlled by local, extreme environmental conditions such as limestone outcrops (karst), and geothermal and various wetland (and floodplain) ecosystems.

3.3.2 Land cover

In these analyses, we took the cover classes in LCDB 1 and LCDB 2 'at face value'. However, the cover data are not accurate. We know there are misclassifications and errors in both databases, but not their full magnitude or locations. Because of mapping/classification error, and the broad scope and qualitative nature of the cover classes (Grūner & Gapare 2004), LCDB 2 cover classes cannot and should not be relied upon to assess whether cover for a given location is in fact indigenous. Field inspection is needed to verify this.

Some cover classes are mixed and particularly problematic to categorise as either indigenous or non-indigenous. For example, Depleted Grassland ground cover is often dominated by the exotic flatweed *Hieracium pilosella*, but native species may dominate in number (e.g. Meurk et al. 2002). We assigned it to the Indigenous category based on expert opinion. Low-Producing Grassland includes some completely exotic cover (e.g. coastal marram grass, sweet vernal and browntop extensive pasture) but also grasslands of variable native and exotic composition dominated by indigenous short tussocks. Based on expert opinion that this class is primarily exotic across New Zealand, we have assigned it to the Non-indigenous category.

Only one cover class (Herbaceous Freshwater Vegetation) is provided for wetlands, and we have assigned it to the Indigenous category. Hence, our figures assume that all wetlands still support native cover, which is unrealistic. Consequently, some environments that support extensive wetlands that have been substantially modified by unsympathetic land use (e.g. Environment L3.1a on the Southland Plains, in the Less Reduced and Better Protected category) will incorrectly be assigned to less threatened categories.

3.3.3 Protection information

The protection dataset used for this analysis has several limitations, such as the inclusion of some Crown land managed by DOC for purposes other than conservation (e.g. buildings, gravel reserves, racecourses, cemeteries, marginal strips) (Walker et al. 2004) and inaccuracies associated with covenant boundaries (Rutledge et al. 2004). These sources of error will tend to increase estimates of protected land in threatened environments. On the other hand, council-protected areas (including regional parks such as the Hunua Ranges near Auckland) and certain types of privately protected land (including biodiversity sanctuaries such as the ecological island at Mt Maungatautari in the Waikato) are not included in the protected dataset. Consequently, the area of indigenous vegetation not protected in some districts will be overestimated.

4. Results

4.1 INDIGENOUS COVER AND THREATENED ENVIRONMENTS IN 2001/02

Approximately two-thirds of New Zealand's land environments were classified within one of the five categories of threatened environment (67% of environments if categories were determined at LENZ Level IV, and 63% of environments if categories were determined at Level II) (Table 2).

The five threat categories accounted for 54% or 53% (with categories determined at LENZ Levels IV and II, respectively) of the total land area of New Zealand. This implies greater environmental heterogeneity (and hence greater potential biodiversity) in threatened environments than across land not assigned to a threat category in our classification. In other words, past biodiversity loss has

been concentrated in the most environmentally diverse (and hence probably biologically diverse) regions of New Zealand.

Less than half of New Zealand's land area (12 632 214 ha, or 49%) was under some form of indigenous cover (Table 2). Acutely Threatened, Chronically Threatened and At Risk environments (i.e. those with < 30% indigenous cover remaining) represented 57% of Level IV environments and 42% of New Zealand's land area (Level IV), and 51% of Level II land environments and 41% of New Zealand's land area (Level II).

The two categories with the highest SBL (Acutely and Chronically Threatened environments, both with less than 20% of indigenous cover) together account for 46% of environments and 32% of New Zealand's land area (at Level IV), or 42% of environments and 26% of New Zealand's land area (at Level II). The area of indigenous cover that remains in Acutely and Chronically Threatened environments is 565 751 ha (6.9% of the total land area of these 232 Level IV environments), or 445 215 ha (6.8% of the total land area of the 42 Acutely and Chronically Threatened Level II environments).

The largest portion of New Zealand's threatened environments have less than 10% of indigenous cover remaining, and fall within the category of highest risk to remaining biodiversity (Acutely Threatened). Acutely Threatened environments account for 32% of Level IV land environments and 23% of total land area (at Level IV), or 29% of Level II environments and 19% of New Zealand's total land area (at Level II). The average percentage of indigenous cover that remains in Acutely Threatened environments is 3.8% (Level IV) or 4.5% (Level II), i.e. towards the lower end of the 0–10% range.

TABLE 2. NEW ZEALAND'S LAND ENVIRONMENT CATEGORIES IN 2001/02, SHOWING THE PERCENTAGE OF THE TOTAL NUMBER OF ENVIRONMENTS IN THE SIX LAND ENVIRONMENT CATEGORIES (% OF LENZ), THE PERCENTAGE OF THE TOTAL NEW ZEALAND LAND AREA THAT THIS AREA REPRESENTS (% OF NZ) AND THE PERCENTAGE OF LAND WITHIN THAT LAND ENVIRONMENT CATEGORY (% OF FULL EXTENT).

	LENZ LEVEL	TOTAL	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDER-PROTECTED	UNDER-PROTECTED	LESS REDUCED AND BETTER PROTECTED
Number of environments								
No. of	IV	500	158	74	52	33	18	165
LENZ	II	100	29	13	9	6	6	37
% of	IV	100.0	31.6	14.8	10.4	6.6	3.6	33.0
LENZ	II	100.0	29.0	13.0	9.0	6.0	6.0	37.0
Full extent of environments								
Area	IV	26 000 680	5 888 292	2 323 074	2 788 941	1 825 031	1 158 487	12 016 855
(ha)	II	26 000 680	4 983 260	1 674 228	4 090 474	772 143	2 138 778	12 341 796
% of	IV	100.00	22.65	8.93	10.73	7.02	4.46	46.22
NZ	II	100.00	19.17	6.44	15.73	2.97	8.23	47.47
Indigenous cover remaining in environments								
Area	IV	12 632 214	220 862	344 889	674 218	794 673	663 006	9 934 566
(ha)	II	12 632 214	223 886	231 329	1 125 322	328 852	1 056 026	9 666 799
% of	IV	48.58	3.75	14.85	24.17	43.54	57.23	82.67
full extent	II	48.58	4.49	13.82	27.51	42.59	49.38	78.33

Figure 4 illustrates the uneven distribution of threatened environments across New Zealand's 20 Level I environments. Level I environment N (Eastern South Island Plains) contains the highest number of Acutely Threatened Level IV environments (26), followed by environment B (Central Dry Lowlands) with 24. The three Level I environments F (Central Hill Country & Volcanic Plateau), J (Central Well-Drained Recent Soils) and A (Northern Lowlands) each contain 15 Acutely Threatened Level IV environments. In contrast, the least modified Level I environments (O, P, R, S and T) contain no Level IV environments with less than 30% indigenous cover remaining, and only one (S1.1a) has less than 20% of its land area protected.

The maps in Figure 5 show the distribution of threatened environments in New Zealand, and indicate that the categories of highest risk to indigenous biodiversity are in lowland environments.

4.2 INDIGENOUS COVER NOT PROTECTED IN THREATENED ENVIRONMENTS

Table 3 contains summary statistics for indigenous cover not within protected areas (INP).

Based on our Indigenous/Non-indigenous categorisation, 38% of New Zealand's indigenous cover (excluding reserves) was not legally protected (Table 3). In the five threatened environments categories, high percentages (c. 60–90%) of indigenous cover were not legally protected. In environments assigned to the sixth category (Less Reduced and Better Protected), lower percentages (c. 27–28%) of indigenous cover were not protected.

Acutely Threatened and Chronically Threatened environments contained smaller total areas of INP than At Risk environments at both LENZ levels (Table 3). The

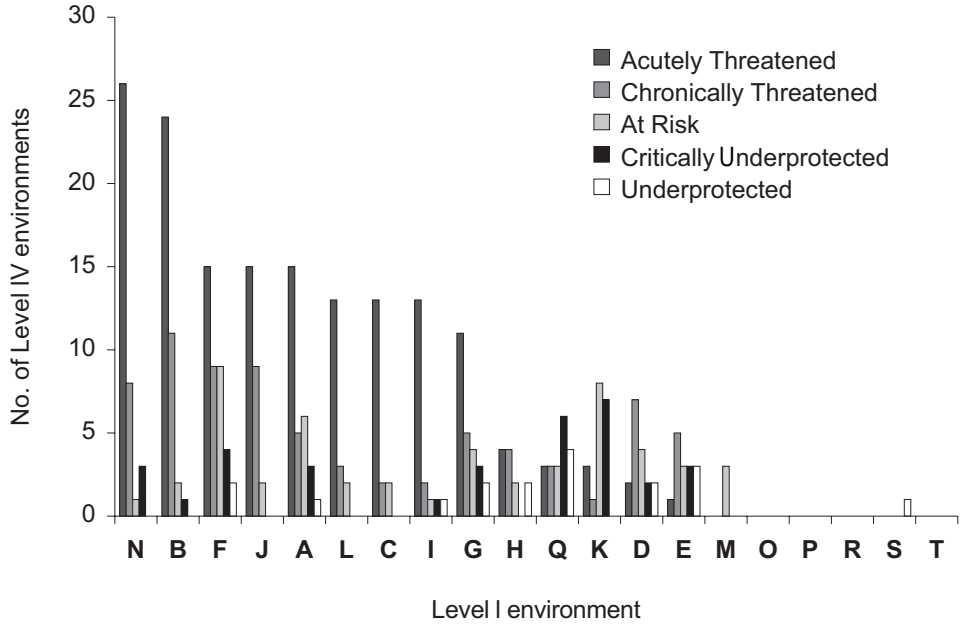

Figure 4. Number of threatened Level IV LENZ land environments in New Zealand's 20 Level I environments (A to T, arranged in order of decreasing threat to indigenous biodiversity).

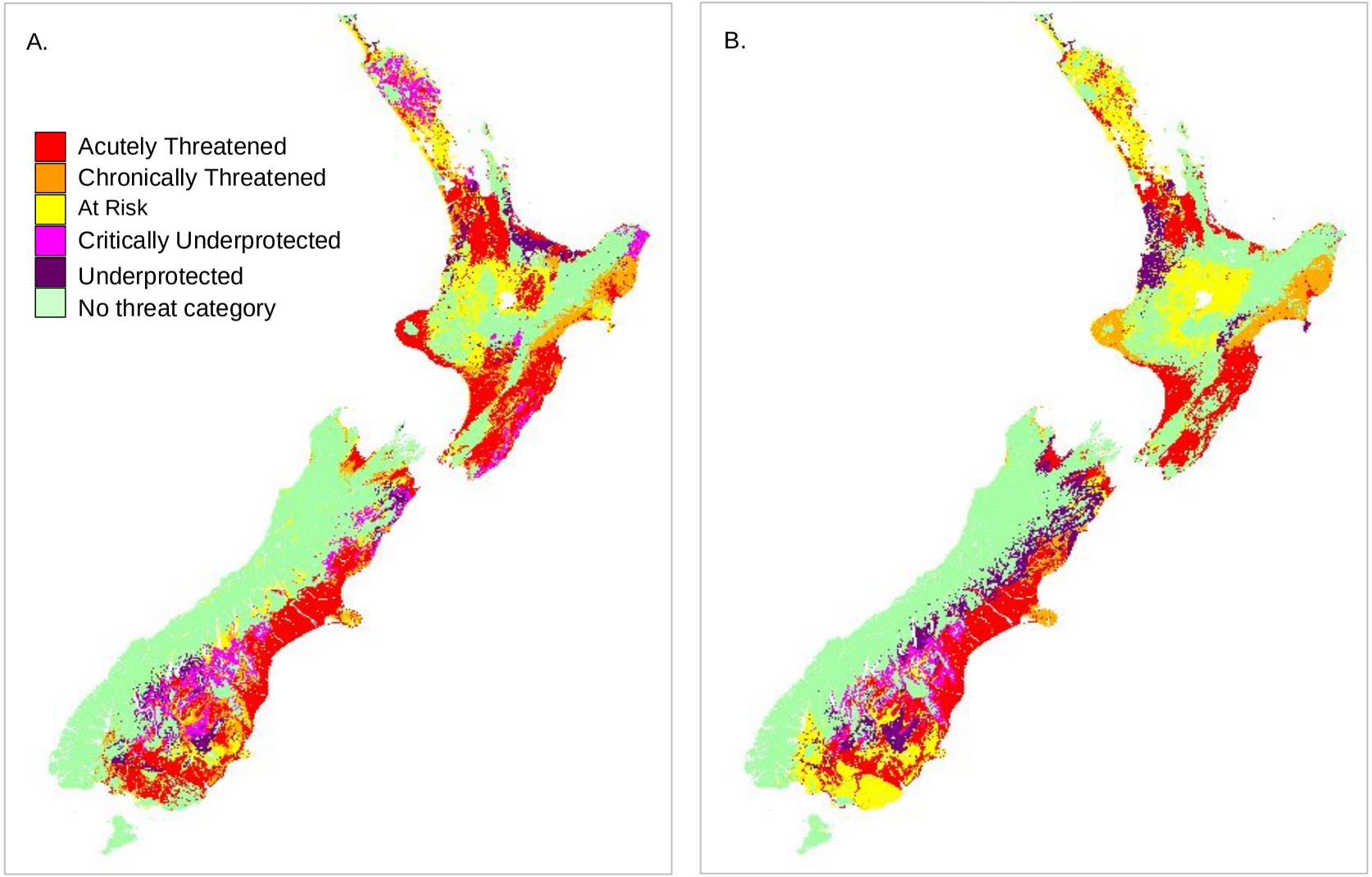

Figure 5. New Zealand's threatened environments. A: Level IV of LENZ. B: Level II of LENZ.

largest areas of INPTE were in environments in the Critically Underprotected and Underprotected categories, i.e. environments having more than 30% of indigenous cover remaining (at Level IV and Level II).

The areas covered by the LCDB 2 classes of INP in the five environment threat categories (i.e. INPTEs) are presented in Table 4 (at LENZ Level IV) and in Table 5 (Level II). In Acutely Threatened and Chronically Threatened environments, INPTE was dominated by forest and regenerating forest (Indigenous Forest, Manuka and/or Kanuka and Broadleaved Indigenous Hardwoods LCDB 2 classes). In contrast, in Critically Underprotected and Underprotected environments, INPTE was dominated by the Tall-Tussock Grassland class (34% and 54%, respectively, at LENZ Level IV). Manuka and/or Kanuka and Indigenous Forest also accounted for large portions of the INPTE in Critically Underprotected and Underprotected threat categories. Depleted Grasslands were a significant component of Critically Underprotected INPTE (17% at LENZ Level IV).

Tables 6 and 7 tabulate total INP and INPTE areas in each of 73 council areas across New Zealand. Figure 6 compares INPTE areas for the 25 councils with the greatest INPTE area. The four top-ranking councils (Central Otago, Queenstown Lakes, Waitaki and Mackenzie) contain 33% of the national total area of INPTE (at both LENZ levels). Level II of LENZ, which is less precise, shows Central Otago, Southland, Mackenzie and Hurunui districts as the top-ranking councils, containing 32% of INPTE.

Tables 8 and 9 tabulate total INP and INPTE areas in each of 13 DOC conservancies and 47 DOC areas across New Zealand. The four top-ranking DOC areas (Central Otago, Twizel, Gisborne and Coastal Otago) contain 35% of the national total area of INPTE, and the top seven (including Wanaka, South Marlborough and Wakatipu) contain 50%. The three highest ranked DOC conservancies are Otago (with 27% of the national area of indigenous cover not protected), Canterbury (with 18%), and East Coast/Hawke's Bay (with 9%).

In 2004, the 304 current and former Crown pastoral leases in the South Island high country contained 31% of New Zealand's INP, and 27% (c. 567 380 ha) of the remaining INPTE. The area of INPTE on pastoral leases may have been higher than this estimate, since indigenous short-tussock grasslands contained

TABLE 3. INDIGENOUS COVER NOT PROTECTED (INP) IN THE SIX LAND ENVIRONMENT CATEGORIES IN 2001/02, SHOWING THE AREA OF INP, THE PERCENTAGE OF THE TOTAL NEW ZEALAND LAND AREA THAT THIS AREA REPRESENTS (% OF NZ), AND THE PERCENTAGE THAT INP REPRESENTS OF ALL REMAINING INDIGENOUS COVER (% OF REMAINING) WITHIN EACH LAND ENVIRONMENT CATEGORY.

	LENZ LEVEL	TOTAL	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDER-PROTECTED	UNDER-PROTECTED	LESS REDUCED AND BETTER PROTECTED
Area	IV	4 794 636	182 573	285 416	468 195	708 816	497 697	2 651 940
(ha)	II	4 794 636	183 726	186 287	688 068	290 562	750 394	2 695 598
% of	IV	18.44	0.70	1.10	1.80	2.73	1.91	10.20
NZ	II	18.44	0.71	0.72	2.65	1.12	2.89	10.37
% of	IV	37.96	82.66	82.76	69.44	89.20	75.07	26.69
remaining	II	37.96	82.06	80.53	61.14	88.36	71.06	27.89

TABLE 4. INDIGENOUS COVER NOT PROTECTED (INP) IN 2001/02, BY INDIGENOUS COVER CLASS, IN ALL OF NEW ZEALAND'S ENVIRONMENTS, AND IN THE FIVE THREATENED ENVIRONMENT CATEGORIES. ALL CATEGORIES WERE DETERMINED AT LEVEL IV OF LENZ.

	TOTAL (ALL 500 ENVIRON-MENTS	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDER-PROTECTED	UNDER PROTECTED
Area (ha)						
Broadleaved Indigenous Hardwoods	348 214	31 197	48 706	52 436	36 960	20 533
Depleted Grassland	225 511	3702	21 524	26 737	118 190	9554
Fernland	43 188	1000	1675	1906	14 411	2616
Grey Scrub	63 624	3650	8079	8398	20 284	3840
Indigenous Forest	1 376 291	47 214	52 214	168 226	98 132	99 768
Manuka and/or Kanuka	834 453	48 671	102 089	132 558	144 537	64 265
Matagouri	26 432	3612	3157	6784	7913	490
Tall-Tussock Grassland	1 347 822	5212	23 055	38 657	237 179	267 834
Alpine[a]	137 602	14	100	263	5289	11 903
Rock[b]	300 354	14 228	12 273	19 335	17 360	11 516
Wetland/Water[c]	91 146	24 073	12 545	12 897	8562	5376
Total	4 794 636	182 573	285 416	468 195	708 816	497 697
Percentage (%)						
Broadleaved Indigenous Hardwoods	7.3	17.1	17.1	11.2	5.2	4.1
Depleted Grassland	4.7	2.0	7.5	5.7	16.7	1.9
Fernland	0.9	0.5	0.6	0.4	2.0	0.5
Grey Scrub	1.3	2.0	2.8	1.8	2.9	0.8
Indigenous Forest	28.7	25.9	18.3	35.9	13.8	20.0
Manuka and/or Kanuka	17.4	26.7	35.8	28.3	20.4	12.9
Matagouri	0.6	2.0	1.1	1.4	1.1	0.1
Tall-Tussock Grassland	28.1	2.9	8.1	8.3	33.5	53.8
Alpine[a]	2.9	0.0	0.0	0.1	0.7	2.4
Rock[b]	6.3	7.8	4.3	4.1	2.4	2.3
Wetland/Water[c]	1.9	13.2	4.4	2.8	1.2	1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a] Alpine = Alpine Grass/Herbfield, Permanent Snow and Ice, Subalpine Shrubland.

[b] Rock = Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, River and Lakeshore Gravel and Rock.

[c] Water/Wetland = Estuarine Open Water, Flaxland, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake and Pond, Mangrove, River.

within the Low-Producing Grassland class in LCDB 2 are classified as 'exotic' and, therefore, not distinguished. Overall, indigenous cover on pastoral leases remained relatively high, probably because the Land Act 1948 and Crown Pastoral Land Act 1998 have constrained vegetation clearance activities, including soil cultivation, at least to some degree. Furthermore, pastoral leases contain high proportions of land of low value for agricultural production that does not lend itself to cultivation. Because South Island high country pastoral leases remained largely indigenous in character, much of the INPTE on pastoral leases was in the At Risk, Critically Underprotected and Underprotected categories, with less depleted indigenous cover (i.e. > 20% remaining). Pastoral leases contain just 5.5% (c. 25 500 ha) of the national INPTE in Acutely Threatened and Chronically Threatened environment threat categories, i.e. environments where indigenous cover has been reduced below 20% of original environment extent.

TABLE 5. INDIGENOUS COVER NOT PROTECTED (INP) IN 2001/02, BY INDIGENOUS COVER CLASS, IN ALL OF NEW ZEALAND'S ENVIRONMENTS, AND IN THE FIVE THREATENED ENVIRONMENT CATEGORIES. ALL CATEGORIES WERE DETERMINED AT LEVEL II OF LENZ.

	TOTAL (ALL 100 ENVIRON-MENTS	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDER-PROTECTED	UNDER PROTECTED
Area (ha)						
Broadleaved Indigenous Hardwoods	348 214	26 228	42 385	52 159	10 430	35 377
Depleted Grassland	225 511	6562	1022	36 709	68 030	64 608
Fernland	43 188	716	914	2623	13 944	4243
Grey Scrub	63 624	4169	1205	18 220	17 302	10 082
Indigenous Forest	1 376 291	35 749	32 992	267 319	10 506	139 394
Manuka and/or Kanuka	834 453	47 684	81 617	175 957	12 369	150 295
Matagouri	26 432	2678	2767	2136	7947	7319
Tall-Tussock Grassland	1 347 822	17 732	2651	101 430	133 427	289 851
Alpine[a]	137 602	32	37	3253	2652	17 322
Rock[b]	300 341	19 062	7827	13 554	7668	20 706
Wetland/Water[c]	91 145	23 103	12 871	14 708	6288	11 195
Total	4 794 636	183 726	186 287	688 068	290 562	750 394
Percentage (%)						
Broadleaved Indigenous Hardwoods	7.3	14.3	22.8	7.6	3.6	4.7
Depleted Grassland	4.7	3.6	0.5	5.3	23.4	8.6
Fernland	0.9	0.4	0.5	0.4	4.8	0.6
Grey Scrub	1.3	2.3	0.6	2.6	6.0	1.3
Indigenous Forest	28.7	19.5	17.7	38.9	3.6	18.6
Manuka and/or Kanuka	17.4	26.0	43.8	25.6	4.3	20.0
Matagouri	0.6	1.5	1.5	0.3	2.7	1.0
Tall-Tussock Grassland	28.1	9.7	1.4	14.7	45.9	38.6
Alpine[a]	2.9	0.0	0.0	0.5	0.9	2.3
Rock[b]	6.3	10.4	4.2	2.0	2.6	2.8
Wetland/Water[c]	1.9	12.6	6.9	2.1	2.2	1.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a] Alpine = Alpine Grass/Herbfield, Permanent Snow and Ice, Subalpine Shrubland.

[b] Rock = Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, River and Lakeshore Gravel and Rock.

[c] Water/Wetland = Estuarine Open Water, Flaxland, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake and Pond, Mangrove, River.

TABLE 6. INDIGENOUS COVER NOT PROTECTED (INP), AND TOTAL INDIGENOUS COVER NOT PROTECTED IN THE FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE) IN 73 DISTRICT COUNCIL AREAS IN 2001/02. ALL CATEGORIES WERE DETERMINED AT LEVEL IV OF LENZ.

COUNCIL (DISTRICT OR CITY)	TOTAL DISTRICT/CITY COUNCIL AREA (ha)	AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
		ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF DISTRICT	PERCENTAGE OF TOTAL NATIONAL AREA	
									%	RANK
Ashburton	588 482	1898	838	8513	2075	2	13 325	2.3	0.6	36
Auckland	62 303	446	480	1264	3835	0	6024	9.7	0.3	47
Banks Peninsula	96 989	2841	4863	4970	0	0	12 674	13.1	0.6	37
Buller	788 090	0	711	2465	21	0	3198	0.4	0.1	58
Carterton	119 784	2266	1630	50	4706	0	8652	7.2	0.4	44
Central Hawke's Bay	327 393	6458	4261	492	3417	0	14 627	4.5	0.7	34
Central Otago	986 431	5282	28 006	19 917	145 511	111 973	310 689	31.5	14.5	1
Christchurch	42 445	471	167	26	0	0	663	1.6	0.0	70
Clutha	629 464	9859	5151	12 440	512	10 510	38 471	6.1	1.8	17
Dunedin	325 742	4290	6694	17 034	1108	21 982	51 108	15.7	2.4	12
Far North	666 822	3643	8561	33 787	58 010	5711	109 712	16.5	5.1	5
Franklin	215 041	4192	6145	4210	972	18 242	33 761	15.7	1.6	21
Gisborne	831 520	3815	47 601	5836	43 485	3728	104 464	12.6	4.9	6
Gore	123 454	743	83	926	2	2503	4256	3.4	0.2	52
Grey	338 118	0	0	2004	0	0	2004	0.6	0.1	64
Hamilton	9762	285	7	0	0	0	292	3.0	0.0	71
Hastings	514 892	3363	17 195	744	418	58	21 779	4.2	1.0	28
Hauraki	117 082	1603	179	1638	4	2564	5987	5.1	0.3	48
Horowhenua	105 152	1556	1166	553	0	0	3276	3.1	0.2	57
Hurunui	845 910	7226	10 219	10 002	27 561	4384	59 393	7.0	2.8	9
Invercargill	38 896	274	126	790	0	0	1190	3.1	0.1	68
Kaikoura	201 337	770	1994	1262	11 019	23 481	38 525	19.1	1.8	16
Kaipara	307 552	1675	4397	10 655	7946	0	24 673	8.0	1.2	27
Kapiti Coast	73 055	1270	300	1312	16	0	2897	4.0	0.1	59
Kawerau	2432	78	58	0	0	54	190	7.8	0.0	73
Lower Hutt	37 486	596	310	3382	399	0	4687	12.5	0.2	50
Mackenzie	685 329	2440	8834	22 176	76 555	1739	111 744	16.3	5.2	4
Manawatu	258 852	4594	5311	522	1	1	10 429	4.0	0.5	41
Manukau	53 186	403	163	1379	3433	3533	8911	16.8	0.4	43
Marlborough	1 032 287	3183	9080	10 724	28 649	21 929	73 566	7.1	3.4	8
Masterton	227 643	4621	4808	297	8893	0	18 618	8.2	0.9	30
Matamata-Piako	175 210	1392	114	1470	0	900	3876	2.2	0.2	53
Napier	9948	216	0	0	0	0	216	2.2	0.0	72
Nelson	42 101	398	213	921	0	74	1605	3.8	0.1	67
New Plymouth	221 207	3960	147	4797	0	479	9383	4.2	0.4	42
North Shore	12 743	51	63	1873	28	0	2015	15.8	0.1	63
Opotiki	309 775	2228	1099	236	1443	2969	7974	2.6	0.4	46
Otorohanga	200 714	744	773	10 414	0	6064	17 995	9.0	0.8	31
Palmerston North	32 537	356	1147	524	2	0	2029	6.2	0.1	61
Papakura	12 023	113	5	1116	3	469	1705	14.2	0.1	66
Porirua	17 648	494	136	992	273	0	1894	10.7	0.1	65

Continued on next page

Table 6—continued

COUNCIL (DISTRICT OR CITY)	TOTAL DISTRICT/CITY COUNCIL AREA (ha)	AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
		ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF DISTRICT	PERCENTAGE OF TOTAL NATIONAL AREA	
									%	RANK
Queenstown Lakes	856 396	1471	2913	2714	53 095	99 483	159 676	18.6	7.5	2
Rangitikei	445 780	11 128	4929	2701	16 337	4276	39 372	8.8	1.8	14
Rodney	232 172	1006	2111	25 119	2125	3	30 364	13.1	1.4	23
Rotorua	238 205	1339	1470	2902	0	6836	12 548	5.3	0.6	38
Ruapehu	669 819	743	2709	43 762	3906	3718	54 838	8.2	2.6	10
Selwyn	604 810	1940	746	8660	2254	0	13 601	2.2	0.6	35
South Taranaki	357 185	6003	146	4083	0	401	10 633	3.0	0.5	40
South Waikato	179 445	849	164	504	0	508	2025	1.1	0.1	62
South Wairarapa	233 337	6377	5804	670	21 762	1	34 614	14.8	1.6	19
Southland	2 905 381	9132	12 146	10 425	12 104	46 513	90 320	3.1	4.2	7
Stratford	213 951	1089	133	14 767	0	0	15 990	7.5	0.7	33
Tararua	435 552	11 237	8189	552	10 400	0	30 379	7.0	1.4	22
Tasman	953 487	3277	6232	7338	166	72	17 086	1.8	0.8	32
Taupo	629 332	3715	284	32 766	757	848	38 369	6.1	1.8	18
Tauranga	12 872	628	1	60	19	0	707	5.5	0.0	69
Thames–Coromandel	219 700	1275	1366	1436	2110	2295	8481	3.9	0.4	45
Timaru	258 233	2263	1132	1012	6320	0	10 727	4.2	0.5	39
Upper Hutt	54 024	675	343	2398	10	0	3426	6.3	0.2	55
Waikato	305 697	6124	4921	3229	0	14 832	29 106	9.5	1.4	24
Waimakariri	213 075	1558	408	295	1609	0	3870	1.8	0.2	54
Waimate	346 519	2373	2630	7193	39 874	216	52 286	15.1	2.4	11
Waipa	144 427	2436	287	1342	0	1157	5223	3.6	0.2	49
Wairoa	403 830	1453	19 804	13 330	1	7	34 595	8.6	1.6	20
Waitakere	36 396	251	210	1327	2361	112	4261	11.7	0.2	51
Waitaki	698 635	4145	14 735	16 392	68 130	28 543	131 945	18.9	6.2	3
Waitomo	350 843	1437	192	27 531	0	10 142	39 302	11.2	1.8	15
Wanganui	234 469	1995	2614	20 104	0	71	24 783	10.6	1.2	26
Wellington	28 742	446	15	2020	920	0	3401	11.8	0.2	56
Western Bay of Plenty	196 035	2910	4	184	1104	21 469	25 671	13.1	1.2	25
Westland	1 145 206	0	0	2233	0	0	2233	0.2	0.1	60
Whakatane	440 625	1628	2395	1783	0	12 842	18 649	4.2	0.9	29
Whangarei	269 661	1575	3351	7655	33 159	2	45 742	17.0	2.1	13
Total	26 000 680	182 573	285 416	468 195	708 816	497 697	2 142 696		100.0	

TABLE 7. INDIGENOUS COVER NOT PROTECTED (INP), AND TOTAL INDIGENOUS COVER NOT PROTECTED IN THE FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE) IN 73 DISTRICT COUNCIL AREAS IN 2001/02. ALL CATEGORIES WERE DETERMINED AT LEVEL II OF LENZ.

		AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
									PERCENTAGE OF TOTAL NATIONAL AREA	
COUNCIL (DISTRICT OR CITY)	TOTAL DISTRICT/CITY COUNCIL AREA (ha)	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF DISTRICT	%	RANK
Ashburton	588 482	2719	167	25	1434	28 555	32 900	5.6	1.6	22
Auckland	62 303	801	187	5029	0	0	6017	9.7	0.3	42
Banks Peninsula	96 989	340	12 334	0	0	0	12 674	13.1	0.6	31
Buller	788 090	7	993	1171	21	28	2220	0.3	0.1	57
Carterton	119 784	3696	0	162	0	0	3859	3.2	0.2	46
Central Hawke's Bay	327 393	8794	16	303	0	367	9480	2.9	0.5	36
Central Otago	986 431	15389	2725	31 485	55 861	167 163	272 623	27.6	13.0	1
Christchurch	42 445	301	358	4	0	0	663	1.6	0.0	67
Clutha	629 464	7395	504	44 430	333	10 970	63 631	10.1	3.0	10
Dunedin	325 742	5672	154	22 895	1842	20 912	51 475	15.8	2.5	15
Far North	666 822	6183	4214	91 873	0	5711	107 981	16.2	5.1	5
Franklin	215 041	5572	360	5186	0	22 091	33 209	15.4	1.6	21
Gisborne	831 520	1400	57 389	223	4258	43	63 313	7.6	3.0	11
Gore	123 454	332	10	5258	2	89	5691	4.6	0.3	43
Grey	338 118	0	0	0	0	3	3	0.0	0.0	72
Hamilton	9 762	264	4	0	0	7	274	2.8	0.0	69
Hastings	514 892	5313	14 938	1171	0	17 117	38 539	7.5	1.8	18
Hauraki	117 082	1442	60	1617	0	247	3366	2.9	0.2	49
Horowhenua	105 152	2428	0	498	0	0	2926	2.8	0.1	55
Hurunui	845 910	3497	21 198	8	526	87 195	112 423	13.3	5.4	4
Invercargill	38 896	790	171	878	0	0	1838	4.7	0.1	59
Kaikoura	201 337	513	2017	5769	1	42 344	50 643	25.2	2.4	16
Kaipara	307 552	2481	1339	20,821	0	0	24 641	8.0	1.2	26
Kapiti Coast	73 055	1332	0	1149	0	0	2481	3.4	0.1	56
Kawerau	2 432	30	48	0	0	0	78	3.2	0.0	71
Lower Hutt	37 486	837	2	773	0	0	1612	4.3	0.1	61
Mackenzie	685 329	4873	1749	10 322	68 604	50 301	135 849	19.8	6.5	3
Manawatu	258 852	2881	5	439	0	0	3325	1.3	0.2	50
Manukau	53 186	540	27	4811	0	3533	8911	16.8	0.4	37
Marlborough	1 032 287	4838	2225	16 649	399	82 514	106 625	10.3	5.1	6
Masterton	227 643	7,321	0	437	0	0	7758	3.4	0.4	39
Matamata–Piako	175 210	1161	38	1470	0	468	3136	1.8	0.1	53
Napier	9 948	178	38	0	0	0	216	2.2	0.0	70
Nelson	42 101	398	50	0	74	1083	1604	3.8	0.1	62
New Plymouth	221 207	16	5852	5271	0	295	11 434	5.2	0.5	33
North Shore	12 743	104	0	1911	0	0	2015	15.8	0.1	58
Opotiki	309 775	1230	701	1241	217	440	3828	1.2	0.2	47
Otorohanga	200 714	98	284	7123	0	14 744	22 249	11.1	1.1	27
Palmerston North	32 537	932	0	524	0	0	1456	4.5	0.1	63
Papakura	12 023	114	0	1119	0	472	1705	14.2	0.1	60
Porirua	17 648	622	0	76	0	0	698	4.0	0.0	66

Continued on next page

Table 7—continued

COUNCIL (DISTRICT OR CITY)	TOTAL DISTRICT/CITY COUNCIL AREA (ha)	AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
		ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF DISTRICT	PERCENTAGE OF TOTAL NATIONAL AREA	
									%	RANK
Queenstown Lakes	856 396	860	938	2979	47 807	15 644	68 228	8.0	3.3	9
Rangitikei	445 780	4238	404	23 579	0	7996	36 218	8.1	1.7	20
Rodney	232 172	2205	730	27 391	0	3	30 329	13.1	1.4	24
Rotorua	238 205	91	205	3272	0	39	3607	1.5	0.2	48
Ruapehu	669 819	306	1 449	69 621	0	405	71 781	10.7	3.4	8
Selwyn	604 810	1532	1194	0	584	27 967	31 278	5.2	1.5	23
South Taranaki	357 185	1063	4774	3959	0	51	9847	2.8	0.5	35
South Waikato	179 445	50	122	539	0	83	794	0.4	0.0	64
South Wairarapa	233 337	11301	0	277	0	0	11 578	5.0	0.6	32
Southland	2 905 381	6930	3129	100 843	10 680	38 299	159 881	5.5	7.6	2
Stratford	213 951	60	1245	9558	0	336	11 199	5.2	0.5	34
Tararua	435 552	8062	0	745	0	0	8807	2.0	0.4	38
Tasman	953 487	3417	1827	1068	238	8122	14 672	1.5	0.7	29
Taupo	629 332	6	1633	48 592	0	1538	51 769	8.2	2.5	14
Tauranga	12 872	685	0	22	0	0	707	5.5	0.0	65
Thames–Coromandel	219 700	2665	81	3326	27	215	6314	2.9	0.3	41
Timaru	258 233	3239	302	141	6466	5027	15 175	5.9	0.7	28
Upper Hutt	54 024	532	119	2302	0	0	2952	5.5	0.1	54
Waikato	305 697	4174	481	3291	0	19 827	27 773	9.1	1.3	25
Waimakariri	213 075	1558	408	0	156	11 951	14 072	6.6	0.7	30
Waimate	346 519	3771	183	8502	38 959	575	51 990	15.0	2.5	13
Waipa	144 427	892	214	770	0	1989	3864	2.7	0.2	45
Wairoa	403 830	1710	30 343	40	0	5030	37 123	9.2	1.8	19
Waitakere	36 396	292	14	3843	0	112	4261	11.7	0.2	44
Waitaki	698 635	10 900	1375	23 156	51 924	9166	96 521	13.8	4.6	7
Waitomo	350 843	134	1275	12 109	0	39 317	52 835	15.1	2.5	12
Wanganui	234 469	3878	255	3168	0	0	7301	3.1	0.3	40
Wellington	28 742	488	0	31	0	0	519	1.8	0.0	68
Western Bay of Plenty	196 035	3073	22	3	151	1	3250	1.7	0.2	52
Westland	1 145 206	0	0	0	0	0	0	0.0	0.0	73
Whakatane	440 625	315	1211	1760	0	2	3288	0.7	0.2	51
Whangarei	269 661	2467	2206	41 065	0	2	45 740	17.0	2.2	17
Total	26 000 680	183 726	186 287	688 068	290 562	750 394	2 099 038		100.0	

TABLE 8. INDIGENOUS COVER NOT PROTECTED (INP), AND TOTAL INDIGENOUS COVER NOT PROTECTED IN THE FIRST FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE) IN 13 DOC CONSERVANCIES IN 2001/02. ALL CATEGORIES WERE DETERMINED AT LEVEL IV OF LENZ.

		AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
									PERCENTAGE OF TOTAL NATIONAL AREA	
CONSERVANCY	TOTAL AREA OF CONSERVANCY (ha)	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF CONSERVANCY	%	RANK
Auckland	544 209	4 680	5 600	35 948	12 755	18 219	77 202	14	4	10
Bay Of Plenty	1 052 894	8 110	4 763	6 754	1 129	42 690	63 446	6	3	11
Canterbury	3 987 916	23 899	34 595	69 225	217 364	30 792	375 876	9	18	2
East Coast/Hawke's Bay	2 739 103	21 640	90 766	20 633	62 239	6 382	201 661	7	9	3
Nelson/Marlborough	2 307 820	7 700	17 741	21 366	43 112	47 715	137 634	6	6	5
Northland	1 245 377	6 893	16 308	52 011	99 116	5 714	180 042	14	8	4
Otago	3 051 847	23 097	52 464	58 724	205 066	243 774	583 125	19	27	1
Southland	3 195 728	11 135	12 409	14 403	11 003	51 122	100 073	3	5	9
Tongariro/Taupo	629 232	2 820	227	32 886	6 368	812	43 114	7	2	12
Waikato	1 833 584	17 402	11 613	62 413	2 126	41 429	134 982	7	6	7
Wanganui	2 100 197	30 512	17 646	75 120	3 652	9 046	135 976	6	6	6
Wellington	1 114 977	24 683	20 574	11 998	44 866	1	102 121	9	5	8
West Coast Tai Poutini	2 210 642	0	711	6 713	21	0	7 445	0	0	13

4.3 WHAT IS THE MOST APPROPRIATE LENZ LEVEL?

Level IV environments represent a finer partitioning of LENZ Level II environments. The habitat loss and protection status of Level IV environments within a single LENZ Level II environment may vary quite widely. This reflects their different environmental characteristics, and hence differences in their value for agricultural production, as well as their biodiversity. Appendix 3 presents a case study of differences among Level IV environments in patterns of protection and land clearance, biodiversity pattern and current land cover types within one Level II land environment (F1). The conclusions we drew from this example were that:

- Environmental differences that drive patterns of biodiversity, and both present and past land clearance, are at a finer scale than the environmental pattern evident at Level II of LENZ.
- Of the four LENZ levels, Level IV best depicts patterns of biodiversity and reflects patterns of past clearance. Level IV also relates most strongly to scales at which people perceive and use the landscape.
- Level IV is the most appropriate LENZ level to assess the vulnerability of remaining biodiversity.

TABLE 9. INDIGENOUS COVER NOT PROTECTED (INP), AND TOTAL INDIGENOUS COVER NOT PROTECTED IN THE FIRST FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE) IN 49 DOC AREAS IN 2001/02. ALL CATEGORIES WERE DETERMINED AT LEVEL IV OF LENZ.

		AREA OF INP (ha)					INP IN FIVE THREATENED ENVIRONMENT CATEGORIES (INPTE)			
									PERCENTAGE OF TOTAL NATIONAL AREA	
AREA	TOTAL AREA OF AREA (ha)	ACUTELY THREATENED	CHRONICALLY THREATENED	AT RISK	CRITICALLY UNDERPROTECTED	UNDERPROTECTED	TOTAL AREA (ha)	PERCENTAGE AREA OF AREA	%	RANK
Aniwaniwa	171 942	73	290	219	0	62	643	0	0	45
Aoraki	67 469	0	0	0	0	0	0	0	0	47
Auckland	312 085	3 565	3 655	12 748	10 350	18 219	48 537	16	2	18
Bay of Islands	292 961	1 812	5 248	16 448	39 478	0	62 986	21	3	12
Buller–Kawatiri	428 996	0	711	1 319	21	0	2 051	0	0	41
Central Otago	801 512	4 047	22 418	18 382	117 171	77 643	239 660	30	11	1
Coastal Otago	1 167 457	16 639	23 320	36 332	7 086	45 326	128 702	11	6	4
Franz Josef–Waiau	226 459	0	0	865	0	0	865	0	0	44
Gisborne	1 128 863	5 324	67 067	19 109	44 016	3 735	139 251	12	6	3
Golden Bay	248 703	17	1 719	1 190	166	0	3 092	1	0	37
Great Barrier Island	29 204	260	81	323	302	0	966	3	0	42
Greymouth–Mawheranui	655 607	0	0	3 025	0	0	3 025	0	0	38
Hauraki	271 822	1 571	1 537	1 586	2 126	4 692	11 511	4	1	31
Hokitika	292 586	0	0	947	0	0	947	0	0	43
Kaitaia	298 010	1 385	3 030	16 904	10 896	5 708	37 923	13	2	20
Kapiti	166 981	2 799	1 022	2 927	296	0	7 043	4	0	33
Kauri Coast	264 662	1 843	2 981	7 278	9 394	0	21 496	8	1	24
Maniapoto	743 367	2 048	318	51 360	0	14 000	67 725	9	3	10
Motueka	437 002	3 658	3 999	6 271	0	146	14 073	3	1	29
Murihiku	1 800 185	11 068	8 763	14 249	11 001	49 565	94 645	5	4	8
Napier	1 059 640	14 082	22 386	1 157	17 311	59	54 994	5	3	17
New Plymouth	263 489	3 781	150	9 715	0	346	13 991	5	1	30
North Canterbury	1 207 001	11 135	15 120	13 853	22 935	2 225	65 268	5	3	11
Opotiki	378 658	2 162	1 022	148	913	2 527	6 773	2	0	34
Palmerston North	721 133	16 184	13 838	3 649	3 652	6 908	44 231	6	2	19
Poneke	119 641	1 713	677	7 734	1 326	0	11 450	10	1	32
Rangitaiki	433 067	2 559	2 405	3 220	18	12 525	20 727	5	1	25
Rotorua Lakes	369 859	1 609	2 295	3 264	0	9 404	16 572	4	1	28
Ruakapuka	1 257 077	7 630	3 966	14 464	34 211	16	60 287	5	3	14
Ruapehu	138 095	1	13	2 032	3 403	24	5 473	4	0	35
Solander Island	95	0	0	0	0	0	0	0	0	48
Sounds	248 684	152	1 307	62	271	1 122	2 914	1	0	39
South Marlborough	972 878	3 873	9 984	12 886	42 295	46 447	115 485	12	5	6
SouthWestland Weheka	606 994	0	0	557	0	0	557	0	0	46
Southern Islands	174 358	0	0	0	0	0	0	0	0	48
St Arnaud	400 554	1	732	958	379	0	2 070	1	0	40
Stratford	363 402	4 823	222	10 952	0	687	16 683	5	1	26
Tauranga	249 970	3 941	63	270	1 111	20 760	26 146	10	1	23
Te Anau	1 221 091	67	3 646	154	3	1 557	5 428	0	0	36
Turangi	492 097	2 821	244	31 021	2 965	788	37 839	8	2	21
Twizel	923 781	2 415	14 449	33 014	155 308	28 551	233 736	25	11	2
Waikato	817 411	13 781	9 727	9 301	0	22 737	55 546	7	3	16
Waimakariri	532 588	2 720	1 061	7 894	4 910	0	16 585	3	1	27
Wairarapa	828 350	20 171	18 874	1 337	43 244	1	83 627	10	4	9
Wakatipu	514 340	616	2 355	1 425	31 592	58 916	94 903	18	4	7
Wanaka	568 538	1 796	4 373	2 586	49 217	61 889	119 859	21	6	5
Wanganui	752 172	5 724	3 436	50 805	0	1 106	61 071	8	3	13
Warkworth	202 921	856	1 863	22 878	2 102	1	27 699	14	1	22
Whangarei	389 743	1 852	5 050	11 382	39 348	6	57 637	15	3	15

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