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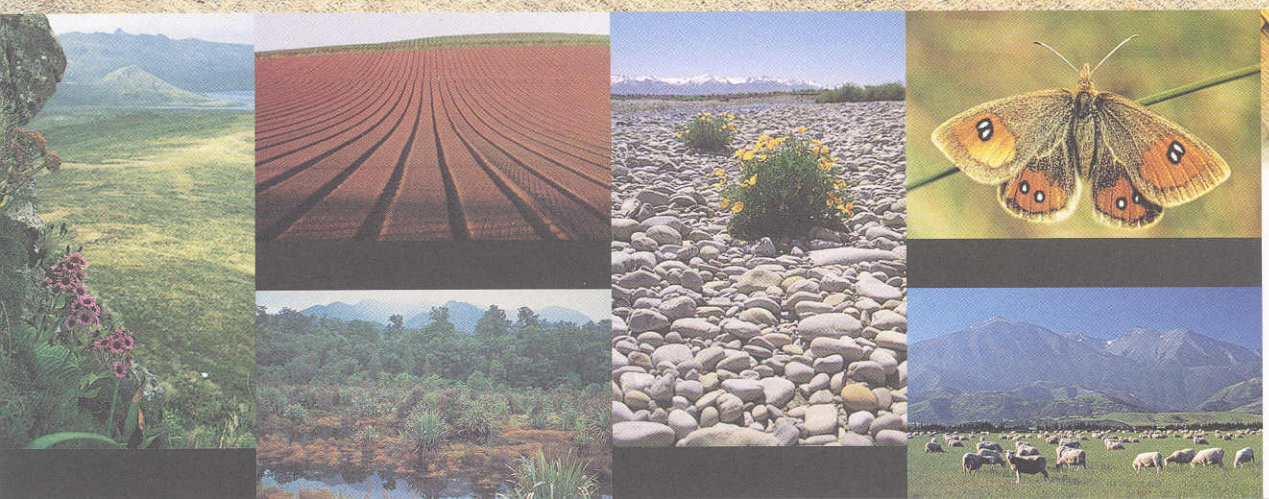

Manaaki Whenua
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Landcare Research Contract Report: LC0405/038

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DATE: March 2005

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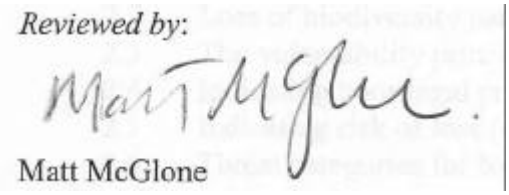

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Contents

Summary

Project and Client
This report to the Department of Conservation (DOC) accompanies maps and tables of national land environments based on digital databases and prepared in September 2004 by Landcare Research, Dunedin and Hamilton.

Objectives
- Identify New Zealand's land environments (LENZ; Leathwick et al. 2003a) that are most vulnerable to biodiversity loss. Calculate the area of unprotected indigenous cover (identified in the national land cover database (LCDB)) in threatened land environments by local authority district.
- Explain the likely consequences for indigenous biodiversity of historical (prehuman to 1996/97) and recent (1996/97 to 2001/02) changes in LCDB land cover across New Zealand's land environments. Estimate the change in 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.

Methods
- Spatial data depicting indigenous cover and legal protection were overlaid on LENZ Level IV environments.
- We identify five categories of threat to remaining indigenous biodiversity in environments ('threatened environments') based on loss of indigenous cover and poor legal protection.
- We tabulate a variety of cover, loss and land use capability data for each threat category.
- We determine change in indigenous cover remaining from 1996/97 to 2001/02 and estimated the likely consequences of this change for remaining indigenous biodiversity in land environments using an index of susceptibility to biodiversity loss. (The theoretical basis for this measure is briefly explained with reference to the ecological literature.)

Results
Almost two-thirds of New Zealand's Level IV Land Environments are classified within one of five categories of threat based on indigenous cover loss and poor protection. Between 60% and 90% of remaining indigenous cover in these threat categories is not legally protected. High proportions of this remaining indigenous cover is on land of low value for agricultural production.

Level IV of LENZ more adequately reflects the distribution of biodiversity, past clearance and current vulnerability across the landscape than higher levels of LENZ (e.g. Level II). Consequently, threat classification at Level IV rather than Level II will result in substantially more effective and efficient identification of threatened remaining indigenous cover.

Comparison of LCDB1 and LCDB2 indicates that 49% of Level IV land environments lost indigenous cover between 1996/97 and 2001/02. The highest rates of indigenous cover loss, and the greatest increases in susceptibility to biodiversity loss (i.e. risk to remaining indigenous biodiversity), were in already threatened environments.

Assessments of indigenous cover displacement based on LDCB cover classes understate loss. For example:

- Net indigenous loss within a 5-year period indicates only gross, rapid (active) clearance associated with marked transformation of areas. It does not identify biodiversity attrition through incompatible activities (e.g. grazing, drainage, fire). It will not show incremental displacement of native cover (e.g. following invasion and dominance of a wetland by an aggressive exotic weed, or a tall tussock grassland by *Hieracium* spp.; these areas will remain classified as indigenous cover).
- Net indigenous loss does not account for loss of indigenous elements of mixed (indigenous/non-indigenous) cover classes such as 'low-producing grasslands'.

Conclusions

New Zealand's coastal, lowland, and montane environments have experienced substantial indigenous habitat loss, and what indigenous cover remains in these environments today has little legal protection.

The much-reduced and highly modified areas of indigenous cover remaining in these threatened environments support a disproportionately large percentage of New Zealand's most seriously threatened species, habitats, and ecosystems. The protection of what remains in these environments is essential to halt the decline of New Zealand's indigenous biodiversity.

Clearance and loss of indigenous cover and associated indigenous biodiversity continues across New Zealand. Because the consequences of continued indigenous cover clearance for biodiversity (i.e. biodiversity loss and increased risk to what remains) are most severe in environments where little remains, the current pattern of clearance greatly exacerbates the status of biodiversity in New Zealand.

Although historically clearance of indigenous cover was concentrated on land of high value for agricultural production, it appears that the trend is now for clearance of indigenous cover on more marginal land (i.e. Land Use Capability classes 6, 7 and 8), notably for exotic forestry.

This evidence suggests that public awareness and education, voluntary protection, RMA provisions, and formal legal protection of remaining indigenous biodiversity have not halted the clearance of vulnerable indigenous biodiversity in much reduced and poorly protected ecosystems and habitats.

Recommendations

Two criteria are required to identify biodiversity that is most vulnerable (most likely to be lost). These are (1) poor legal protection (reflected by low percentages legally protected) and (2) past habitat loss (reflected by low percentages of remaining indigenous cover).

Based on these two criteria, we recommend five categories of threatened environments to identify environments containing indigenous biodiversity at most risk of loss. The biodiversity that remains in these threatened environments is some of the most severely threatened in New Zealand.

We recommend that Level IV of LENZ is the most appropriate level at which to identify environments that are most vulnerable to biodiversity loss, in order to effectively protect biodiversity at district and local (property) scales. Information based on a Level IV classification of threatened environments may be summarised to higher levels (e.g. Level I or II) for national or regional summaries.

Existing databases (e.g. LENZ, LCDB) do not identify many rare and distinctive ecosystems and habitats that are also reduced and poorly protected parts of the full range of New Zealand's biodiversity pattern. We therefore recommend that such rare and distinctive habitats and ecosystems are also regarded as threatened.

There needs to be some investigation and comparison of the social, economic and regulatory drivers of indigenous vegetation protection and loss in councils where most loss (e.g. Far North, Central Otago and Marlborough districts) and least loss (e.g. Kaikoura District, Waitakere City, Queenstown Lakes District) have occurred. This may help policy makers to understand some of the key factors for successful biodiversity conservation on private land.

This analysis cannot be repeated in the future, unless further full national updates of the Land Cover Database are produced, using satellite imagery taken over as short a time period as possible (e.g. a single summer). We recommend that the interval between comprehensive national updates of the land cover database is no less than 5 years, so that progress towards halting the decline in biodiversity can be monitored within relevant and acceptable timeframes.

1. Introduction

In this report we assess the effectiveness of protection of remaining indigenous biodiversity in New Zealand's land environments and identify those land environments in which remaining biodiversity is most vulnerable (i.e. at risk of loss). We then examine recent changes in the extent of indigenous cover identified in national databases, and estimate the likely consequences of these changes for the indigenous biodiversity associated with New Zealand's land environments.

This work has two objectives:

- Identify New Zealand's land environments (LENZ; Leathwick et al. 2003a) that are most vulnerable to biodiversity loss. Calculate the area of unprotected indigenous cover (identified in the national LCDB database) in threatened land environments by local authority district.

- Explain the likely consequences for indigenous biodiversity of historical (prehuman to 1996/97) and recent (1996/97 to 2001/02) changes in LCDB land cover across New Zealand's land environments. Estimate the change in 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.

1.1 Need for measures of biodiversity protection effectiveness

Action Plan Objective 1.1 Action d) of the *New Zealand Biodiversity Strategy* (NZBS) (DOC & MFE 2000) is to 'prepare a national policy statement and related material to provide guidance to local authorities on implementing provisions of the Resource Management Act relevant to conserving and sustainably managing indigenous biodiversity'.

National measures (indices or indicators) of the effectiveness of biodiversity protection across the landscape are essential to underpin national policy statement guidance to local authorities. Spatially explicit measures that indicate the effectiveness of biodiversity protection are needed to identify those places that are important for indigenous biodiversity and, in particular, to objectively and defensibly identify those places that are at significant risk of loss or decline. Secondly, such measures enable progress towards national biodiversity goals to be monitored, and allow for spatially explicit assessment of policy success and informed adaptation of policy over time.

1.2 National measures are available for pattern but not for process

The persistence of the full range of biodiversity requires both the protection of 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 them (Margules & Pressey 2000; Moritz 2002). Internationally, more progress has been made towards the objective measurement and description of biodiversity *pattern* than of biodiversity *processes*, and New Zealand is no exception. National databases and measures that can indicate the effectiveness of protection of biodiversity pattern across New Zealand have recently become available. However, databases and methods to describe and monitor biodiversity processes in New Zealand are still under development (e.g. Lee et al. 2004, unpubl.).

In this report, we use simple indicators or measures to describe the effectiveness of protection of biodiversity pattern across New Zealand, based on the current extent of habitat loss and legal protection status within land environments. These measures can be used to guide local authorities and other agencies to where remaining indigenous biodiversity is likely to be most at risk. However, we caution that the measures provide partial assessment of how well current protection ensures biodiversity persistence and ensures against loss. This is because we cannot yet systematically account for factors such as the isolation effects of fragmentation, co-extinctions of host-dependent organisms, or the impacts of pests, weeds and other pressures, including the long-term effects of climate change. Full estimates of the effectiveness of protection for biodiversity across New Zealand requires the development of indices and measures that account for these effects.

1.3 Recommended measures of biodiversity protection effectiveness

Two complementary measures of the effectiveness of protection of biodiversity pattern (*Representativeness* and *Vulnerability*) are needed to indicate progress towards biodiversity goals and to direct protection effort. The first, *Representativeness*, expresses the extent to which an element (biological, landscape, historical) is contained (i.e. represented) within an area of interest. The *Representativeness* of land environments within the national network of protected areas indicates how much of the 'full range' of New Zealand land environments (and their associated biodiversity) is protected. In order to secure a 'full range', protection effort should be directed to poorly represented elements of the full range [1].

However, the *Representativeness* of protection (the extent to which the full range is represented in protected areas) is not informative about a second aspect of protection effectiveness, which is how well a network of protected areas ensures against loss (e.g. Faith & Walker 1996; Gaston et al. 2002; Lawler et al. 2003). The *Representativeness* of a network of protected areas may be high (e.g. it may include a high proportion of the environments within a region) but this network may (and typically does) nonetheless systematically exclude the most vulnerable environments (those in which loss or degradation of biodiversity is most likely and imminent). Therefore, a second, complementary measure (*Vulnerability*, or likelihood of loss) is required to assess how well a network of protected areas ensures against loss (e.g. Pressey & Taffs 2001a, b; Sierra et al. 2002; Rouget et al. 2003) and to direct protection effort to those elements of the full range at greatest risk of imminent loss or degradation.

2. Background

In this section, we describe the conceptual basis and underlying assumptions we adopt to assess the effectiveness of protection, and to identify land environments in which remaining biodiversity is most vulnerable. Specifically, we expand on the separation of pattern and process (2.1), the drivers and consequences of habitat loss in New Zealand

[1] The term 'representativeness' is therefore also applied to a related significance assessment criterion (i.e. a critieron used to determine whether or not an area – e.g. of indigenous vegetation – deserves protection). An area would be assessed as significant on the basis of the 'representativeness' criterion if its protection would result in a greater proportion of the full range being protected.

(2.2), and the principle (2.3) and components parts of vulnerability (2.4 & 2.5). We also describe the basis for a proposed index of risk of loss (one component of vulnerability; 2.5) and a proposed threat classification for New Zealand environments based on the two components of vulnerability (2.6).

2.1 Pattern and process

The NZBS (p. 35) recognises the two key threats to indigenous species on land as loss of biodiversity *pattern* ('insufficient and fragmented habitat') and loss of biodiversity *process* 'introduced invasive species which damage their habitat and important ecosystem processes'.

This report and the measures within it (e.g. susceptibility to biodiversity loss) indicate the loss, and likelihood of future loss, of biodiversity *pattern* only. Specifically, we use indigenous cover classes to represent habitat for indigenous species, and exotic cover as representing habitat that is lost to indigenous species. The principal cause of loss of indigenous cover is direct (or 'active') clearance for human land use (e.g. ploughing, felling, planting in exotic forestry trees) although marginal loss also occurs by attrition and the deterioration of fundamental processes (or 'passive' clearance; e.g. dieback of forest edges may be caused by browsing).

We do *not* address the incremental loss of biodiversity through degradation within indigenous habitats owing to pressures (such as predators, weeds, pollution, fire, and drainage) that damage ecosystem processes. National, spatially explicit measures and estimates of process disruption in development (Lee et al. 2004) are not yet available for us to do so. The NZBS states (p. 35) that invasive pests and weeds (threats to biodiversity processes) pose the greatest single threat to biodiversity on land in New Zealand, 'surpassing even habitat loss'. Although the magnitude of impacts of pattern and process loss cannot at this time be objectively compared, 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 alone considerably underestimates actual threat.

2.2 Loss of biodiversity pattern and threat of extinction in New Zealand

Historically, protection for biodiversity in New Zealand 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 ecosystems, habitats and species where indigenous habitat loss has been greatest, and

the proportion of land set aside for protection is smallest (e.g. Heijnis et al. 1999; Heydenrych et al. 1999; Gaston et al. 2002).

In New Zealand, the consequences of habitat loss 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 regional scales. For example, Lee and Walker (2004, unpubl.) report that 80% of the Acutely and Chronically Threatened vascular plants of inland Central Otago District occur in the lowland and montane zones of the district.

Intensive land use and habitat loss, coupled with critically low levels of protection in lowland landscapes, is therefore a primary contributor to the extent of indigenous biodiversity loss in New Zealand, and to the degree of threat to what remains. This is recognised in the NZBS, which emphasises a need to focus biodiversity protection effort to retain remaining indigenous biodiversity in lowland and modified areas previously perceived as low protection priorities. Specifically, Objective 1.1 (Protecting indigenous habitats and ecosystems) seeks to:

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

One of the reasons for the biased patterns of habitat loss and protection across New Zealand, and hence the threatened status of many New Zealand species, may be the absence, in the past, of such an overarching strategy to guide protection policy.

2.3 The vulnerability principle

It is widely recognised within New Zealand (e.g. in NZBS 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[2]. Therefore, over time, realistic opportunities for the protection of biodiversity are narrowed down, by incremental or rapid loss, to a diminished 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).

[2] For example, The NZBS (p. 34) highlights a number of examples of imminently threatened 'scarce habitats' that remain largely unprotected and vulnerable to ongoing decline through the clearance pressures of intensive land uses (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 either unsuitable for or remote from human-induced pressures.

Because realistic opportunities for protection of biodiversity are narrowed down over time, achieving representativeness (i.e. protecting representatives of the full range of biological diversity) is a retreating option. 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, 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 of biodiversity pattern*') is also emphasised in the NZBS. 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
- at significant risk of irreversible loss or decline.

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

Land Environments of New Zealand (LENZ) provides a national spatial framework of units (Land Environments). An assessment of the vulnerability of biodiversity within each land environment can be made on the basis of poor legal protection and risk of loss (Fig. 1).

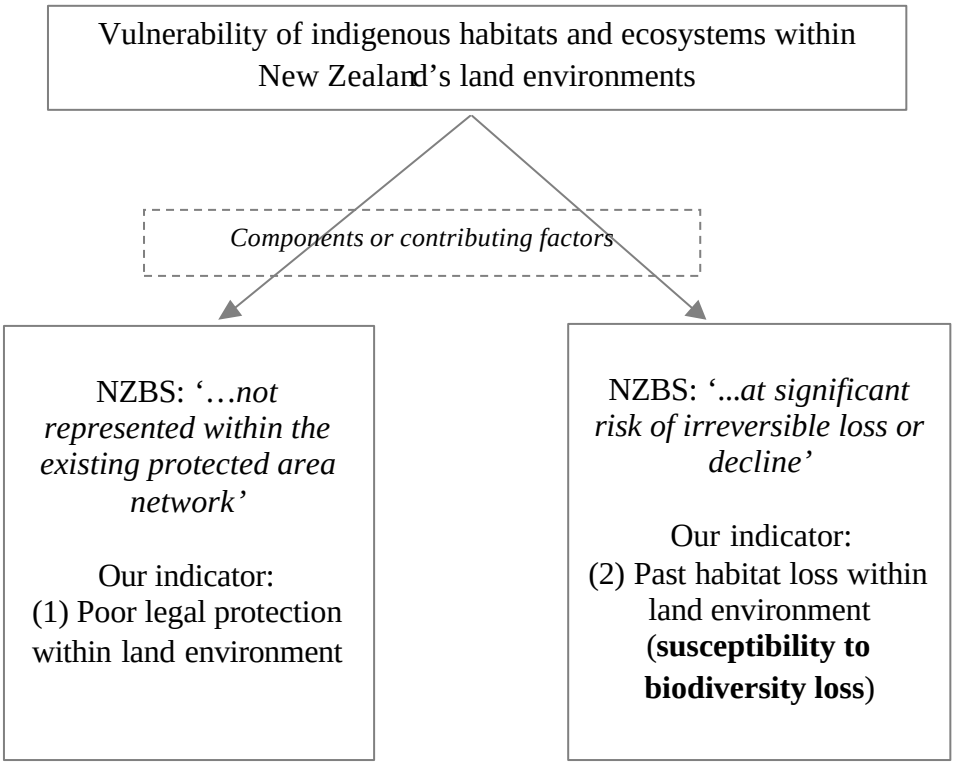


Figure 1. Vulnerability of indigenous habitats and ecosystems within New Zealand's land environments: components and indicators.

2.4 Indicating poor legal protection

Loss of indigenous biodiversity that has poor legal protection is more likely, both (1) as a consequence of direct (or active) clearance activities (burning, felling bulldozing, drainage, planting in exotic forestry species etc.) and (2) through attrition, degradation or 'passive' clearance (e.g. exclusion of indigenous species by invasive weeds, predation by pests, regeneration failure due to browsing), since management inputs to mitigate pressures tend to be lower. Poor legal protection is therefore a major contributor to biodiversity vulnerability (likelihood of loss), and this is recognised in a key component of the primary criterion for assessing significance[3] (i.e. representativeness): high representative value (i.e. high significance) is given to communities or ecosystems that are poorly represented in reserves (Myers et al. 1987).

How should *poor* legal protection be defined? 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). 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 one of the worst records of biodiversity loss of anywhere on earth (NZBS; DOC & MfE 2000 p. 4). Therefore, to sustain biodiversity in New Zealand, it is probably necessary to retain *and* to actively manage indigenous biodiversity across greater proportions of original ecosystem extent than in most other nations.

Accordingly, we suggest that in New Zealand a 'safety net' of legal protection covering at least 20% of original area is desirable to retain a full range of biodiversity (cf. Lee & Walker 2004, unpubl.; Walker et al. 2004, unpubl.; Walker & Lee 2004, unpubl. reports). 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 due to isolation, co-extinction and other associated factors).

2.5 Indicating risk of loss (susceptibility to biodiversity loss)

Estimation of the risk of loss to remaining indigenous biodiversity within a land environment can be informed by ecological theory. Perhaps most helpful in this regard are ecological theories that relate risk for remaining biodiversity to loss of natural habitat. Below we give synoptic descriptions of two helpful ecological theories: species–area relationships and fragmentation effects[4].

[3] The Crown Pastoral Lands Act (1998) defines *significant inherent values* as those inherent values that are of such importance, nature, quality or rarity that the land deserves protection under the Reserves Act or the Conservation Act.

[4] The species–area relationship and fragmentation thresholds 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

(a) Characteristics of the species–area relationship

The generalised species–area relationship describes the relationship between area of habitat and species number (Rosenweig 1995; Fig. 2). The relationship between the extent of an area and the number of species that it holds is not linear, but a curve, usually described by the generalised power function ($S = A^z$ where $z<1$).

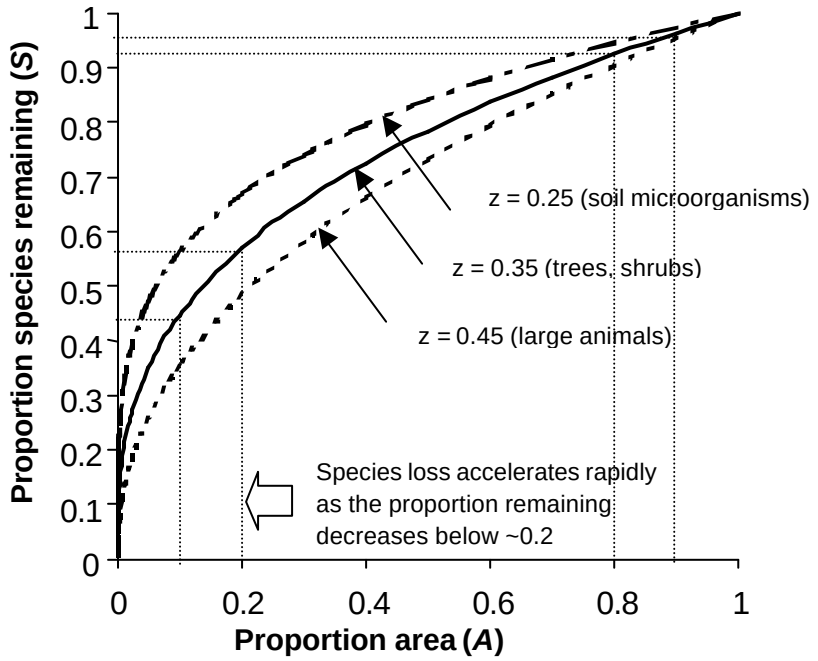


Figure 2. Generalised species–area relationship applied to the proportion of indigenous habitat remaining (*A*), showing curves for biota of different body size (z = 0.25, 0.35 and 0.45). The narrow vertical and horizontal lines are interpreted in the text (Section 2.5.1(b)).

The curve of the species–area relationship indicates that the number of species contained in any area (*A*; be this a quadrat, a paddock, a lake or a mountain range) will be more than half of the number of species in an area twice that size.

The species–area relationship is largely a mathematical effect derived from the sampling of areas of different size. It arises because 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 will also vary across different habitats, ecosystems and landscapes. Nevertheless, the general shape of the curve remains the same (Fig. 2).

Because larger areas are always able to support more species, 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 of the curves in Fig. 2), the rate of species loss may be relatively low. Large-bodied, host-dependent, narrow-range and/or habitat-specialist biota and those dependent on large contiguous habitats tend to be most affected at this stage. However, as habitat area is further reduced, the rate of species

loss increases, and biota in smaller size classes become affected (lower left of the curves in Fig. 2) together with more wide-ranging, generalist species. Within any size class of species, the manner of fragmentation (i.e. the retention of large continuous areas v. small scattered ones) is also likely to influence which species are lost first.
As the area of indigenous habitat remaining decreases, each increment of further loss results in a greater magnitude of loss of remaining biodiversity (lower left of the curves in Fig. 2). However, because of the shape 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.

(b) Indicating susceptibility to biodiversity loss using the species–area relationship
A species–area relationship with an exponent of 0.35 (i.e. the curve $z = 0.35$ in Fig. 2) may be an appropriate 'average' to apply to biodiversity protection, since it approximates the curve that could be expected for prominent vegetation components, which are readily recognised (including by remote sensing) and often pragmatically used as an 'umbrella' or surrogate for other elements of indigenous biodiversity.

Species–area relationships predict an increasing rate of biodiversity loss as habitat area decreases. For example, the curve $z = 0.35$ (Fig. 2) predicts a 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 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 the horizontal line pairs on Fig. 2.) This increasing rate of loss encapsulates one important aspect of the vulnerability: the degree of risk to remaining biodiversity. It can be quantified mathematically as a function of proportion habitat remaining, as the derivative of the generalised species–area relationship (the slope, or instantaneous rate of change at any point; Fig. 3). We use this relationship as an index of risk to remaining indigenous biodiversity, which we term 'susceptibility to biodiversity loss'.

The mathematical expression of the index of susceptibility to biodiversity loss (SBL), based on a generalised species–area relationship with an exponent of 0.35 is:

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

This index of susceptibility to biodiversity loss (Fig. 3) ranges from 0.35 in an intact habitat to infinity when habitat area remaining is negligible. The non-linearity of the index is a representation of the increased risk to remaining biodiversity that might be expected with each increment of further habitat loss.

The SBL index can therefore be used 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. (In Section 4.6, we use the SBL index to indicate change in risk to remaining indigenous biodiversity within land environments as a result of changes in indigenous cover from 1996/97 to 2001/02.)

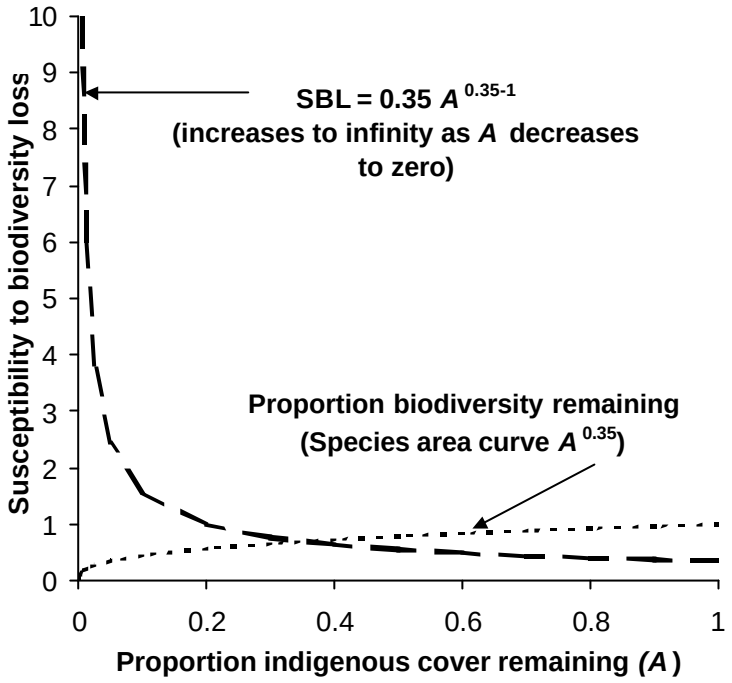


Figure 3. Method for estimating susceptibility to biodiversity loss (SBL, *y*-axis) and proportion of species remaining for each land environment. The proportion of indigenous cover remaining (*x*-axis) is represented by *A*. SBL is represented by the instantaneous rate of change at any point of the species–area curve where z = 0.35.

2.5.2 Fragmentation effects

The species–area relationship and the index of susceptibility to biodiversity loss (above) indicate the likely consequences of loss of habitat *area* for risk to remaining biodiversity, assuming that remaining habitat fragments are simply smaller, random samples from larger tracts. However, in biological systems, habitat loss and fragmentation is typically non-random, and also alters the *nature* of habitat, with negative consequences for biodiversity beyond that due to the loss of habitat area alone.

Some of the additional fragmentation effects of habitat loss are also non-linear in that they increase more rapidly in severity as habitat loss increases. For example, Andrén (1994) demonstrated that there is a rapid increase in the average distance between habitat patches (isolation) as the proportion of habitat remaining in a landscape decreases below about 0.3 (or 30%; Fig. 4).

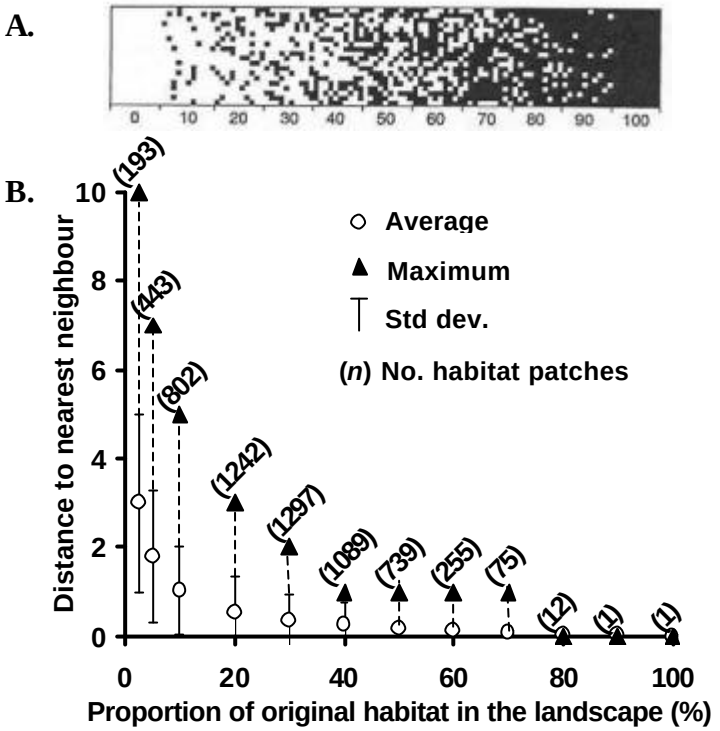


Figure 4. Average and maximum simulated isolation (distance to nearest neighbouring habitat) in relation to the proportion of habitat remaining (here represented as %), based on simulations of habitat fragmentation (redrawn from Andrén (1994)). The upper inset (**A**) shows one possible configuration of fragmentation of habitat (black pixels). **B** shows, for different proportions of habitat remaining, the average (open circles) and maximum (closed triangles) isolation (distance to nearest neighbour) of remaining pixels derived from multiple random spatial configurations of fragmentation.

Increased distance between habitat patches can limit species' access to key resources, restrict the potential of species and populations to migrate as climate change progresses, and prevent exchange of genetic material with other 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. (2004)). Andrén (1994, 1996) suggests that increased isolation may lead to sharp population declines once some 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 average habitat patch area decreases with increased habitat loss. Small fragments in modified landscapes may be largely or entirely edge (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).

Recent studies indicate that co-extinctions (the loss of host-dependent species) can compound the rate of biodiversity loss, and these effects need to be taken into account when estimating extinction rates (Koh et al. 2004).

We draw attention to some of these additional, non-linear effects of habitat loss and fragmentation because they illustrate that multiple factors may contribute to more rapid biodiversity loss, and higher risk to remaining indigenous biodiversity, than predicted on the basis of 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.

2.5.3 Limitations of the susceptibility to biodiversity loss index and future work

The SBL index indicates 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 indices of risk to remaining biodiversity across landscapes will be developed in future, based on 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 threat classification for remaining indigenous biodiversity in New Zealand's 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 <30% indigenous cover is considered 'threatened'. Remaining 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, remaining indigenous biodiversity is considered to be 'Acutely Threatened'. We have chosen the terminology for these three threat categories to be symmetrical with the national system for classifying species according to threat of extinction (Molloy et al. 2002)[5].

A threat classification based on past habitat loss alone (and hence susceptibility to loss) is insufficient, since it fails to recognise poor legal protection as a key component of biodiversity vulnerability. Many environments with low (i.e. less than 20%) levels of legal protection are included in the 'At Risk', 'Chronically Threatened' and 'Acutely Threatened' categories. However, a number of environments that have more than 30% indigenous cover remaining are poorly protected (i.e. they have less than 20% of their area under legal protection). Remaining indigenous biodiversity in these environments is assigned to two further threat categories (Table 1): Critically

[5] 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: 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); in order of increasing threat.

Underprotected if <10% is protected, and Underprotected if 10–20% is protected. For convenience, we refer to environments within these five categories as 'threatened environments'.

Table 1. Recommended categories of threat to environments, and defining criteria.

Category	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected
Criteria	<10% indigenous cover remaining	10–20% indigenous cover remaining	20–30% indigenous cover remaining	>30% indigenous cover remaining	
				<10% legally protected	10–20% legally protected

3. General methods

3.1 Data sources

The following five spatial data sources in digital format (GIS shapefiles and grids) were used in the analyses:

1. Three versions of the land cover database.
    (a) LCDB1_2 (imagery 1996/97, second version, released in 2001, 14 cover classes),
    (b) LCDB1C (corrected version, imagery 1996/97, released July 2004, 43 classes), and
    (c) LCDB2 (Satellite imagery acquired between September 2001 and March 2002, released July 2004, 43 classes; Terralink 2004).

We use LCDB1C (recently released with the LCDB2 in July 2004) as the principal data source defining the status of indigenous cover in New Zealand in the summer of 1996/97.

LCDB1C is a corrected and improved version of LCDB1_2, and uses a greater range of cover classes (43 v. 14) and hence there is a greater resolution of cover types. For example, a single class for 'scrub' in LCDB1_2 is divided into five predominantly indigenous and three mainly exotic classes in LCDB1C. However, we note that the classes are qualitative and all contain considerable variation in composition.

In this report, we use LCDB1C and LCDB2 to represent land cover in 1996/97 and 2001/02, respectively. Note that in this report LCDB1C is referred to as 'LCDB1' and LCDB1_2 data are presented only in Section 4.6. To allow comparisons to be made, digital tables that accompany this report contain statistics for all three databases (LCDB1_2, LCDB1 and LCDB2).

Work completed earlier this year for MfE (i.e. Rutledge et al. (2004, unpubl.) and MfE, DOC & LGNZ (2004)) pre-dates the release of LCDB2 and LCDB1 and is based on LCDB1_2. Therefore, figures produced in our analyses with this database will differ from that previous work (see Section 4.6).

The 43 classes of land cover within LCDB1 and LCDB2 were assigned to indigenous (22 'natural' LCDB2 cover classes), and non-indigenous (21 'exotic' LCDB2 cover classes) categories (Appendix 1). A third category (non-indigenous cover recently

disturbed, or NIRD) was developed for LCDB2. NIRD represents areas classified as non-indigenous in 1996/97 that had changed by 2001/02 to one of the following LCDB2 classes: 10, Coastal Sand and Gravel; 11, River and Lakeshore Gravel and Rock; or 12, Landslide. Because NIRD pixels do not represent recovery of indigenous vegetation, and are unlikely to revert to indigenous cover in time, we excluded them from assessment of indigenous cover in our analyses of LCDB2 land cover.

The percentage of indigenous cover remaining in an environment in 2001/02 (based on indigenous cover classes of LCDB2) is used as the primary threat criterion, and to estimate the risk to remaining biodiversity within that environment, i.e. its susceptibility to loss. Change in the percentage of indigenous cover remaining in an environment between 1996/97 and 2001/02 is used to estimate the change in the risk to remaining indigenous biodiversity within an environment.

2. Land Environments of New Zealand Level IV (LENZ; Leathwick et al. 2003a, b). The LENZ classification explicitly identifies the diversity of New Zealand's terrestrial environments, and is therefore a surrogate for the likely past (i.e. prehuman) pattern of terrestrial ecosystems and their associated biodiversity.

Land environments are classified at four different national scales: Levels I (20 land environments nationally, A to T), II (100 land environments nationally, A1 to T1), III (200 land environments nationally, A1.1 to T1.1) and IV (500 land environments nationally, A1.1a to T1.1a). Each level is nested within higher levels. The 500 Level IV environments of LENZ provide the most detailed information on the diversity of New Zealand's terrestrial environments, and is therefore our best nationally comprehensive estimate of the 'full range' of ecosystems, habitats, and biodiversity. However (as noted in 3.3. Data Limitations and in our Recommendations) Level IV of LENZ does not adequately represent many distinctive small-scale habitats that make disproportionately large contributions to biodiversity.

3. Protected areas (comprising public conservation lands and covenants). We use the 'protection' dataset compiled for MfE, DOC & LGNZ (2004), comprising land managed by the Department of Conservation, 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, unpubl.). We 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. 2003b; Lee & Walker 2004, unpubl.).

4. (a) Districts (a national GIS database delineating 73 local authority districts and cities). We have not split districts where they are divided across more than one political Region (e.g. Franklin District is split between Auckland and Waikato regions). Note that in this, our analysis differs from work by Landcare Research for the Ministry for the Environment on 20 September

2004 (that work separated districts split across regions, and therefore recognised 81 district × region combinations).
(b) Regions (a national GIS database delineating 16 local authority regions; Appendix 3(b,c) only)

5. Eight classes of land use capability (LUC) from the NZLRI (New Zealand Land Resource Inventory, held by Landcare Research). The NZLRI is a spatial database of 100,000 polygons (map units) covering the whole of New Zealand, each of which describes a parcel of land in terms of characteristics or attributes (rock, soil, slope, erosion, vegetation). LUC assessments are included for each polygon. 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, classifying 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 are based on, and described by, Rutledge et al. (2004, unpubl.).

3.2 Data analysis

3.2.1 Indigenous cover and threatened environments in 2001/02

Using LENZ at Levels II and IV, and the LCDB2 and protection databases, 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'). We calculated the number of environments, the total areal extent of environments, and the total remaining area of indigenous cover in each of five environment threat categories (Acutely Threatened, Chronically Threatened, At Risk, Critically Underprotected or Underprotected; Table 1).

Most analyses were performed twice, with threat classification at Levels II and IV, respectively. Each of the 100 Level II environments contains several of the 500 Level IV environments, sometimes with quite different threat status. Although Level II analysis provides a simpler framework for national overview data, it is less suitable than Level IV for assessing (and hence protecting) vulnerable biodiversity at local and regional scales (Leathwick et al. 2003a; MfE, DOC & LGNZ 2004). The relative merits of Level II v. Level IV threat classification are more fully covered in Results and Discussion.

To provide an overview of the distribution of threat categories across New Zealand's land environments, we (1) calculated and plotted 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 in threatened environments

We calculated the area of each land environment that was mapped as remaining indigenous cover *and* not within legally protected land (Indigenous cover not protected, hereafter INP) in 2001/02. We summarised the number of land environments, and the total area of indigenous cover not protected in threatened

environments (hereafter INPTE). We then calculated the total area, and area of INPTE in each of 73 district councils across New Zealand.

3.2.3 Determining the appropriate LENZ level to assess New Zealand's threatened environments

In this part, we compare the effectiveness and efficiency of threat classification at Level II and Level IV for identifying New Zealand's most vulnerable indigenous biodiversity at scales relevant to local authority users.

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

We calculated the area of INP in each of eight land use capability (LUC) classes assigned to those areas in the NZLRI.

3.2.5 Changes in indigenous cover 1996/97 to 2001/02 and its consequences for risk to remaining indigenous biodiversity

By comparing LCDB1 and LCDB2, we

1. Quantified loss of indigenous cover and rates of loss of indigenous cover from 1996/97 to 2001/02 by environment threat category and indigenous cover class.
2. Quantified change in the susceptibility to biodiversity loss index for land environments from 1996/97 to 2001/02, based on the total area (and hence proportion) of indigenous cover remaining at each date, and compared these changes across environment threat categories.
3. Finally, we quantified the contribution of each of the 73 council areas to change in indigenous cover, and summed change in susceptibility to biodiversity loss across New Zealand's land environments from 1996/97 to 2001/02.

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.

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

2. Land cover. In these analyses, we have taken the cover classes in LCDB1 and LCDB2 'at face value'. However, we know there are misclassifications and errors in both databases (but not their full magnitude or locations) and therefore that the cover data are not perfectly accurate. Because of mapping/classification error, and the broad scope and qualitative nature of the cover classes (Grüner & Gapare 2004), LCDB2 cover classes cannot and

should not be relied upon to assess whether cover is in fact indigenous on the ground. Field inspection will be needed to verify this. Some classes (depleted grassland and low-producing grassland) are particularly problematic for indigenous/non-indigenous categorisation. In 'depleted grassland' (assigned to 'indigenous'), ground cover is often dominated by the exotic flatweed *Hieracium pilosella*, but native species may dominate in number (e.g. Meurk et al. 2002). 'Low producing grassland' includes some completely exotic cover types (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. We have assigned 'low-producing grassland' to the non-indigenous category. The single 'Herbaceous freshwater vegetation' class is assigned to the Indigenous category, and therefore the degree to which indigenous wetlands have been modified and reduced cannot be estimated. Hence where little indigenous vegetation remains in LENZ environments distinguished by poor drainage and wetland vegetation (e.g. Environment L3.1a on the Southland Plains) these environments will incorrectly be assigned to 'no threat category'.

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, unpubl.) and inaccuracies associated with covenant boundaries (Rutledge et al. 2004, unpubl.). These sources of error will tend to increase estimates of protected land in threatened environments. However, 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, and in some cases considerably. Improved national biodiversity protection data will rely on continued co-ordinated endeavours of several agencies.

4. Results

4.1 Indigenous cover and threatened environments in 2001/02

Almost two-thirds of New Zealand's land environments are classified within one of the five threat categories: Acutely Threatened, Chronically Threatened, At Risk, Critically Underprotected or Underprotected environments (hereafter 'threatened environments') and account for 67% of Level IV environments (threat classification at Level IV) or 63% of Level II environments (threat classification at Level II). The five threat categories account for 54% or 53% (threat classification at 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.

LCDB2 data indicate that less than half of New Zealand's land area (12,632,214 ha, or 49%) remained under some form of indigenous cover in the summer of 2001/02 (the date of LCDB2 imagery) (Table 2). Acutely Threatened, Chronically Threatened and At Risk environments (i.e. those with <30% indigenous cover remaining) represent 57% of Level IV environments and 42% of New Zealand's land area (threat classification at Level IV), and 51% of Level II land environments and 41% of New Zealand's land area (threat classification at Level II).

The two highest categories of risk to remaining biodiversity (Acutely and Chronically Threatened environments, both with <20% of indigenous cover remaining) together account for 46% of environments and 32% of New Zealand's land area (threat classification at Level IV), or 42% of environments and 26% of New Zealand's land area (threat classification 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 <10% of indigenous cover remaining, and fall within the highest category of risk to remaining biodiversity (Acutely Threatened). Acutely Threatened environments account for 32% of Level IV land environments and 23% of total land area (threat classification at Level IV), or 29% of Level II environments and 19% of New Zealand's total land area (threat classification 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 threatened land environments in 2001/02, based on (1) threat classification at Levels IV and II of LENZ, (2) LCDB2, and (3) legal protection in conservation land and covenants. Number of environments, the area of full extent of environments, and area of remaining indigenous cover in environments are shown.

	LENZ level	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Under-protected	Under-protected	No threat category
	Number of environments							
No. of	Lvl_IV	500	158	74	52	33	18	165
LENZ	Lvl_II	100	29	13	9	6	6	37
% of	Lvl_IV	"	31.6	14.8	10.4	6.6	3.6	33.0
LENZ	Lvl_II	100.0	29.0	13.0	9.0	6.0	6.0	37.0
	Full extent of environments							
Area	Lvl_IV	26,000,680	5,888,292	2,323,074	2,788,941	1,825,031	1,158,487	12,016,855
(ha)	Lvl_II		4,983,260	1,674,228	4,090,474	772,143	2,138,778	12,341,796
% of	Lvl_IV	100.00	22.65	8.93	10.73	7.0	8.2	46.2
NZ	Lvl_II		19.17	6.44	15.73	3.0	3.0	47.5
	Indigenous cover remaining in environments							
Area	Lvl_IV	12,632,214	220,862	344,889	674,218	794,673	663,006	9,934,566
(ha)	Lvl_II		223,886	231,329	1,125,322	328,852	1,056,026	9,666,799
% of	Lvl_IV	48.58	3.75	14.85	24.17	43.5	57.2	82.7
full	Lvl_II		4.49	13.82	27.51	42.6	49.4	78.3
extent								

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 <30% indigenous cover remaining, and only one (S1.1a) has <20% of its land area protected.

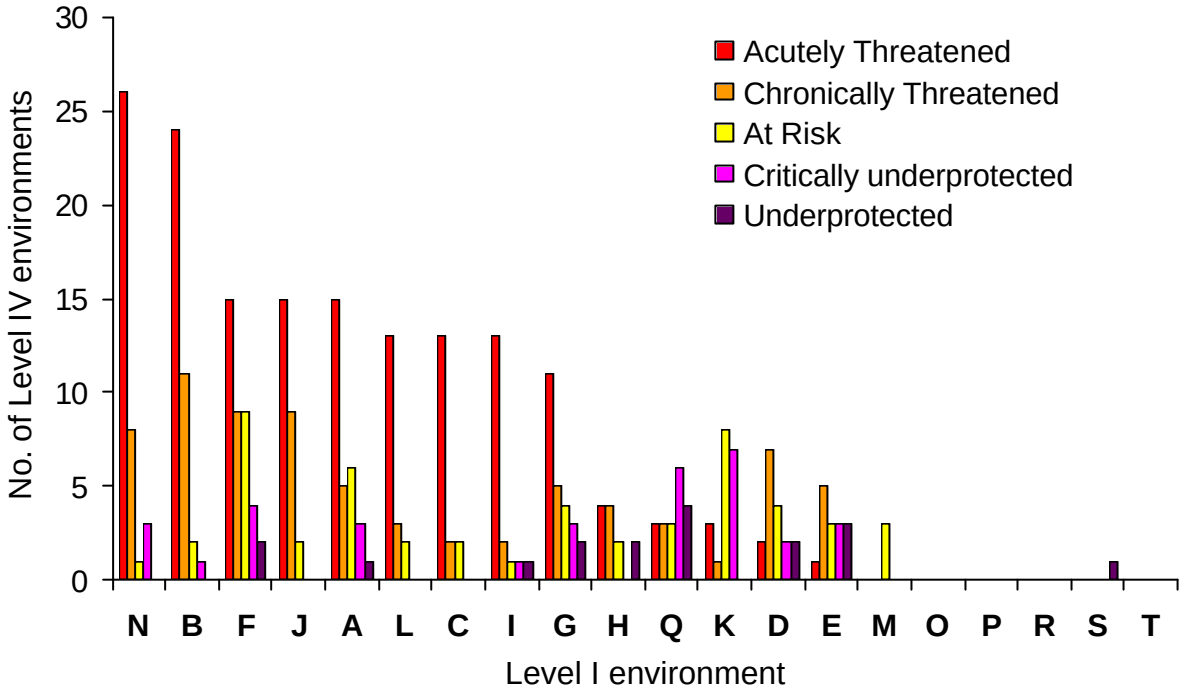
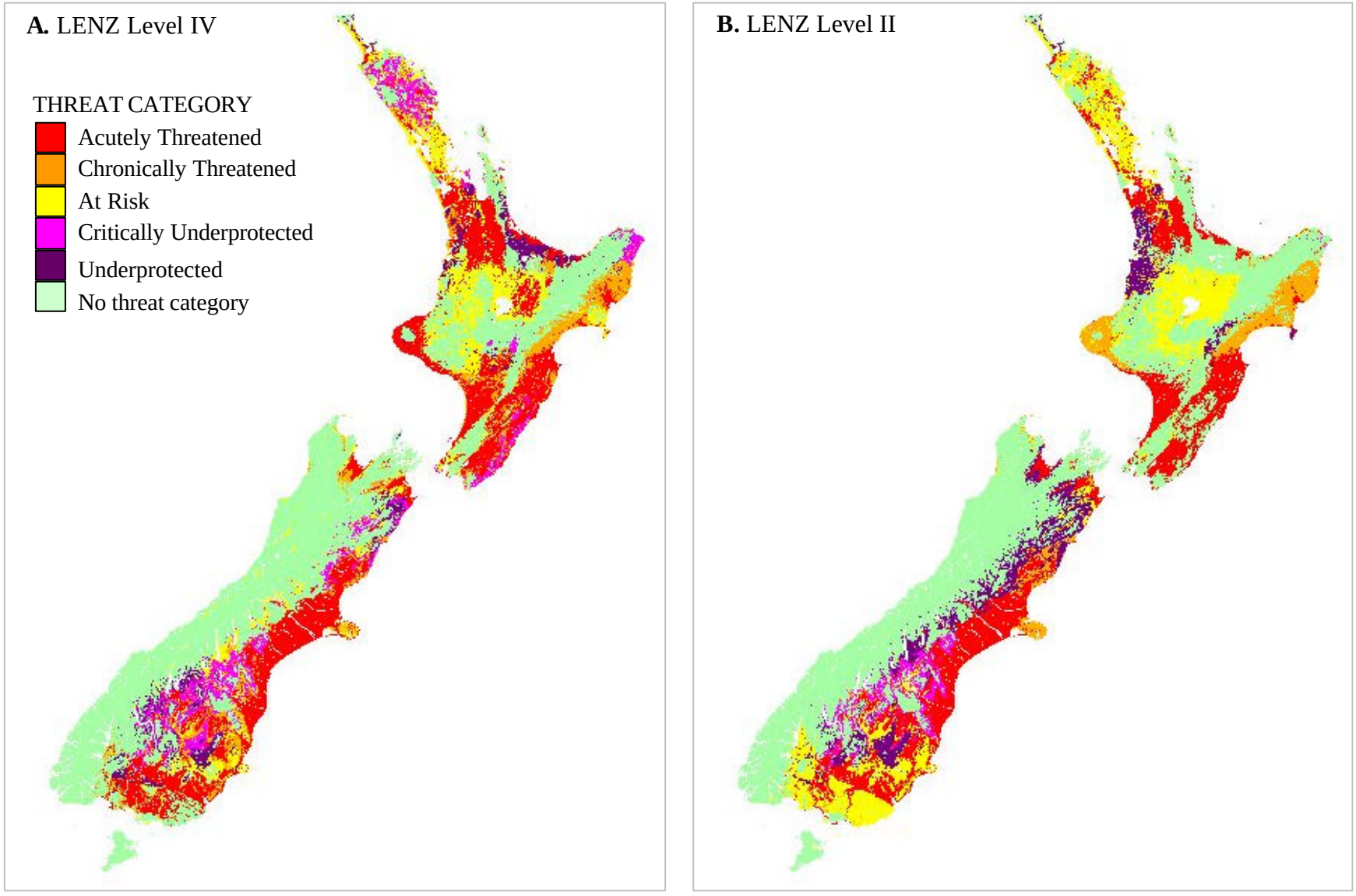


Figure 4. Number of threatened Level IV land environments in New Zealand's 20 Level I environments (A to T, arranged in order of decreasing threat to remaining indigenous biodiversity). Analyses are based on (1) Levels I and IV of LENZ, (2) LCDB2, and (3) legal protection in conservation land and covenants.

Map 1 shows the distribution of threatened environments in New Zealand, and indicates that lowland environments predominate in the categories of highest risk to remaining indigenous biodiversity.

Map 1. New Zealand's threatened environments, classified at **A.** Level IV and **B.** Level II of LENZ.
Analyses are based on (1) Levels IV and II of LENZ, (2) LCDB2, and (3) legal protection in conservation land and covenants.



4.2 Indigenous cover not protected in threatened environments

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

Table 3. Indigenous cover remaining (area and % of full extent of all environments in a threat category), and indigenous cover not protected (area, % of New Zealand, and % of total remaining indigenous cover in a threat category) in 2001/02. The table shows statistics for environment threat categories classified at LENZ Levels IV and II. The analyses are based on (1) threat classification at Levels IV and II of LENZ, (2) LCDB2, and (3) legal protection in conservation land and covenants.

	LENZ level	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Under-protected	Under-protected	No threat category
	Indigenous cover remaining in environments							
Area	Lvl_IV	12,632,214	220,862	344,889	674,218	794,673	663,006	9,934,566
(ha)	Lvl_II		223,886	231,329	1,125,322	328,852	1,056,026	9,666,799
% of	Lvl_IV	48.58	3.75	14.85	24.17	43.5	57.2	82.7
Full extent	Lvl_II		4.49	13.82	27.51	42.6	49.4	78.3
	Indigenous cover not protected (INP) in environments							
Area	Lvl_IV	4,794,636	182,573	285,416	468,195	708,816	497,697	2,651,940
(ha)	Lvl_II		183,726	186,287	688,068	290,562	750,394	2,695,598
% of	Lvl_IV	18.44	0.70	1.10	1.80	2.73	1.91	10.20
NZ	Lvl_II		0.71	0.72	2.65	1.12	2.89	10.37
% of	Lvl_IV	37.96	82.66	82.76	69.44	89.20	75.07	26.69
remaining	Lvl_II		82.06	80.53	61.14	88.36	71.06	27.89

Based on our indigenous/non-indigenous categorisation of LCDB2 classes and the protection database (which excludes council reserves), 38% of New Zealand's remaining indigenous cover is not legally protected. High percentages (c. 60–90%) of remaining indigenous cover in all categories of threatened environments are not legally protected. In environments with no assigned threat category, a lower percentage (c. 27–28%) of the remaining indigenous cover is not protected.

Acutely Threatened and Chronically Threatened environments contain smaller total areas of INP than At Risk environments. The largest areas of INPTE (i.e. INP in all threatened environments) are in the Critically Underprotected and Underprotected environments, which have >30% of indigenous cover remaining.

The 304 Crown pastoral leases in the South Island high country presently contain 31% of New Zealand's remaining unprotected indigenous cover, and 27% (c. 567,380 ha) of the remaining INPTE (i.e. unprotected indigenous cover in threatened environments). The area of INPTE on pastoral leases may be higher than this estimate, since indigenous short-tussock grasslands contained within the low-producing grasslands class in LCDB2 are classified as exotic and therefore not distinguished. Overall, indigenous cover on pastoral leases remains 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.

Tables 4 and 5 show the types of remaining indigenous cover that are not legally protected in environment threat categories determined at Level IV and Level II of LENZ, respectively. In Acutely Threatened and Chronically Threatened environments, indigenous cover not protected (INPTE) is dominated by forest and regenerating forest (Indigenous Forest, Manuka and/or Kanuka and Broadleaved Indigenous Hardwoods LCDB2 classes). In contrast, in Critically Underprotected and Underprotected environments INPTE is dominated by the Tall Tussock Grassland LCDB2 class (34% and 54%, respectively, of these environment threat categories determined at LENZ Level IV). Manuka and/or Kanuka and Indigenous Forest also account for large portions of the INPTE in Critically Underprotected and Underprotected threat categories. Depleted Grasslands are a significant component of Critically Underprotected INPTE (17% of this environment threat category determined at LENZ Level IV).

Tables 6 and 7 tabulate total INP (indigenous cover not protected) and INPTE (indigenous cover not protected in threatened environments) areas in each of 73 district councils across New Zealand. Figure 5 illustrates INPTE area for 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. A threat classification at Level II of LENZ is less precise, and shows Central Otago, Southland, Mackenzie, and Hurunui districts as the top-ranking councils, containing 32% of INPTE.

A relatively large portion (c. 567,380 ha, or 26%) of total INPTE (indigenous cover not protected in threatened environments) is on reviewable pastoral leases in the South Island high country. Because South Island high country pastoral leases remain largely indigenous in character, much of the INPTE on pastoral leases is in the At Risk, Critically Underprotected and Underprotected environment categories that have 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. in environments where remaining indigenous cover has been reduced below 20% of original environment extent.

Table 4. Remaining indigenous cover not protected (INP) in all of New Zealand's environments, and in the five categories of threatened environments (INPTE) in 2001/02, by indigenous cover class. Analysis is based on environment threat categories determined at *Level IV* of LENZ, LCDB2 indigenous cover classes, and legal protection in conservation land and covenants.

	Indigenous cover not protected (INP)					
	Total (all 500 environments)	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected
Area (ha)						
Broadleaved Indigenous Hardwoods	348,214	31,197	48,706	52,436	36,960	20,533
Depleted Grassland	225,511	3,702	21,524	26,737	118,190	9,554
Fernland	43,188	1,000	1,675	1,906	14,411	2,616
Grey Scrub	63,624	3,650	8,079	8,398	20,284	3,840
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	3,612	3,157	6,784	7,913	490
Tall-Tussock Grassland	1,347,822	5,212	23,055	38,657	237,179	267,834
Alpine[1]	137,602	14	100	263	5,289	11,903
Rock[2]	300,354	14,228	12,273	19,335	17,360	11,516
Wetland/Water[3]	91,146	24,073	12,545	12,897	8,562	5,376
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[1]	2.9	0.0	0.0	0.1	0.7	2.4
Rock[2]	6.3	7.8	4.3	4.1	2.4	2.3
Wetland/Water[3]	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

[1]Alpine = Alpine Grass/ Herbfield, Permanent Snow and Ice, Subalpine Shrubland.
[2]Rock = Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, River and Lakeshore Gravel and Rock.
[3]Water/Wetland = Estuarine Open Water, Flaxland, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake and Pond, Mangrove, River.

Table 5. Remaining indigenous cover not protected (INP) in all of New Zealand's environments, and in the five categories of threatened environments (INPTE) in 2001/02, by indigenous cover class. Analysis is based on environment threat categories determined at *Level II* of LENZ, LCDB2 indigenous cover classes, and legal protection in conservation land and covenants.

	Indigenous cover not protected (INP)					
	Total (all 100 environments)	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected
Area (ha)						
Broadleaved Indigenous Hardwoods	348,214	26,228	42,385	52,159	10,430	35,377
Depleted Grassland	225,511	6,562	1,022	36,709	68,030	64,608
Fernland	43,188	716	914	2,623	13,944	4,243
Grey Scrub	63,624	4,169	1,205	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	2,678	2,767	2,136	7,947	7,319
Tall-Tussock Grassland	1,347,822	17,732	2,651	101,430	133,427	289,851
Alpine[1]	137,602	32	37	3,253	2,652	17,322
Rock[2]	300,341	19,062	7,827	13,554	7,668	20,706
Wetland/Water[3]	91,145	23,103	12,871	14,708	6,288	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[1]	2.9	0.0	0.0	0.5	0.9	2.3
Rock[2]	6.3	10.4	4.2	2.0	2.6	2.8
Wetland/Water[3]	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

[1]Alpine = Alpine Grass/ Herbfield, Permanent Snow and Ice, Subalpine Shrubland.
[2]Rock = Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, River and Lakeshore Gravel and Rock.
[3]Water/Wetland = Estuarine Open Water, Flaxland, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake and Pond, Mangrove, River.

Table 6. Indigenous cover not protected in New Zealand's threatened environments in 73 district council areas in 2001/02. The analysis shows environment threat categories determined at *Level IV* of LENZ, on the basis of LCDB2 indigenous cover classes, and legal protection in conservation land and covenants.

		Area indigenous cover not protected (INP) (ha)					INP in all five threatened environments (INPTE)			
									% 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	% of district	%	Rank (across 73 councils)
Ashburton	588,482	1,898	838	8,513	2,075	2	13,325	2.3	0.6	36
Auckland	62,303	446	480	1,264	3,835	0	6,024	9.7	0.3	47
Banks Peninsula	96,989	2,841	4,863	4,970	0	0	12,674	13.1	0.6	37
Buller	788,090	0	711	2,465	21	0	3,198	0.4	0.1	58
Carterton	119,784	2,266	1,630	50	4,706	0	8,652	7.2	0.4	44
Central Hawke's Bay	327,393	6,458	4,261	492	3,417	0	14,627	4.5	0.7	34
Central Otago	986,431	5,282	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	9,859	5,151	12,440	512	10,510	38,471	6.1	1.8	17
Dunedin	325,742	4,290	6,694	17,034	1,108	21,982	51,108	15.7	2.4	12
Far North	666,822	3,643	8,561	33,787	58,010	5,711	109,712	16.5	5.1	5
Franklin	215,041	4,192	6,145	4,210	972	18,242	33,761	15.7	1.6	21
Gisborne	831,520	3,815	47,601	5,836	43,485	3,728	104,464	12.6	4.9	6
Gore	123,454	743	83	926	2	2,503	4,256	3.4	0.2	52
Grey	338,118	0	0	2,004	0	0	2,004	0.6	0.1	64
Hamilton	9,762	285	7	0	0	0	292	3.0	0.0	71
Hastings	514,892	3,363	17,195	744	418	58	21,779	4.2	1.0	28
Hauraki	117,082	1,603	179	1,638	4	2,564	5,987	5.1	0.3	48
Horowhenua	105,152	1,556	1,166	553	0	0	3,276	3.1	0.2	57
Hurunui	845,910	7,226	10,219	10,002	27,561	4,384	59,393	7.0	2.8	9
Invercargill	38,896	274	126	790	0	0	1,190	3.1	0.1	68
Kaikoura	201,337	770	1,994	1,262	11,019	23,481	38,525	19.1	1.8	16
Kaipara	307,552	1,675	4,397	10,655	7,946	0	24,673	8.0	1.2	27
Kapiti Coast	73,055	1,270	300	1,312	16	0	2,897	4.0	0.1	59
Kawerau	2,432	78	58	0	0	54	190	7.8	0.0	73
Lower Hutt	37,486	596	310	3,382	399	0	4,687	12.5	0.2	50
Mackenzie	685,329	2,440	8,834	22,176	76,555	1,739	111,744	16.3	5.2	4
Manawatu	258,852	4,594	5,311	522	1	1	10,429	4.0	0.5	41
Manukau	53,186	403	163	1,379	3,433	3,533	8,911	16.8	0.4	43
Marlborough	1,032,287	3,183	9,080	10,724	28,649	21,929	73,566	7.1	3.4	8
Masterton	227,643	4,621	4,808	297	8,893	0	18,618	8.2	0.9	30
Matamata – Piako	175,210	1,392	114	1,470	0	900	3,876	2.2	0.2	53
Napier	9,948	216	0	0	0	0	216	2.2	0.0	72
Nelson	42,101	398	213	921	0	74	1,605	3.8	0.1	67
New Plymouth	221,207	3,960	147	4,797	0	479	9,383	4.2	0.4	42
North Shore	12,743	51	63	1,873	28	0	2,015	15.8	0.1	63
Opotiki	309,775	2,228	1,099	236	1,443	2,969	7,974	2.6	0.4	46
Otorohanga	200,714	744	773	10,414	0	6,064	17,995	9.0	0.8	31
Palmerston North	32,537	356	1,147	524	2	0	2,029	6.2	0.1	61
Papakura	12,023	113	5	1,116	3	469	1,705	14.2	0.1	66
Porirua	17,648	494	136	992	273	0	1,894	10.7	0.1	65
Queenstown Lakes	856,396	1,471	2,913	2,714	53,095	99,483	159,676	18.6	7.5	2
Rangitikei	445,780	11,128	4,929	2,701	16,337	4,276	39,372	8.8	1.8	14
Rodney	232,172	1,006	2,111	25,119	2,125	3	30,364	13.1	1.4	23
Rotorua	238,205	1,339	1,470	2,902	0	6,836	12,548	5.3	0.6	38

Council (district or city)	Total district/city council area (ha)	Area indigenous cover not protected (INP) (ha)					INP in all five threatened environments (INPTE)			
		Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	Total area	% of district	% of total national area	
									%	Rank (across 73 councils)
Ruapehu	669,819	743	2,709	43,762	3,906	3,718	54,838	8.2	2.6	10
Selwyn	604,810	1,940	746	8,660	2,254	0	13,601	2.2	0.6	35
South Taranaki	357,185	6,003	146	4,083	0	401	10,633	3.0	0.5	40
South Waikato	179,445	849	164	504	0	508	2,025	1.1	0.1	62
South Wairarapa	233,337	6,377	5,804	670	21,762	1	34,614	14.8	1.6	19
Southland	2,905,381	9,132	12,146	10,425	12,104	46,513	90,320	3.1	4.2	7
Stratford	213,951	1,089	133	14,767	0	0	15,990	7.5	0.7	33
Tararua	435,552	11,237	8,189	552	10,400	0	30,379	7.0	1.4	22
Tasman	953,487	3,277	6,232	7,338	166	72	17,086	1.8	0.8	32
Taupo	629,332	3,715	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	1,275	1,366	1,436	2,110	2,295	8,481	3.9	0.4	45
Timaru	258,233	2,263	1,132	1,012	6,320	0	10,727	4.2	0.5	39
Upper Hutt	54,024	675	343	2,398	10	0	3,426	6.3	0.2	55
Waikato	305,697	6,124	4,921	3,229	0	14,832	29,106	9.5	1.4	24
Waimakariri	213,075	1,558	408	295	1,609	0	3,870	1.8	0.2	54
Waimate	346,519	2,373	2,630	7,193	39,874	216	52,286	15.1	2.4	11
Waipa	144,427	2,436	287	1,342	0	1,157	5,223	3.6	0.2	49
Wairoa	403,830	1,453	19,804	13,330	1	7	34,595	8.6	1.6	20
Waitakere	36,396	251	210	1,327	2,361	112	4,261	11.7	0.2	51
Waitaki	698,635	4,145	14,735	16,392	68,130	28,543	131,945	18.9	6.2	3
Waitomo	350,843	1,437	192	27,531	0	10,142	39,302	11.2	1.8	15
Wanganui	234,469	1,995	2,614	20,104	0	71	24,783	10.6	1.2	26
Wellington	28,742	446	15	2,020	920	0	3,401	11.8	0.2	56
Western Bay of Plenty	196,035	2,910	4	184	1,104	21,469	25,671	13.1	1.2	25
Westland	1,145,206	0	0	2,233	0	0	2,233	0.2	0.1	60
Whakatane	440,625	1,628	2,395	1,783	0	12,842	18,649	4.2	0.9	29
Whangarei	269,661	1,575	3,351	7,655	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 in New Zealand's threatened environments in 73 district council areas in 2001/02. The analysis shows environment threat categories determined at *Level II* of LENZ, on the basis of LCDB2 indigenous cover classes, and legal protection in conservation land and covenants.

		Area indigenous cover not protected (INP) (ha)					INP in all five threatened environments (INPTE)			
									% 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	% of district	%	Rank (across 73 councils)
Ashburton	588,482	2,719	167	25	1,434	28,555	32,900	5.6	1.6	22
Auckland	62,303	801	187	5,029	0	0	6,017	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	1,171	21	28	2,220	0.3	0.1	57
Carterton	119,784	3,696	0	162	0	0	3,859	3.2	0.2	46
Central Hawke's Bay	327,393	8,794	16	303	0	367	9,480	2.9	0.5	36
Central Otago	986,431	15,389	2,725	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	7,395	504	44,430	333	10,970	63,631	10.1	3.0	10
Dunedin	325,742	5,672	154	22,895	1,842	20,912	51,475	15.8	2.5	15
Far North	666,822	6,183	4,214	91,873	0	5,711	107,981	16.2	5.1	5
Franklin	215,041	5,572	360	5,186	0	22,091	33,209	15.4	1.6	21
Gisborne	831,520	1,400	57,389	223	4,258	43	63,313	7.6	3.0	11
Gore	123,454	332	10	5,258	2	89	5,691	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	5,313	14,938	1,171	0	17,117	38,539	7.5	1.8	18
Hauraki	117,082	1,442	60	1,617	0	247	3,366	2.9	0.2	49
Horowhenua	105,152	2,428	0	498	0	0	2,926	2.8	0.1	55
Hurunui	845,910	3,497	21,198	8	526	87,195	112,423	13.3	5.4	4
Invercargill	38,896	790	171	878	0	0	1,838	4.7	0.1	59
Kaikoura	201,337	513	2,017	5,769	1	42,344	50,643	25.2	2.4	16
Kaipara	307,552	2,481	1,339	20,821	0	0	24,641	8.0	1.2	26
Kapiti Coast	73,055	1,332	0	1,149	0	0	2,481	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	1,612	4.3	0.1	61
Mackenzie	685,329	4,873	1,749	10,322	68,604	50,301	135,849	19.8	6.5	3
Manawatu	258,852	2,881	5	439	0	0	3,325	1.3	0.2	50
Manukau	53,186	540	27	4,811	0	3,533	8,911	16.8	0.4	37
Marlborough	1,032,287	4,838	2,225	16,649	399	82,514	106,625	10.3	5.1	6
Masterton	227,643	7,321	0	437	0	0	7,758	3.4	0.4	39
Matamata – Piako	175,210	1,161	38	1,470	0	468	3,136	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	1,083	1,604	3.8	0.1	62
New Plymouth	221,207	16	5,852	5,271	0	295	11,434	5.2	0.5	33
North Shore	12,743	104	0	1,911	0	0	2,015	15.8	0.1	58
Opotiki	309,775	1,230	701	1,241	217	440	3,828	1.2	0.2	47
Otorohanga	200,714	98	284	7,123	0	14,744	22,249	11.1	1.1	27
Palmerston North	32,537	932	0	524	0	0	1,456	4.5	0.1	63
Papakura	12,023	114	0	1,119	0	472	1,705	14.2	0.1	60
Porirua	17,648	622	0	76	0	0	698	4.0	0.0	66
Queenstown Lakes	856,396	860	938	2,979	47,807	15,644	68,228	8.0	3.3	9
Rangitikei	445,780	4,238	404	23,579	0	7,996	36,218	8.1	1.7	20
Rodney	232,172	2,205	730	27,391	0	3	30,329	13.1	1.4	24
Rotorua	238,205	91	205	3,272	0	39	3,607	1.5	0.2	48

Council (district or city)	Total district/city council area (ha)	Area indigenous cover not protected (INP) (ha)					INP in all five threatened environments (INPTE)			
		Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	Total area	% of district	% of total national area	
									%	Rank (across 73 councils)
Ruapehu	669,819	306	1,449	69,621	0	405	71,781	10.7	3.4	8
Selwyn	604,810	1,532	1,194	0	584	27,967	31,278	5.2	1.5	23
South Taranaki	357,185	1,063	4,774	3,959	0	51	9,847	2.8	0.5	35
South Waikato	179,445	50	122	539	0	83	794	0.4	0.0	64
South Wairarapa	233,337	11,301	0	277	0	0	11,578	5.0	0.6	32
Southland	2,905,381	6,930	3,129	100,843	10,680	38,299	159,881	5.5	7.6	2
Stratford	213,951	60	1,245	9,558	0	336	11,199	5.2	0.5	34
Tararua	435,552	8,062	0	745	0	0	8,807	2.0	0.4	38
Tasman	953,487	3,417	1,827	1,068	238	8,122	14,672	1.5	0.7	29
Taupo	629,332	6	1,633	48,592	0	1,538	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	2,665	81	3,326	27	215	6,314	2.9	0.3	41
Timaru	258,233	3,239	302	141	6,466	5,027	15,175	5.9	0.7	28
Upper Hutt	54,024	532	119	2,302	0	0	2,952	5.5	0.1	54
Waikato	305,697	4,174	481	3,291	0	19,827	27,773	9.1	1.3	25
Waimakariri	213,075	1,558	408	0	156	11,951	14,072	6.6	0.7	30
Waimate	346,519	3,771	183	8,502	38,959	575	51,990	15.0	2.5	13
Waipa	144,427	892	214	770	0	1,989	3,864	2.7	0.2	45
Wairoa	403,830	1,710	30,343	40	0	5,030	37,123	9.2	1.8	19
Waitakere	36,396	292	14	3,843	0	112	4,261	11.7	0.2	44
Waitaki	698,635	10,900	1,375	23,156	51,924	9,166	96,521	13.8	4.6	7
Waitomo	350,843	134	1,275	12,109	0	39,317	52,835	15.1	2.5	12
Wanganui	234,469	3,878	255	3,168	0	0	7,301	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	3,073	22	3	151	1	3,250	1.7	0.2	52
Westland	1,145,206	0	0	0	0	0	0	0.0	0.0	73
Whakatane	440,625	315	1,211	1,760	0	2	3,288	0.7	0.2	51
Whangarei	269,661	2,467	2,206	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	

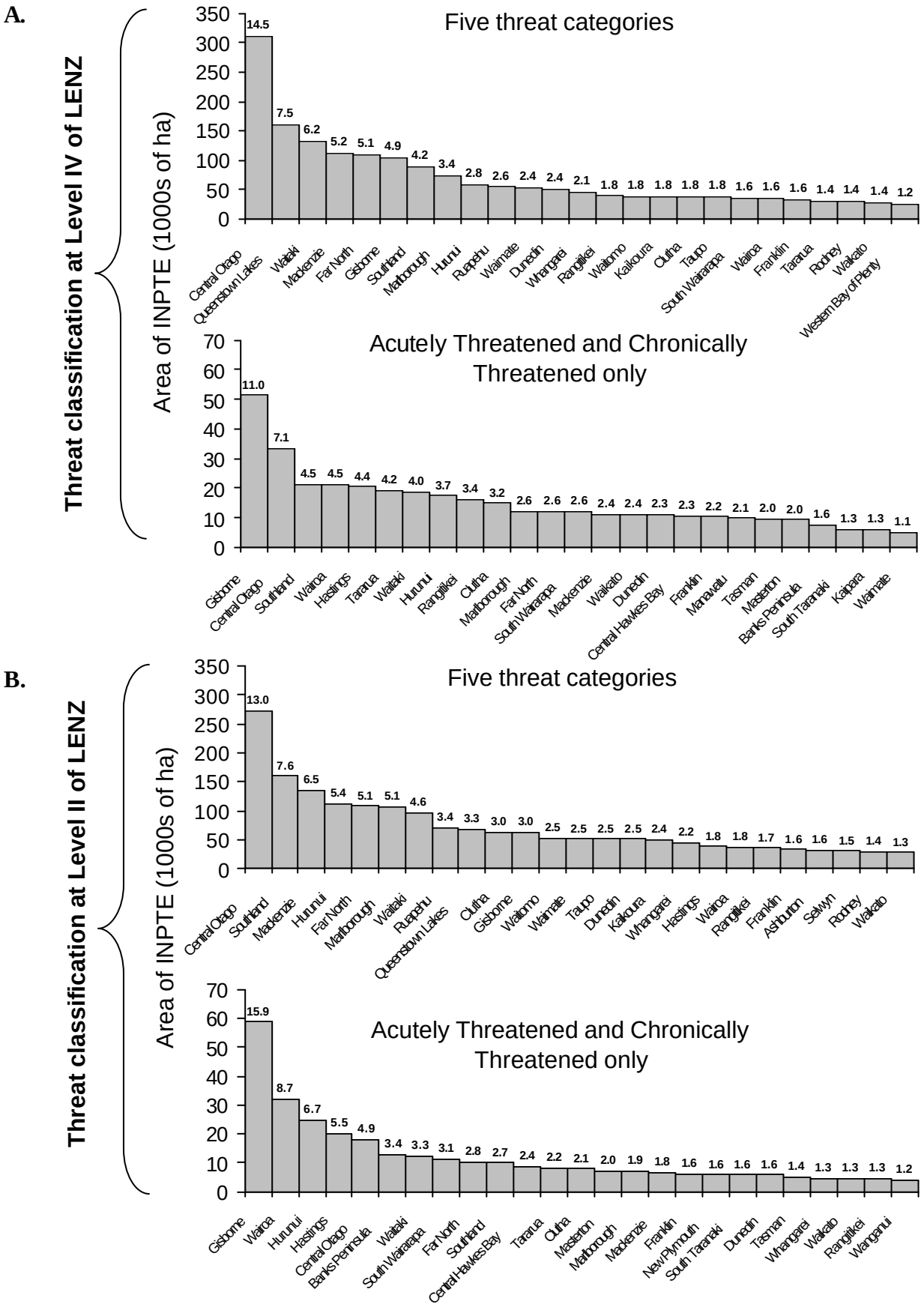


Figure 5. INPTE in the 25 top-ranking councils. Figures associated with each district are the percentage of the total national INPTE represented. **A**. Threat classification at Level IV of LENZ, **B**. Threat classification at Level II.

4.3 What is the most appropriate LENZ level at which to assess New Zealand's threatened environments?

The threat status of a land environment indicates risk to remaining indigenous biodiversity in that environment. Given that the purpose of a threat classification for environments is to direct protection effort to those areas of remaining indigenous cover most at risk of irreversible loss or decline, then a key question is: 'what is the most appropriate land environment classification level to achieve that purpose?'

Land Environments are published at four levels (Levels I to IV), each distinguishing more detail of New Zealand's environmental pattern (which we use here as a surrogate for biodiversity pattern). LENZ Levels I (20 environments) and II (100 environments) are useful for providing overview information at national scales, and Levels III (200 environments) and IV (500 environments) are more useful for applications at local, district and regional scales (Leathwick et al. 2003a, b). Level IV is the finest level of detail published and distinguishes environmental variation at scales down to about 1:50,000.

Level IV environments represent a finer partitioning of LENZ Level II environments and therefore have different aspects of native biodiversity, amounts of habitat loss, and levels of protection. In fact the current 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 2 illustrates differences among Level IV environments in patterns of protection and land clearance, biodiversity pattern, and current vegetation cover types within one Level II land environment (F1). The conclusions we draw from this example is that:

(1) 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.
(2) 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.
(3) Level IV is the most appropriate LENZ level to assess the vulnerability of remaining biodiversity.

We draw these conclusions from quantitative data. However, it is also intuitively obvious to land managers and administrators that Level IV better distinguishes variation in the environment, loss of indigenous cover, and threat to biodiversity at the regional, district and local (e.g. property) scales at which they work. For example, a hypothetical biodiversity officer in Tararua District Council would find little credibility in Level II information classifying remaining indigenous cover in environment F1.1g within the 'no threat category' (see Appendix 2), since it would be obvious to that officer that there was negligible indigenous cover of its type left, and it was poorly protected. Clearly, Level IV would be the better choice for identifying vulnerable biodiversity and prioritising future protection needs in this local authority area.

Having established that it is more appropriate to assess the vulnerability of remaining biodiversity at local, district and regional scales at Level IV than Level II, we can quantify two issues that arise through threat classification at Level II:

1. Less effective identification (and therefore less effective protection) of threatened biodiversity because areas containing much reduced or poorly protected biodiversity are assigned to a lower category of threat, or to the 'no threat' category. Remaining indigenous vegetation in areas of Environment F1 in central Rangitikei District (environment F1.3d; Appendix 2) are an example.
2. Less efficient identification of much reduced or poorly protected biodiversity because some areas of INP that is less reduced or relatively well protected will be classified as threatened.

Overall, the bias will be towards 1. Less effective identification (and therefore less effective protection), rather than 2. Less efficient identification and hence protection. This is because a few well-protected or relatively intact Level IV environments will weight Level II environment totals and averages towards the 'no threat' category. An example of the latter is Environment F1 (Appendix 2), in which 12 of the 19 Level IV environments are threatened, but the whole area is classified as 'no threat category' if threat status is determined by classification at LENZ Level II.

The magnitude of these drawbacks can be quantified. Table 8 shows that threat classification at Level II assigns between 38% and 62% of the area of INPTE identified at Level IV (hereafter 'Level IV INPTE') to the same threat category. The lowest correspondence (38%) is in Critically Underprotected environments identified with threat classification at Level IV. Of total Level IV INPTE (i.e. across the five categories of threat) 503,896 ha (24%) is not assigned to a threat category if threat classification is performed at Level II; in other words, identification of threatened biodiversity is 24% less effective with a Level II threat classification. Furthermore, the cost of less efficient identification is that 17% of INP (460,239 ha) that is not within a threatened Level IV environment is included in one of the five threat categories if classification is performed at Level II (Table 9). We note that using Level IV rather than Level II to more effectively and efficiently target vulnerable biodiversity does not result in large increases in the area identified as under threat: total area of INPTE increases only by 43,657 ha nationally (or less than 0.2% of New Zealand's total land area).

Table 8. Number of environments and area of indigenous cover not protected (INP) in threatened environments determined at Level IV (the finest published level of detail; rows) assigned to threat categories classified at Level II.

		Number of environments		Area of indigenous cover not protected		
		Assigned to same threat category (determined at Level II)	% assigned to same threat category (determined at Level II)	Total (ha) assigned to threat category (determined at Level IV)	Total (ha) assigned to same threat category (determined at Level II)	% assigned to same threat category (determined at Level II)
Threat categories determined at LENZ Level IV	Acutely Threatened	117	74.1	182,573	113,435	62.1
	Chronically Threatened	24	32.4	285,416	115,230	40.4
	At Risk	18	34.6	468,195	273,390	58.4
	Critically Underprotected	13	39.4	708,816	270,033	38.1
	Underprotected	9	50.0	497,697	204,827	41.2
	No threat category	143	86.7	2,651,940	2,191,702	82.6

Table 9. Comparison of areas of indigenous cover not protected in threatened environments (INPTE) determined at LENZ Levels IV (rows) and II (columns). Each unshaded cell shows the area of INPTE (Level IV classification) not identified by LENZ Level II threat classification. Areas in shaded cells are areas that are assigned to the same threat category. Outlined cells (right column) show total areas of INP in threatened environments determined at LENZ Level IV, but *not* assigned to any one of the five threat categories by Level II classification, and therefore not identified as threatened.

		Area (ha) INP in threat categories determined at LENZ Level II					
		Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No threat category
Area (ha) INP in threat categories determined at LENZ Level IV	Acutely Threatened (182,573 ha)	113,435	29,543	14,353	1	1,924	23,316
	Chronically Threatened (285,416 ha)	63,870	115,230	55,197	2,609	23,339	25,171
	At Risk (468,195 ha)	6,338	34,247	273,390	16,109	73,093	65,020
	Critically Under-protected (708,816 ha)	0	1,938	175,161	270,033	126,326	135,358
	Under-protected (497,697 ha)	0	0	36,029	1,810	204,827	255,031
	No threat category (2,651,940 ha)	84	5,330	133,939	0	320,886	2,191,702

Of the 467,988 ha of Level IV INPTE in Acutely Threatened and Chronically Threatened environments, only about two-thirds (69%, or 322,078 ha) of INPTE area is assigned to one of these two threat categories if classification is performed at Level II. Thus almost a third (31%) of threatened, unprotected indigenous cover in these two highest categories of threat is not identified as highly threatened through less effective targeting. Level II classification is less efficient by 47,936 ha (13% of total INP); this is the area of indigenous cover identified as threatened when a finer level of detail indicates that it is in a better-protected or less-reduced environment.

Fig. 6A shows that in 42 district councils (58% of the 73), more than 10% of the total area of Level IV INPTE is not included if threat classification is performed at Level II, 19 (26% of the 73) district councils have more than half of the area of Level IV INPTE not included, and three (4% of the 73) have more than 90% of the area of Level IV INPTE not included. Queenstown Lakes (106,534 ha), Central Otago (69,493 ha), Gisborne (41,172 ha) and Waitaki (37,139 ha) districts contain the largest areas of Level IV INPTE not identified as threatened if threat classification is undertaken at Level II (Fig. 6B).

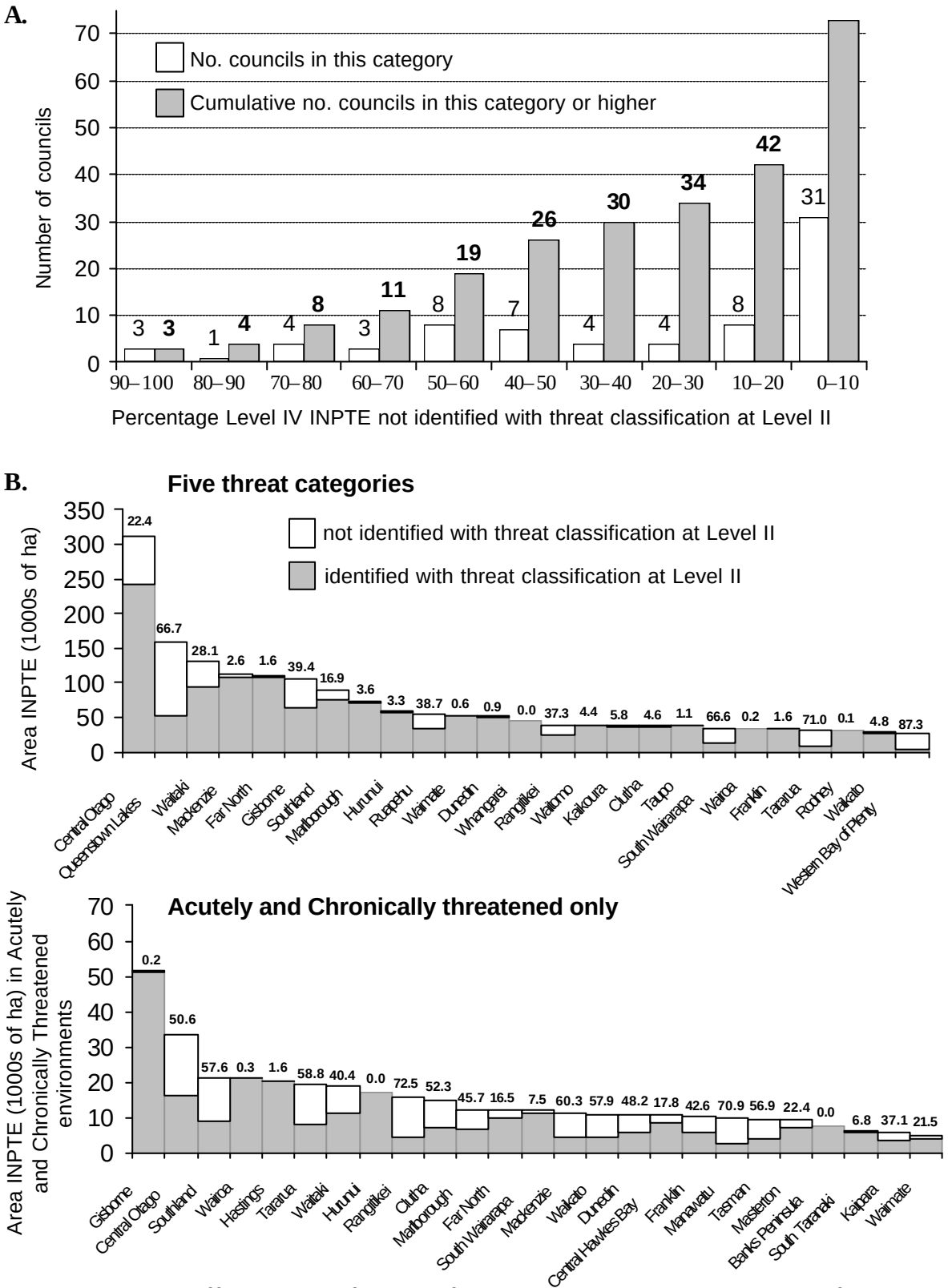
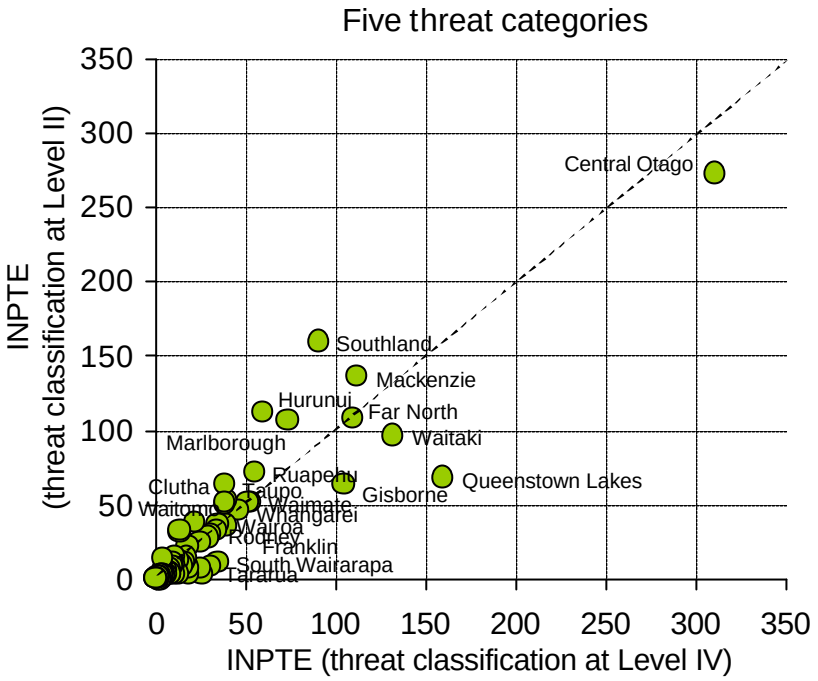


Figure 6. Less effective identification of threat through Level II threat classification. **A.** Percentage Level IV INPTE not identified if threat classification is carried out at Level II: the histogram shows 10% increments of percentage not identified, and the number and cumulative number of councils affected to that extent. **B.** Area of Level IV INPTE not identified (white portion of column) and identified (grey portion of column) in threatened environments in the 25 top-ranking councils if threat classification is carried out at Level II. Figures associated with columns show the percentage area of Level IV INPTE not identified.

A.



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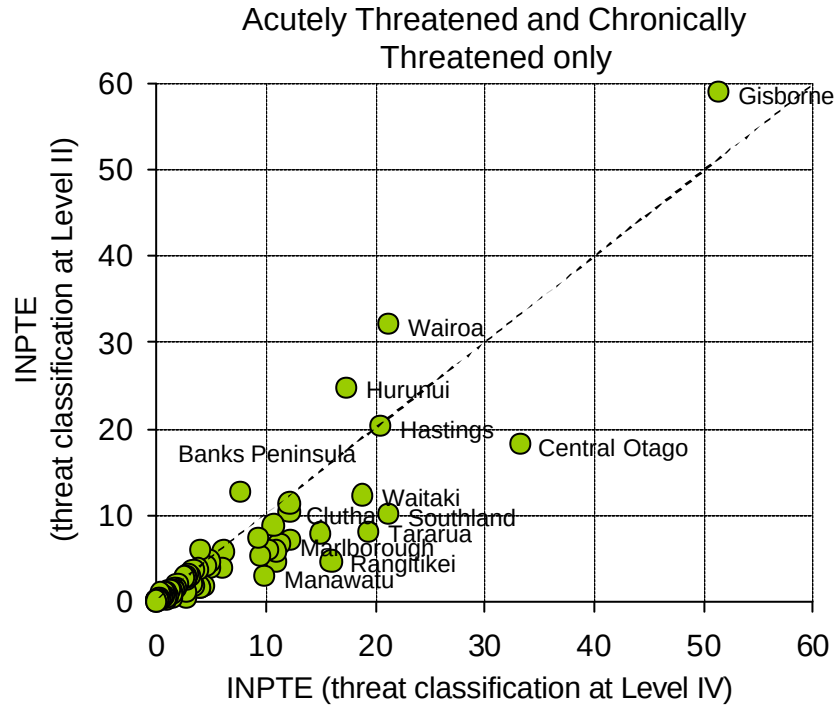


Figure 7. Less efficient targeting through Level II threat classification; consequences for districts (each represented by a green dot). The figures compare area of Level IV INPTE (*x*-axis) and Level II INPTE (*y*-axis). **A.** All threatened environments, **B.** Acutely Threatened and Chronically Threatened environments only.

In Acutely Threatened and Chronically Threatened environments only (Fig. 6B) Central Otago (16,832 ha), Southland (12,250 ha), Rangitikei (11,635 ha), Tararua (11,415 ha) and Clutha (7846 ha) districts have the greatest areas of Level IV INPTE not identified as threatened if threat classification is undertaken at Level II (these areas account for more than half of the unprotected indigenous cover in Acutely Threatened and Chronically Threatened environments in those districts, and include some of New Zealand's most threatened ecosystems and species).

Figure 7 illustrates the inefficiency costs of Level II classification for individual districts. The area of INPTE estimated with Level II threat classification substantially exceeds the Level IV INPTE area in Mackenzie, Southland, Marlborough, Hurunui, Ruapehu, Dunedin, Waitomo, Kaikoura, Clutha, Taupo, and Wairoa districts (Fig. 7A). The largest excesses are in Southland (c. 70,000 ha) and Hurunui (c. 53,000 ha) districts. In environments identified at Level IV as Acutely and Chronically Threatened alone, the area of Level II INP is greater than the actual area in 17 districts, with largest excesses in Gisborne, Wairoa, Hurunui and Banks Peninsula districts.

4.4 Land use capability of land under indigenous cover not protected in threatened environments (INPTE)

The characteristics of the eight land use capability (LUC) classes of the NZLRI are summarised in Table 10.

Table 10. Suitability of the eight land-use classes in the NZLRI for different land-use types (reproduced from Ministry of Works and Development (1979)).

Increasing limitations to use

Class	Cropping suitability	*Pastoral & Production Forestry Suitability	General suitability
I	High	High	Multiple use
II			
III	Medium		
IV	Low		
V	Unsuitable	Medium	Pastoral or forestry
VI			
VII		Low	
VIII		Unsuitable	Catchment protection land

Decreasing versatility

* LUCs 4 to 7 which have wetness as the major limitation, and those units in very low rainfall areas, or those occurring on shallow soil, are normally not suited to production forestry.

Figure 8 illustrates that indigenous vegetation clearance in New Zealand has historically been concentrated in high-versatility LUC classes. Consequently, there is high risk of loss of what little indigenous biodiversity remains in higher LUC classes today, and high proportions of remaining indigenous cover on versatile soils lie within threatened environments.

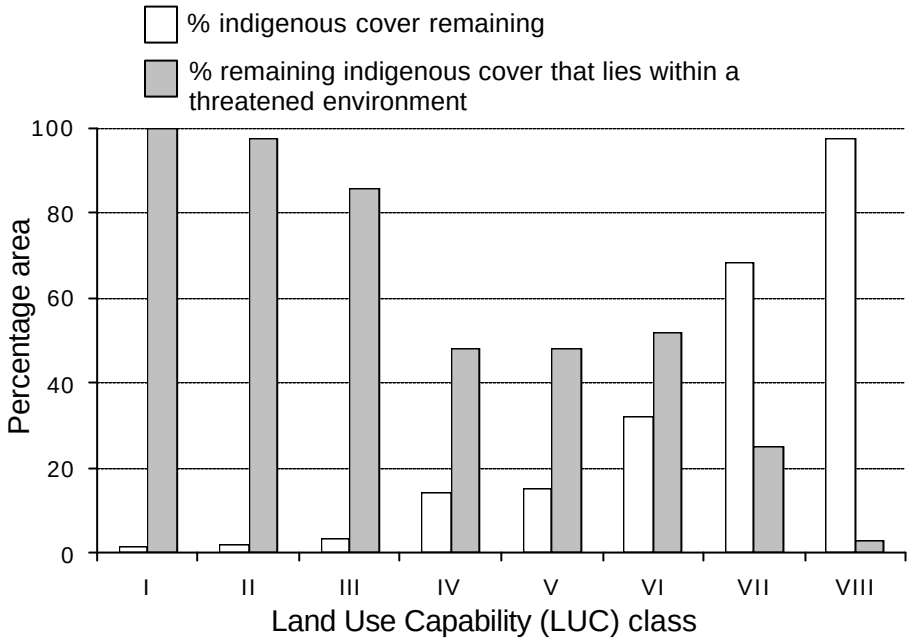


Figure 8. Past clearance of remaining indigenous cover, and threat to what remains, across LUC classes. White columns show % area of indigenous cover remaining across LUC classes I to VIII in 2001/02, and grey columns show percentage of remaining indigenous cover that is classified within one of our five environment threat categories.

Tables 11 and 12 list the areas of remaining indigenous cover not protected (INP) in all environments and in each threat category (INPTE), across the eight LUC classes of the NZLRI. The tables illustrate that the great majority of remaining INPTE area is on land with low value for agricultural production. Just 0.1% of INPTE is on elite soils (Class I); inspection of the relevant pixels suggests that although classified as 'elite' much of this land actually presents severe hazards for productive use; for example, it includes river scarps or floodplains under forest or shrubland (e.g. in Manawatu District) or gullies (e.g. around Hamilton City). Class I to IV soils together account for 11% (threat classification at Level IV) or 12% (threat classification at Level II) of the total INPTE area.

The highest portion of INPTE is in LUC class VI ('non-arable land with moderate limitations and hazards'), which accounts for 51% (threat classification at Level IV) of the total INPTE area or 47% (threat classification at Level II). Although some of this LUC Class VI land supporting INPTE is listed as relatively stable (i.e. low erosion hazard), a large amount (c. 65%) of it has wetness, low rainfall, shallow soil, or erosion limitations. Over one-third of INPTE is in the lowest LUC classes VII and VIII; these classes accounts for 37% (threat classification at Level IV) or 41% (threat classification at Level II) of the total INPTE area.

Table 11. Area of INP (indigenous cover not protected) in the eight NZLRI LUC classes (analysis with threat classification at *Level IV* of LENZ)

	Indigenous Cover not Protected (INP) in environments						
	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No threat category
				Area (ha)			
I	2,222	2,042	165	3	6	0	7
II	19,168	12,881	3,443	702	1,318	424	400
III	71,199	31,645	13,207	9,857	4,321	3,693	8,476
IV	213,363	35,716	29,182	44,834	18,299	10,611	74,721
V	22,311	2,027	1,431	4,186	4,134	275	10,258
VI	1,497,129	61,389	136,387	298,201	356,544	151,580	493,029
VII	1,989,144	25,960	88,223	87,168	296,708	278,776	1,212,311
VIII	943,202	5,749	11,472	18,511	23,292	51,716	832,462
Misc.[1]	10,206	2,780	905	2,813	2,844	358	507
Unclass[2]	27,424	2,871	1,143	1,935	1,378	296	19,802
Subtotal	4,795,368	183,058	285,556	468,209	708,843	497,728	2,651,973
NIRD[3]	732	485	140	14	27	31	33
Total	4,794,636	182,573	285,416	468,195	708,816	497,697	2,651,940
				% Total INPTE area (2,142,696 ha)			
I		0.1	0.0	0.0	0.0	0.0	
II		0.6	0.2	0.1	0.0	0.0	
III		1.2	0.7	0.9	0.1	0.1	
IV		1.6	0.8	3.9	0.2	0.8	
V		0.0	0.1	0.5	0.2	0.1	
VI		3.5	3.7	21.5	7.3	14.6	
VII		1.3	2.9	4.5	5.6	17.0	
VIII		0.2	0.3	1.2	0.3	3.2	

[1]Misc = towns, water etc, [2]Unclassified = Stewart Island and other offshore islands not included in the NZLRI, [3]NIRD = non-indigenous vegetation recently disturbed, not included as indigenous cover in this work.

Pastoral leases in the South Island high country contain more than a quarter (c. 552,000 ha or 29%) of the total area of INPTE in low versatility LUC classes V to VIII, but a far smaller percentage (7%) of New Zealand's INPTE on more versatile soils (c. 15,500 ha in LUC classes I to IV). Much of the INPTE on pastoral leases is in At Risk, Critically Underprotected and Underprotected threat categories, because there is a tendency for pastoral leases to have retained high largely indigenous cover. Pastoral leases contain just 5.5% of the total national INPTE in the Acutely Threatened and Chronically Threatened threat categories (c. 25,500 ha). Of INPTE in Acutely Threatened and Chronically Threatened on pastoral leases, c. 21% (c. 5,300 ha) is in the more versatile LUC classes I to IV.

Table 12. Area of INP (indigenous cover not protected) in the eight NZLRI Land Use Capability classes (analysis with threat classification at *Level II* of LENZ).

	Indigenous Cover not Protected (INP) in environments						
	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No threat category
				Area (ha)			
I	2,222	1,470	561	32	0	112	48
II	19,168	12,654	3,610	1,338	158	70	1,338
III	71,199	25,078	13,950	18,387	2,108	1,624	10,052
IV	213,363	33,607	17,266	82,196	4,578	16,157	59,559
V	22,311	669	2,649	10,071	4,804	1,307	2,810
VI	1,497,129	72,865	78,473	451,656	153,335	307,102	433,699
VII	1,989,144	26,944	60,801	93,813	117,294	356,267	1,334,025
VIII	943,202	4,821	7,338	25,564	6,002	67,231	832,246
Misc.[1]	10,206	2,664	1,053	2,632	2,082	60	1,714
Unclass[2]	27,424	3,457	708	2,423	226	466	20,144
Subtotal	4,795,368	184,229	186,410	688,111	290,588	750,395	2,695,635
NIRD[3]	732	503	122	43	26	2	37
Total	4,794,636	183,726	186,287	688,068	290,562	750,394	2,695,598
				% Total INPTE area (2,099,038 ha)			
I		0.1	0.0	0.0	0.0	0.0	
II		0.6	0.2	0.0	0.1	0.0	
III		1.5	0.6	0.5	0.2	0.2	
IV		1.7	1.4	2.1	0.9	0.5	
V		0.1	0.1	0.2	0.2	0.0	
VI		2.9	6.4	13.9	16.6	7.1	
VII		1.2	4.1	4.1	13.8	13.0	
VIII		0.3	0.5	0.9	1.1	2.4	

[1]Misc = towns, water etc., [2]Unclassified = Stewart island and other offshore islands not included in the NZLRI, [3]NIRD = non-indigenous vegetation recently disturbed, not included as indigenous cover in this work.

4.5 Changes in indigenous cover 1996/97 to 2001/02 and its consequences for risk to remaining indigenous biodiversity

In this section, we present data for threatened environments from threat classification at *Level IV of LENZ only*.

4.5.1 Indigenous cover loss

Broadleaved Indigenous Hardwoods (6,745 ha), Manuka and/or Kanuka (5,609 ha), Tall-Tussock Grassland (2,482 ha) and Indigenous Forest (2,232 ha) are the indigenous cover types that experienced the largest conversion to non-indigenous cover types nationally from 1996/97 to 2001/02 (Table 13). Harvesting or felling of c. 2,000 ha of indigenous forest (Forest – Harvested LCDB2 class) accounted for 11% of the change, conversion to exotic forestry accounted for c. 13,500 ha or 66% of the total change, conversion to high-producing grassland (i.e. pasture) or cropland for 6%, and conversion to low-producing grassland for 16%.

Table 13. Changes from indigenous to non-indigenous cover types 1996/97–2001/02

	Built-up Area	Surface Mine	Short-Rotation Cropland	High-Producing Exotic Grassland	Low-Producing Grassland	Gorse and/or Broom	Afforestation (not imaged)	Afforestation (imaged, post LCDB 1)	Forest – Harvested	Other Exotic Forest	Total
Coastal Sand and Gravel	0	0	0	0	32	0	0	22	0	1	55
River and Lakeshore Gravel and Rock	0	0	0	0	0	3	0	0	0	0	3
Landslide	0	0	0	0	172	6	0	0	0	0	178
Tall-Tussock Grassland	0	0	0	0	0	0	54	1,196	0	1,236	2,486
Herbaceous Freshwater Vegetation	0	2	0	55	0	0	38	6	0	0	101
Herbaceous Saline Vegetation	0	0	0	86	0	0	0	0	0	0	86
Fernland	0	0	0	0	0	0	0	90	0	0	90
Manuka and/or Kanuka	0	8	0	565	2,052	0	797	2,148	3	42	5,615
Matagouri	0	0	0	0	0	0	6	0	0	0	6
Broadleaved Indigenous Hardwoods	2	1	3	361	490	227	1,802	3,815	46	0	6,748
Subalpine Shrubland	0	0	0	0	0	0	0	46	0	0	46
Indigenous Forest	3	4	0	0	34	0	0	259	1,934	0	2,233
Total change	5	16	3	1,067	2,779	236	2,697	7,582	1,982	1,278	17,646
% of 17,646 ha	0.0	0.1	0.0	6.0	15.7	1.3	15.3	43.0	11.2	7.2	
Total in threatened environments	5	3	3	801	1,765	222	1,079	2,947	1,368	1,238	9,431
% of 9,431 ha	<0.0	0.1	<0.0	5.6	15.8	1.3	15.4	43.2	11.3	7.3	

Change in indigenous cover (i.e. conversion from indigenous to exotic land cover types) was very similar to net loss of indigenous cover. This is because the databases show that nationally only 347 ha changed from a non-indigenous cover class to an indigenous cover class; of this, 270 ha was succession to Manuka and/or Kanuka shrubland, and much of the remainder was change to Broadleaved Indigenous Hardwoods). The same indigenous cover types that showed the largest changes to non-indigenous cover across all environments accounted for the most loss in threatened environments (Table 14): 47% of the total loss of Broadleaved Indigenous Hardwoods, 53% of the total loss of Manuka and/or Kanuka, 66% of the total loss of Tall-Tussock Grassland, and 65% of the total loss of Indigenous Forest was in threatened environments.

Table 14. Indigenous cover loss (ha; 1996/97 to 2001/02) by environment threat category.

	Change from indigenous cover to non-indigenous cover						
	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No threat category
Coastal Sand and Gravel	55	0	0	53	2	0	0
River and Lakeshore Gravel and Rock	2	1	0	0	0	0	1
Landslide	177	0	0	0	0	1	177
Tall-Tussock Grassland	2,482	47	462	7	478	655	833
Herbaceous Freshwater Vegetation	101	16	35	25	0	0	24
Herbaceous Saline Vegetation	4	1	0	3	0	0	0
Fernland	90	0	0	25	2	0	63
Manuka and/or Kanuka	5,609	371	1,154	551	798	81	2,654
Matagouri	6	6	0	0	0	0	0
Broadleaved Indigenous Hardwoods	6,745	552	635	1,303	598	98	3,559
Subalpine Shrubland	46	7	2	0	1	1	35
Indigenous Forest	2,232	145	249	313	534	210	781
Total change	17,550	1,147	2,537	2,281	2,413	1,046	8,126
	Change from non-indigenous cover to indigenous cover						
All non-indigenous cover classes	347	20	8	74	6	0	238
	Net loss of indigenous cover						
Net loss of indigenous cover	17,204	1,127	2,529	2,207	2,407	1,046	7,888
Net loss of indigenous cover not protected (% of net loss of indigenous cover)	16,271 (94.6%)	1,121 (99.5%)	2,483 (98.2%)	2,201 (99.7%)	2,360 (98.1%)	956 (91.4%)	7,151 (90.7%)
	Change from low-producing grassland to other non-indigenous cover						
Low-producing grassland	29,338	3,157	9,135	6,840	1,287	3,510	5,409

Indigenous cover loss in threatened environments was also due to very similar activities: harvesting or felling of indigenous forestry accounted for 11% (1,368 ha) and exotic forestry for 66% (5,264 ha) of the total change in threatened environments, conversion to high-producing grassland (i.e. pasture) or cropland for 6% (804 ha), and conversion to low-producing grassland for 16% (1,765 ha).

Table 14 (final row) also highlights 29,338 ha of change from low-producing grassland cover (classified as non-indigenous) to other non-indigenous classes between 1996/97 and 2001/02. A large proportion of this change (29,160 ha) was conversion to exotic forestry, and much of this conversion (c. 81%) occurred in threatened environments, particularly in Chronically Threatened and At Risk environments (9,135 and 6,840 ha, respectively). The land area of low-producing grassland affected by these changes (29,338 ha) is greater (i.e. 1.67×) than the total national decrease in indigenous cover classes (17,204 ha). Since many areas of low-producing grassland contain mixtures of indigenous and exotic species, significant further loss of indigenous biodiversity may have been incurred owing to these changes.

4.5.2 Distribution of indigenous cover loss across land environments and threat categories

There was a net loss of indigenous cover in almost half (245, or 49%) of New Zealand's 500 Level IV Land Environments between 1996/97 and 2001/02. One Level IV environment (F1.3d, in central Rangitikei District) changed threat category from Chronically Threatened to Acutely Threatened due to indigenous cover loss. Of the 500 Level IV environments, 251 (50%) showed no change in indigenous cover, and indigenous cover increased in just four (0.8%) environments. These four net increases were relatively small (i.e. 1, 3, 6 and 35 ha, respectively).

Approximately 54% of the total area that changed from indigenous to non-indigenous cover from 1996/97 to 2001/02 (9,316 ha) was in threatened environments. Of the five threat categories, the largest total decrease was in Chronically Threatened environments (2,537 ha), but total losses in At Risk and Critically Underprotected environments were almost as large. Most indigenous cover lost was not legally protected (95% of total loss). In threatened environments, 98% of indigenous cover lost was on land not legally protected (at least, according to our database), whereas within environments assigned to no threat category, 91% of indigenous cover lost had no legal protection status.

There was no relationship between the area of indigenous cover lost within a land environment and the percentage of indigenous cover remaining in that environment in 1996/97 (Fig. 9A). However, the total area of indigenous cover lost in the 158 Acutely Threatened Level IV environments was relatively small (representing only 6.5% of the total area of indigenous cover lost from 1996/97 to 2001/02). This is likely to be because (1) there is relatively little indigenous cover left to lose in Acutely Threatened environments and (2) because clearance is occurring more rapidly in environments where more remains. Loss of indigenous cover in New Zealand's most intact environments (more than 90% indigenous cover remaining) also accounts for a relatively small proportion of the total area lost. This is likely to be because these environments are remote, well protected, and have few alternative land uses.

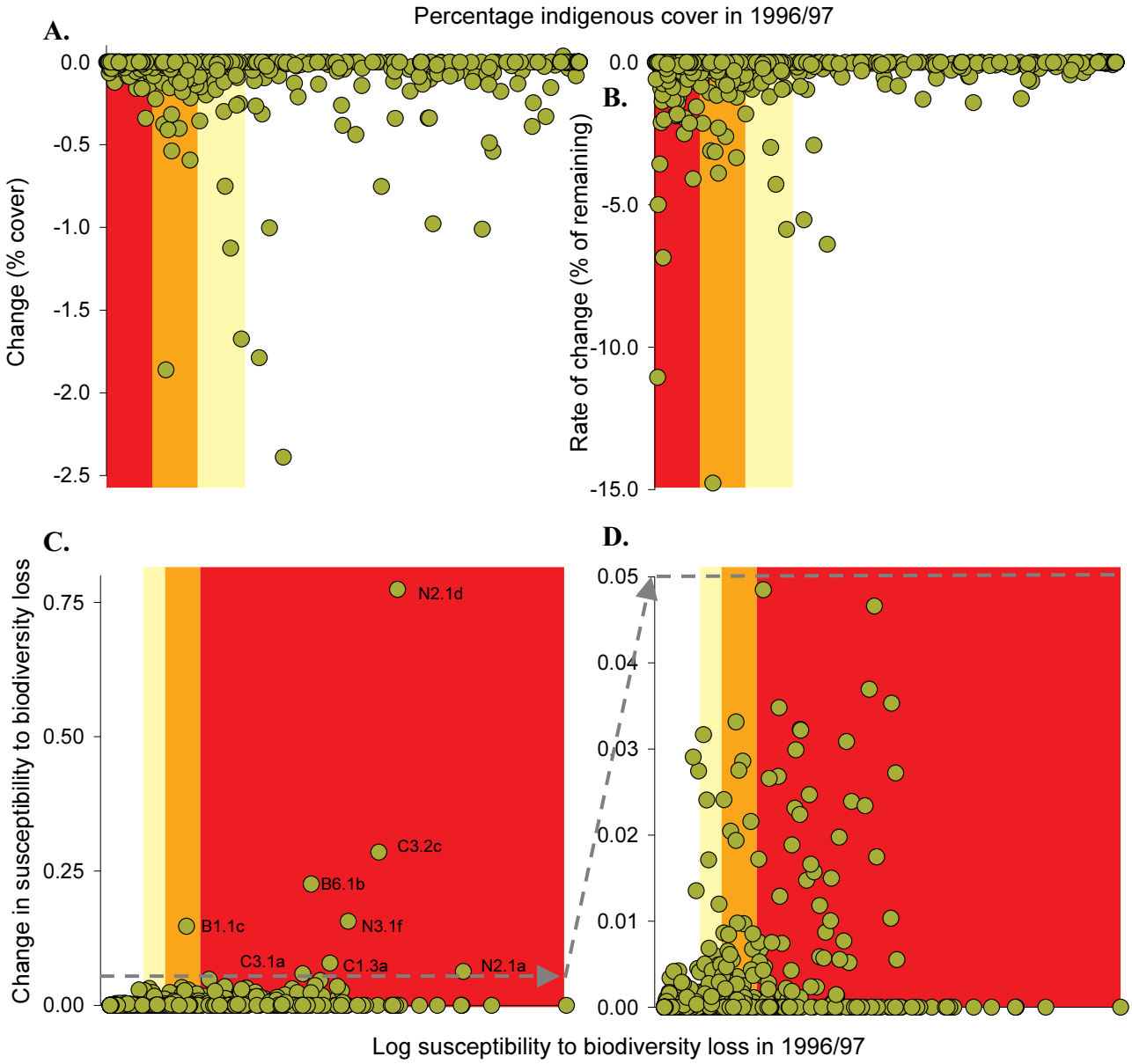


Figure 9. Change from 1996/97 to 2001/02 in New Zealand's Level IV land environments (represented by green circles). **A.** Change in indigenous cover (% of whole environment). **B.** Rate of change in indigenous cover (% of remaining indigenous cover in 1996/97). **C.** & **D.** Change in susceptibility to biodiversity loss (note different *y*-axis scales). A few environments that showed large increases in susceptibility to biodiversity loss are labelled and referred to in the text.

Although there is less remaining indigenous cover to lose in threatened environments, rates of loss of indigenous cover (expressed as a percentage of indigenous cover remaining) were higher in threatened environments than in environments that are not assigned to any threat category (Fig. 9B; Table 15). Rates of loss were particularly high in Chronically Threatened environments (those with 10–20% cover remaining). The percentage of environments in which indigenous cover decreased was also higher in Chronically Threatened environments than in other threat categories; loss occurred in almost 65% of Chronically Threatened environments, whereas in other threat categories probability of loss was between 39 and 50%. Map 2A shows the geographic distribution of the rate of indigenous cover loss within New Zealand's Level IV land environments.

Map 2. A. Rate of change in indigenous cover (% of remaining indigenous cover in 1996/97) and **B.** Change in the susceptibility to biodiversity loss index in New Zealand's Level IV Land Environments from 1996/97 to 2001/02. Analyses are based on LCDB1 and 2.

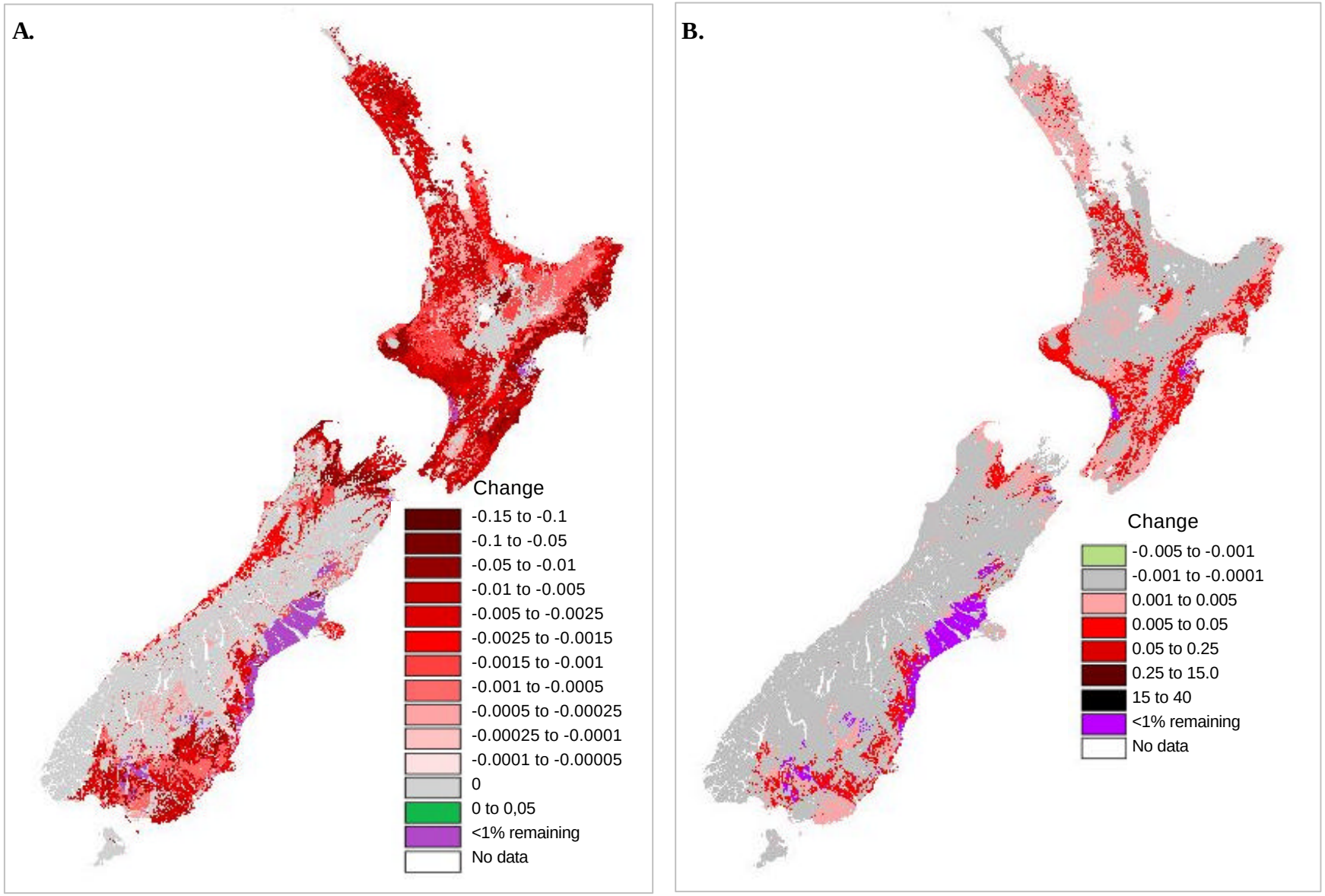


Table 15. Percentage loss and rate of loss of indigenous cover (1996/97 to 2001/02) by environment threat category

	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No Threat Category
	A. Probability of loss in 5 years (% of environments with a net loss of indigenous cover)						
Probability	49.0	48.1	64.9	50.0	39.4	55.6	43.6
	B. Five-year change (% of whole environment area)						
	All environments						
Average	–0.07	–0.02	–0.10	–0.11	–0.09	–0.16	–0.07
	Changed environments only						
Average	–0.13	–0.04	–0.16	–0.21	–0.22	–0.28	–0.15
Median	–0.04	–0.02	–0.08	–0.08	–0.13	–0.07	–0.05
Maximum	–2.39	–0.34	–1.86	–1.68	–1.00	–1.79	–2.39
	C. Five-year rate of change (% of remaining indigenous cover)						
	All environments						
Average	–0.37	–0.49	–0.73	–0.42	–0.22	–0.41	–0.11
	Changed environments only						
Average	–0.74	–1.00	–1.13	–0.81	–0.55	–0.74	–0.25
Median	–0.27	–0.51	–0.47	–0.30	–0.36	–0.16	–0.07
Maximum	–14.77	–11.06	–14.77	–5.86	–2.91	–5.53	–6.39

4.5.3 Distribution of susceptibility to biodiversity loss across land environments and threat categories

As the area of indigenous habitat remaining decreases, each increment of further loss results in a greater loss of remaining biodiversity. To represent this change in risk to remaining indigenous biodiversity, we use a function of the generalised species–area relationship (which we name 'susceptibility to biodiversity loss'). This allows us to identify those environments and districts where the loss of indigenous cover from 1996/97 to 2001/02 resulted in the greatest increase in risk to remaining biodiversity.

Table 16 shows that more than three-quarters (78%) of the summed increase in susceptibility to biodiversity loss was in the 158 Acutely Threatened Level IV environments. A further 15% of that increased risk to remaining indigenous biodiversity was in the 74 Chronically Threatened environments. The general pattern of increase in susceptibility to biodiversity loss (shown in Fig. 9C. & D.) is:

1. Large increases in the susceptibility to biodiversity loss index in a few, Acutely Threatened environments (e.g. N2.1d – South Canterbury Plains, C3.2c – coastal Rangitikei and Manawatu, B6.1b and B1.1c – Awatere and Wairau valley terraces in Marlborough, N3.1f – upper Maniototo and Strath Taieri Plains in Otago).
2. Somewhat smaller increases in several Acutely Threatened, Chronically Threatened and At Risk environments.

3. Minor increases in susceptibility to biodiversity loss in a high proportion of environments across all threat categories.

Table 16. Summed, average and maximum change in susceptibility to biodiversity loss (1996/97 to 2001/02) across Level IV Land Environments by environment threat category.

	Five-year change in susceptibility to biodiversity loss index						
	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Underprotected	No threat category
No. Level IV environments	500	158	74	52	33	18	165
Summed change (% of total)	3.202 (100.0)	2.483 (77.5)	0.465 (14.5)	0.122 (3.8)	0.031 (1.0)	0.034 (1.1)	0.066 (2.1)
Average change	0.006	0.016	0.006	0.002	0.001	0.002	<0.001
Maximum change		0.774	0.147	0.032	0.014	0.027	0.029

Map 2B shows the geographic distribution of change in susceptibility to biodiversity loss within New Zealand's Level IV land environments.

4.5.4 Distribution of loss of indigenous cover and change in susceptibility to biodiversity loss, across council areas

In our final analysis, we calculated change in indigenous cover from 1996/97 to 2001/02 in each council area, and the contribution of the indigenous cover loss in each council area to the total change in susceptibility to biodiversity loss across the 500 Level IV Land Environments nationally. These statistics are tabulated for each of the 73 councils in Tables 17 and 18. The loss and change in those councils contributing most to total indigenous cover loss, and to summed change in susceptibility to biodiversity loss, is illustrated in Fig. 10.

Table 17 and Fig. 10 show that high proportions of total loss of indigenous cover, loss of INPTE, and summed change in susceptibility to biodiversity loss occurred in a relatively small number of districts. More than 50% of the total loss of indigenous cover occurred in six districts (Marlborough, Far North, Tasman, Central Otago, Southland and Gisborne), and more than 50% of loss of INPTE occurred in five districts (Far North, Central Otago, Gisborne, Marlborough and Southland). Hastings, Marlborough and Horowhenua districts contributed 57% of the summed increase in susceptibility to biodiversity loss across all land environments, with Central Otago, South Taranaki and Tasman districts together contributing another 17%. In 13 districts or cities (Auckland, Christchurch, Franklin, Gore, Hamilton, Kaikoura, Kawerau, Napier, Papakura, Queenstown Lakes, Selwyn, Tauranga, Waitakere) no indigenous cover loss at all was recorded (and therefore no increase in susceptibility to biodiversity loss).

Table 17. Loss of indigenous cover by council area, and contribution to summed national change in the index of susceptibility to biodiversity loss across Level IV land environments from 1996/97 to 2001/02. The table shows area of loss (ha) of **A**. indigenous cover and **B.** indigenous cover not protected, across all environments (All env.) and in threatened environments only (Threatened) within each of these categories. **C.** Contribution, and percent contribution to summed change in susceptibility to biodiversity loss across land environments is shown for each council. Council rank (Rk) is shown for their contribution to each loss statistic.

	A. Loss of indigenous cover				B. Loss of indigenous cover not protected				C. Change in susceptibility to biodiversity loss		
	All env.		Threatened		All env.		Threatened				
Council	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Change	% of summed change	Rk
Ashburton	9	55	1	55	9	54	1	55	0.002	0.07	45
Auckland	0	61	0	58	0	60	0	58	0.000	0.00	61
Banks Peninsula	16	51	16	44	16	50	16	43	0.004	0.14	37
Buller	29	42	21	37	49	35	20	37	0.002	0.07	43
Carterton	191	19	159	15	191	18	159	15	0.021	0.64	20
Central Hawke's Bay	81	31	75	23	80	30	74	22	0.083	2.60	8
Central Otago	1234	4	1234	2	1233	3	1233	2	0.191	5.95	4
Christchurch	0	61	0	58	0	60	0	58	0.000	0.00	61
Clutha	847	7	16	45	839	7	16	44	0.006	0.18	31
Dunedin	55	34	55	27	54	33	54	25	0.006	0.18	32
Far North	1737	2	1418	1	1695	2	1389	1	0.072	2.23	12
Franklin	0	61	0	58	0	60	0	58	0.000	0.00	61
Gisborne	1063	6	856	3	1035	6	839	3	0.072	2.25	11
Gore	0	61	0	58	0	60	0	58	0.000	0.00	61
Grey	186	21	20	39	129	23	20	38	0.002	0.07	46
Hamilton	0	61	0	58	0	60	0	58	0.000	0.00	61
Hastings	460	10	370	7	458	10	369	7	0.982	30.66	1
Hauraki	84	30	63	24	83	29	62	23	0.003	0.10	40
Horowhenua	24	44	14	46	24	44	14	46	0.285	8.90	3
Hurunui	38	39	36	29	38	39	36	28	0.082	2.57	9
Invercargill	6	57	0	58	6	56	0	58	0.000	0.00	59
Kaikoura	0	61	0	58	0	60	0	58	0.000	0.00	61
Kaipara	219	16	185	14	219	15	185	14	0.008	0.24	29
Kapiti Coast	213	17	35	30	213	16	35	29	0.008	0.25	28
Kawerau	0	61	0	58	0	60	0	58	0.000	0.00	61
Lower Hutt	42	38	3	54	42	38	3	54	0.001	0.03	53
Mackenzie	17	49	17	42	17	49	17	42	0.020	0.62	22
Manawatu	43	37	43	28	43	37	43	27	0.018	0.56	23
Manukau	17	50	17	43	16	51	16	44	0.000	0.00	58
Marlborough	3044	1	722	4	2972	1	699	4	0.544	16.98	2
Masterton	446	11	431	6	443	11	428	6	0.096	3.00	7
Matamata – Piako	1	60	1	57	1	59	1	57	0.000	0.01	55
Napier	0	61	0	58	0	60	0	58	0.000	0.00	61
Nelson	7	56	7	50	7	55	7	50	0.003	0.08	41
New Plymouth	36	40	9	49	36	41	9	49	0.002	0.08	42
North Shore	6	57	6	51	6	56	6	51	0.000	0.00	60
Opotiki	188	20	19	40	185	19	19	39	0.005	0.14	36
Otorohanga	122	28	99	21	121	26	99	21	0.002	0.05	47
Palmerston North	1	59	1	56	1	58	1	56	0.000	0.01	56
Papakura	0	61	0	58	0	60	0	58	0.000	0.00	61

Council	A. Loss of indigenous cover				B. Loss of indigenous cover not protected				C. Change in susceptibility to biodiversity loss		
	All env.		Threatened		All env.		Threatened				
	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Change	% of summed change	Rk
Porirua	138	23	107	19	138	21	107	19	0.026	0.81	17
Queenstown Lakes	0	61	0	58	0	60	0	58	0.000	0.00	61
Rangitikei	129	26	113	18	114	27	111	18	0.020	0.63	21
Rodney	98	29	93	22	107	28	102	20	0.002	0.07	44
Rotorua	79	32	62	25	64	31	49	26	0.015	0.48	25
Ruapehu	623	9	368	8	623	8	368	8	0.006	0.18	30
Selwyn	0	61	0	58	0	60	0	58	0.000	0.00	61
South Taranaki	839	8	212	13	532	9	208	13	0.152	4.75	5
South Waikato	30	41	25	32	30	42	25	32	0.005	0.16	34
South Wairarapa	122	27	24	33	122	25	24	33	0.005	0.15	35
Southland	1101	5	703	5	1093	5	694	5	0.054	1.68	13
Stratford	44	36	18	41	44	36	18	41	0.000	0.01	54
Tararua	136	24	119	17	135	22	117	17	0.039	1.22	15
Tasman	1294	3	255	10	1221	4	251	10	0.111	3.47	6
Taupo	52	35	56	26	51	34	54	24	0.023	0.71	18
Tauranga	0	61	0	58	0	60	0	58	0.000	0.00	61
Thames – Coromandel	58	33	5	52	58	32	5	52	0.002	0.05	48
Timaru	23	47	23	35	23	47	23	35	0.011	0.35	26
Upper Hutt	163	22	30	31	163	20	30	30	0.021	0.67	19
Waikato	131	25	130	16	126	24	126	16	0.027	0.85	16
Waimakariri	20	48	20	38	19	48	19	40	0.011	0.33	27
Waimate	11	53	11	47	11	52	11	47	0.006	0.17	33
Waipa	23	45	22	36	23	45	22	36	0.004	0.14	38
Wairoa	383	12	350	9	383	12	350	9	0.044	1.38	14
Waitakere	0	61	0	58	0	60	0	58	0.000	0.00	61
Waitaki	11	53	11	47	11	52	11	47	0.016	0.49	24
Waitomo	23	46	23	34	23	46	23	34	0.001	0.04	50
Wanganui	366	13	234	12	365	13	234	12	0.073	2.29	10
Wellington	24	43	5	53	24	43	5	53	0.000	0.01	57
Western Bay of Plenty	191	18	105	20	37	40	26	31	0.001	0.03	52
Westland	335	14	0	58	194	17	0	58	0.001	0.04	51
Whakatane	11	52	- 3	73	- 3	73	- 3	73	0.001	0.05	49
Whangarei	284	15	245	11	279	14	240	11	0.004	0.12	39

Table 18. Loss of indigenous cover by council area across Level IV land environments from 1996/97 to 2001/02. The table shows area of loss (ha) of **A.** indigenous cover and **B.** indigenous cover not protected, in Acutely Threatened and Chronically Threatened environments within each of these categories. Council rank (Rk) is shown for their contribution to each loss statistic.

	A. Loss of indigenous cover				B. Loss of indigenous cover not protected			
	Acutely Threatened		Chronically Threatened		Acutely Threatened		Chronically Threatened	
Council	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk
Ashburton	1	42	0	34	1	43	0	34
Auckland	0	50	0	35	0	50	0	35
Banks Peninsula	3	37	6	23	3	37	6	23
Buller	0	50	0	35	0	50	0	35
Carterton	16	21	1	31	16	21	1	31
Central Hawke's Bay	36	9	26	12	35	9	26	12
Central Otago	9	29	461	1	9	29	460	1
Christchurch	0	50	0	35	0	50	0	35
Clutha	16	22	0	35	16	22	0	35
Dunedin	13	27	0	35	13	27	0	35
Far North	49	7	364	3	49	8	363	3
Franklin	0	50	0	35	0	50	0	35
Gisborne	27	14	450	2	27	14	450	2
Gore	0	50	0	35	0	50	0	35
Grey	0	50	0	35	0	50	0	35
Hamilton	0	50	0	35	0	50	0	35
Hastings	50	6	321	4	49	7	320	4
Hauraki	2	39	18	16	2	39	18	16
Horowhenua	14	26	0	35	14	26	0	35
Hurunui	9	28	27	11	9	28	27	11
Invercargill	0	50	0	35	0	50	0	35
Kaikoura	0	50	0	35	0	50	0	35
Kaipara	5	33	13	17	5	33	13	17
Kapiti Coast	34	11	0	35	34	11	0	35
Kawerau	0	50	0	35	0	50	0	35
Lower Hutt	1	46	0	32	1	46	0	32
Mackenzie	5	32	12	18	5	32	12	18
Manawatu	19	18	24	14	19	17	24	14
Manukau	0	50	0	35	0	50	0	35
Marlborough	34	10	267	5	34	10	245	5
Masterton	194	1	25	13	192	1	25	13
Matamata – Piako	1	47	0	35	1	47	0	35
Napier	0	50	0	35	0	50	0	35
Nelson	1	43	0	35	1	42	0	35
New Plymouth	4	35	0	35	4	35	0	35
North Shore	0	50	0	35	0	50	0	35
Opotiki	18	19	1	29	18	18	1	29
Otorohanga	1	40	0	35	1	40	0	35
Palmerston North	0	50	1	29	0	50	1	29
Papakura	0	50	0	35	0	50	0	35
Porirua	30	13	0	35	30	13	0	35
Queenstown Lakes	0	50	0	35	0	50	0	35
Rangitikei	72	4	37	9	70	4	37	9
Rodney	1	44	- 5	73	1	44	- 1	73
Rotorua	25	15	0	35	22	15	0	35
Ruapehu	0	50	0	72	0	50	0	72
Selwyn	0	50	0	35	0	50	0	35

	A. Loss of indigenous cover				B. Loss of indigenous cover not protected			
	Acutely Threatened		Chronically Threatened		Acutely Threatened		Chronically Threatened	
Council	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk	Area (ha)	Rk
South Taranaki	99	2	0	35	99	2	0	35
South Waikato	21	17	0	33	21	16	0	33
South Wairarapa	8	30	3	26	8	30	3	26
Southland	44	8	201	6	53	6	184	6
Stratford	1	48	0	35	1	48	0	35
Tararua	74	3	6	24	73	3	5	24
Tasman	16	23	83	8	16	23	79	8
Taupo	53	5	0	35	53	5	0	35
Tauranga	0	50	0	35	0	50	0	35
Thames – Coromandel	1	40	1	28	1	40	1	28
Timaru	15	24	7	22	15	24	7	21
Upper Hutt	15	25	11	19	15	25	11	19
Waikato	21	16	2	27	18	19	2	27
Waimakariri	1	49	20	15	1	49	18	15
Waimate	6	31	0	35	6	31	0	35
Waipa	18	20	0	35	18	20	0	35
Wairoa	0	50	97	7	0	50	97	7
Waitakere	0	50	0	35	0	50	0	35
Waitaki	5	34	5	25	5	34	5	25
Waitomo	2	38	0	35	2	38	0	35
Wanganui	31	12	27	10	31	12	27	10
Wellington	0	50	0	35	0	50	0	35
Western Bay of Plenty	0	50	0	35	0	50	0	35
Westland	0	50	0	35	0	50	0	35
Whakatane	1	44	8	21	1	44	8	20
Whangarei	4	36	10	20	4	36	6	22

Table 18 shows that Masterton, South Taranaki and Tararua Districts had the largest areal losses of indigenous cover from Acutely Threatened environments, while Central Otago, Far North and Gisborne districts lost the largest areas of indigenous cover in Chronically Threatened environments.

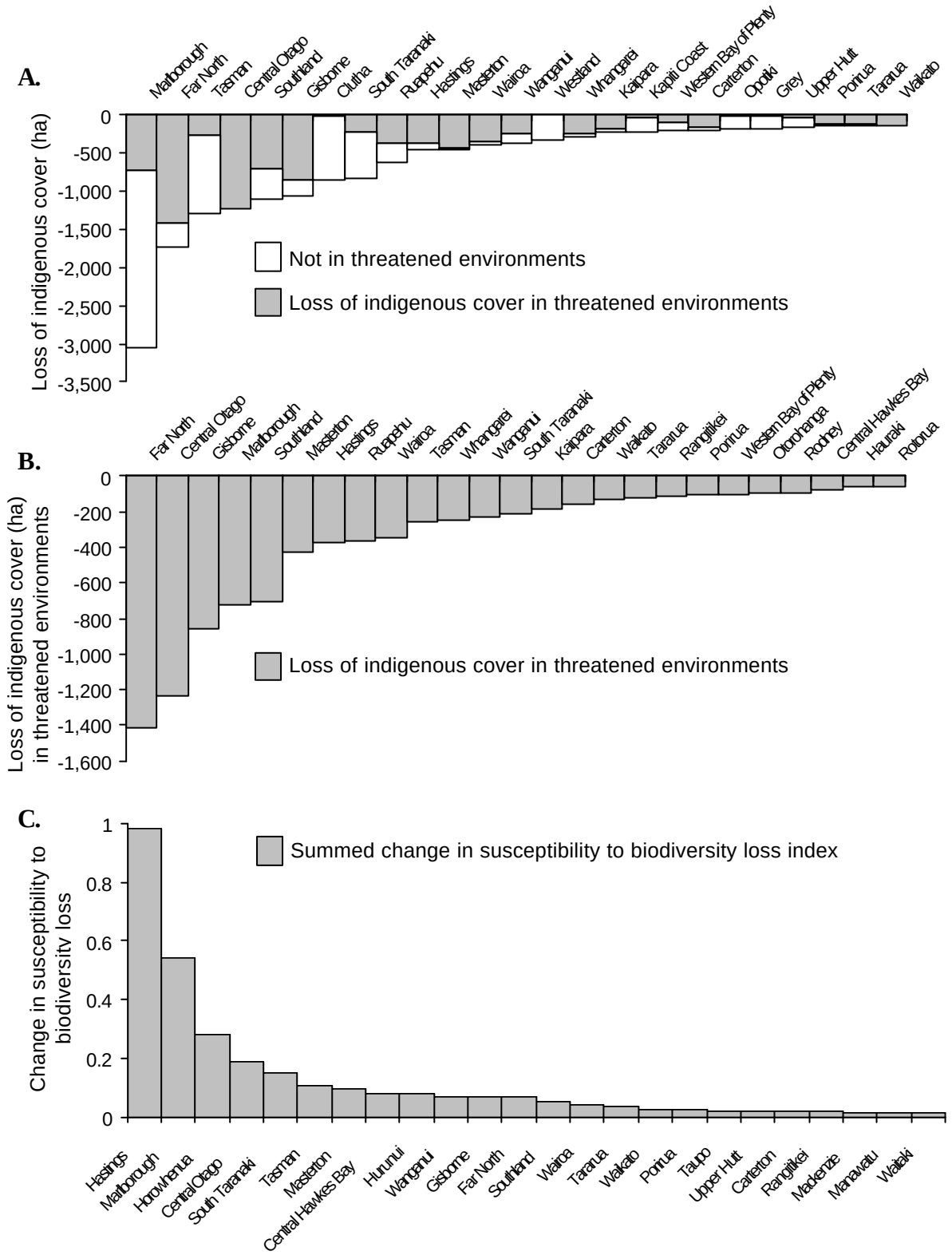


Figure 10. Contribution of district and city council areas to national loss of indigenous cover and increase in susceptibility to biodiversity loss, showing the top 25 districts and cities arranged in rank order. **A.** Loss of indigenous cover (showing the proportion of cover that is in threatened environments), **B.** Loss of indigenous cover in threatened environments only, and **C.** Summed change in susceptibility to biodiversity loss index due to loss of indigenous cover in that district.

4.6 Changes in indigenous cover in threatened environments due to database refinements and actual loss

Work completed earlier this year for MfE (i.e. Rutledge et al. (2004, unpubl.) and MfE, DOC & LGNZ (2004)) pre-dates the release of LCDB2 and LCDB1 and is based on LCDB1_2. Figures produced in our analyses for this report therefore differ from that previous work. Table 19 compares estimates from the three databases. It also shows the extent to which the different estimates based on LCDB2 are due to improved classification (from 14 to 43 classes of cover) and to habitat loss.

Table 19 Areas of remaining indigenous cover in Acutely Threatened and Chronically Threatened environments identified using the three different land cover databases (LCDB1_2 (14 cover classes), LCDB1 and LCDB2 (both 43 cover classes)).

	Area indigenous cover not protected (INP) (ha)				
	LCDB1_2[1] (1996/97)	LCDB1 (1996/97)	LCDB2 (2001/02)	Change in estimated INP from LCDB1 to LCDB2 as a consequence of	
	(14 cover classes)	(43 cover classes)		Improved classification (LCDB1_2[1] to LCDB1)	Indigenous habitat loss (1996/97 to 2001/02)
Environment threat classification at *Level IV*					
Acutely Threatened	187,543	173,249	182,573	–14,294	9,324
Chronically Threatened	282,757	298,343	285,416	15,587	–12,928
(Acutely Threatened + Chronically Threatened)	(470,300)	(471,592)	(467,988)	(1,293)	(–3,604)
All environments	5,936,173	4,810,907	4,794,636	-1,125,266	-16,271
Environment threat classification at *Level II*					
Acutely Threatened	179,564	185,476	183,726	5,912	-1,750
Chronically Threatened	261,412	187,756	186,287	-73,656	-1,468
(Acutely Threatened + Chronically Threatened)	(440,976)	(373,232)	(370,014)	(- 67,744)	(- 3,218)
All environments	5,936,173	4,810,907	4,794,636	-1,125,266	-16,271

[1] data used in Rutledge et al. (2004, unpubl.) and MfE, DOC & LGNZ (2004)

5. Discussion

5.1 Risk to remaining biodiversity in New Zealand

The security of indigenous biodiversity across New Zealand varies enormously, from a state of virtual extinction in some warm, flat, fertile eastern lowland environments to substantially intact and well protected in cold, wet, steep western environments. This variation reflects the uneven distribution of human development pressures, clearance of indigenous cover, and legal protection for biodiversity for conservation purposes across New Zealand's environments. Flat, warm, fertile environments have been

almost entirely cleared of indigenous cover, and what little remains is poorly protected and threatened. Conversely, indigenous cover remains intact, well protected and largely unthreatened in those environments that have been residual (or surplus) to productive uses.

Remaining unprotected indigenous cover in threatened land environments, although often highly modified, supports high proportions of New Zealand's threatened ecosystems and species. Its protection is therefore essential for halting the decline in indigenous biodiversity nationally, regionally and locally.

Advanced loss of habitat area (the primary criterion we use to assess threat to biodiversity) is just one of many factors that may contribute high risk to remaining indigenous biodiversity. Isolation, edge effects, co-extinctions, and increased susceptibility to exotic pests and weeds are factors that disrupt biodiversity processes and need to be considered in a comprehensive and realistic assessment of risk to the persistence of New Zealand's indigenous biota. These pressures and threats require active and ongoing management to halt the decline of biodiversity in most remaining indigenous habitats (e.g. Perley et al. 2001). Hence poor legal protection (associated with an absence of basic management inputs such as fencing and pest control) is a central contributing factor to the vulnerability of biodiversity.

Poor legal protection is a particularly important risk factor in seral (successional) communities where percentage indigenous cover is an inadequate estimate of extent of past habitat loss, and risk to remaining indigenous biodiversity. For example, tall-tussock grasslands in the eastern South Island were largely created by destruction of diverse shrublands and forests by early Polynesian fires, and subsequently depleted by European fires and mammalian grazing. Although still largely indigenous, these communities now support only a fraction of their original biodiversity. Remnant shrubland, forests, and wetlands within these tussock grasslands are much reduced, and the risk posed to their remaining biodiversity by further clearance is high. Many environments that support seral indigenous vegetation are Critically Underprotected and Underprotected. Recognition of their threatened status in future management will be important to maintain remaining biodiversity and to secure a disproportionately large number of threatened species (Rogers et al. 2004, unpubl.).

In Introduction and Background we note that effective biodiversity protection (enabling a full range of biodiversity to persist into the future) requires protection of both pattern and process. So far, advances in spatial databases and measures allow us to indicate national protection effectiveness and its converse (risk to remaining biodiversity) in terms of pattern alone (specifically, in this report, the distribution of loss of indigenous cover and legal protection across land environments). The risk to biodiversity through the disruption of essential processes, and the contribution of efforts to maintain their health (e.g. pest and weed control) to reducing biodiversity loss, remain unquantified beyond the scale of relatively small sites. Spatially explicit measures of process (under development in New Zealand and elsewhere) are very much more demanding than those for pattern. They are nevertheless essential for full, objective and defensible identification of places at most significant risk of biodiversity loss or decline, and for measuring progress towards biodiversity goals as a consequence of biodiversity conservation policies and activities.

5.2 Loss of remaining indigenous cover

There was indigenous cover loss in almost half (49%) of the Level IV Land Environments in the 5 years from 1996/97 to 2001/02. More than 95% of this loss was of indigenous cover not legally protected; in other words, lack of legal protection appears to a very strong predictor of loss. However, there appears to be some randomness in the pattern of recent loss of unprotected indigenous cover across land environments. We anticipate that in many environments, unprotected indigenous cover not cleared in this 5-year period may suffer loss in the next 5 years. Similarly, some environments where loss occurred in this 5-year period may not lose indigenous cover in the next.

Indigenous cover that is not protected in threatened environments now remains only on soils and landscape types of low value for agricultural production. Nevertheless, comparison of cover in 1996/97 and 2001/02 suggests that the trend is now for indigenous cover clearance on more marginal land. The highest rates of loss of remaining indigenous cover were in environments that are already threatened, particularly in Chronically Threatened environments, where there is more indigenous cover left to lose than in Acutely Threatened environments. Consequently the greatest increase in risk to remaining indigenous biodiversity in that 5-year period was in threatened environments.

Exotic afforestation was the major cause of indigenous cover loss in the period from 1996/97 to 2001/02, accounting for about 66%. Clearance for low-production pasture was a secondary cause of indigenous cover loss, intensive pasture development was a relatively minor contributor (<6%), and loss to invasive weeds was minor (c. 1%).

Of the total increase in exotic afforestation across New Zealand in this period (c. 139,600 ha), at least 8.3% (c. 11,500 ha) involved clearance of indigenous cover. At least 3.8% (c. 5,300 ha) of new afforestation involved clearance of remaining indigenous cover types in threatened environments. The proposed future land use of an additional c. 2,000 ha of cleared indigenous forest (c. 11% of total loss of indigenous cover) is unknown. A proportion of this indigenous forest loss was in logging coupes within indigenous forest tracts (which may therefore slowly regenerate) but at least some of the remainder may have been felled in preparation for planting in exotic forestry species. A further 29,198 ha of exotic forestry was established in vegetation classed in 1996/97 as 'low-producing grassland' (e.g. large areas in Southland, Clutha, Waitaki, Timaru, Hurunui and Marlborough districts). The 'low-producing grassland' cover class is a mixture of indigenous and non-indigenous vegetation types, and we therefore expect indigenous cover loss due to forestry activities was greater than the minimum estimate of c. 11,500 ha, and perhaps considerably greater.

Much of the remaining indigenous vegetation that was cleared (both in threatened environments and in those not classified as threatened) was forest or seral shrubland, or tall-tussock grassland. The greatest loss in a single class was in the Broadleaved Indigenous Hardwoods cover class (principally in Marlborough, South Taranaki and Ruapehu districts) – comprising broadleaved hardwood species, such as wineberry (*Aristotelia serrata*), mahoe (*Melicytus ramiflorus*), *Pseudopanax* spp., *Pittosporum* spp., *Fuchsia* spp., ngaio (*Myoporum laetum*), and titoki (*Alectryon excelsus*), together with tutu (*Coriaria* spp.) and tree ferns (Thompson et al. 2003). This

vegetation type is usually in an advanced seral stage back to indigenous forest, but also includes primary coastal broadleaved forest. Loss of vegetation classed as Manuka and/or Kanuka shrubland (principally in Marlborough, Gisborne, Tasman and Far North districts), Primary Indigenous Forest (principally in Far North and Southland districts), and Tall-Tussock Grassland (principally in Central Otago, Clutha and Southland districts) also accounted for significant portions of the total loss. In the past, seral (regenerating) woody vegetation may have been dismissed as insufficiently pristine to warrant protection. However, successional shrubland is probably of high importance for biodiversity in New Zealand. For example, Perley et al. (2001) highlight general observational and quantified comparative studies that suggest that in New Zealand late-successional shrubland communities are richer in insects than are tall, undisturbed forest (e.g. Dugdale & Hutcheson 1997; Hutcheson & Jones 1999).

We caution that because 'low-producing grassland' is a mixture of indigenous and non-indigenous vegetation types, we cannot estimate the extent of indigenous vegetation loss (e.g. short-tussock grassland) from this extensive cover class. Our estimate of total loss, and therefore increased susceptibility to biodiversity loss within New Zealand environments, is probably an underestimate.

5.3 The most appropriate LENZ level at which to assess New Zealand's threatened environments

Leathwick et al. (2003a, b) suggest that LENZ Level II (100 environments) is useful for providing overview information at a national scale, but is less useful and relevant for applications at local, district and regional scales than Levels III (200 environments) and IV (500 environments). Our work strongly supports this suggestion. We also advise that regional, district and local protection for biodiversity should be directed by a threat classification at Level IV rather than Level II.

The first consideration for this advice is that a national threat classification to guide local authority protection for biodiversity should have demonstrated relevance at the appropriate scale. Patterns of biodiversity, as well as present and past land clearance, occur and are perceived at regional, district and local scales that are better depicted at Level IV than at Level II. A threat classification at Level II therefore is less appropriate for identifying vulnerable biodiversity at regional, district and local scales than a Level IV threat classification. (As Appendix 2 shows, a 'no threat category' classification for remaining indigenous cover Level II environment F1 might be credible in South Taranaki, but would be implausible in Tararua District where the local subset of Level IV environments have experienced far greater loss of indigenous cover in the past.)

The second major consideration is that substantial areas of threatened unprotected indigenous cover identified by threat classification at Level IV are not identified as threatened if classification is performed at Level II. Almost a third (31.2%) of INPTE area in Acutely Threatened and Chronically Threatened environments and almost a quarter (23.5%) of INPTE area in all five categories is not classified as threatened if classification is carried out at Level II. In three of the 73 districts, the proportion of INPTE not identified is >90%, and in more than a quarter of council areas it is >50%. These underestimates are substantial and concerning, firstly, because the threat categories we assign are conservative (i.e. understated) rather than precautionary estimates of risk to remaining biodiversity, and secondly, because indigenous

biodiversity associated with environments not identified as threatened at Level II are known to contain some of New Zealand's most threatened species and ecosystems. These underestimates will also diminish the credibility of LENZ-based protection guidelines, especially in those districts where the error is large.

It has been suggested that the inefficiency cost of poorer targeting at Level II could be reduced by identifying only those areas of INP within environments classified as threatened at Level II that are also within Level IV environments classified as threatened at Level IV. This approach would:

- introduce greater conceptual and computational complexity than is involved in undertaking a threat classification at Level IV of LENZ directly,
- nullify any perceived or actual advantage to implementation associated with the comparative simplicity of Level II threat classification, and
- fail to mitigate the serious primary drawbacks of poor targeting, which are substantially less plausible and less effective identification of the biodiversity protection need.

We therefore strongly recommend that Level IV is the most appropriate level of LENZ at which to classify threatened environments for the protection of vulnerable remaining indigenous biodiversity at local, district and regional scales.

Level II of LENZ is an appropriate level at which to present national and regional summaries of threatened unprotected indigenous cover. However, it is more appropriate to summarise a threat classification performed at Level IV (cf. Walker et al. 2004, unpubl.), than to carry out a separate threat classification based on percentage indigenous cover remaining at Level II. For example, summarising areas of Level IV INPTE up to Level II both maintains constant estimates of national, regional and district INPTE areas and removes the considerable problems of less plausible, effective and efficient identification of threatened unprotected indigenous cover that arise from Level II threat classification. An example of such a summary is presented in Appendix 3(c).

5.4 Dissemination of threat classification information

Threat classification information is equally straightforward to disseminate and apply whether environments are classified at Level IV or Level II (all LENZ users have all four levels at their disposal).

The threat classification information can be tabulated and distributed to end-users such as council planners and ecological consultants in the form of a small (40KB for Level IV) ASCII text file (and, if desired, an associated GIS legend file of 4KB). The table can be joined to the LENZ grid table in a GIS (an operation that takes a few seconds at most). This converts the information to a national map (25-m resolution at LENZ Level IV) that can be accessed interactively and used for a wide variety of purposes such as consents processing, significance assessment, reserve planning, prioritising pest control etc.

We distributed Level IV threat classification information as described above to a small group of DOC, environmental NGO, and regional council staff in October and November 2004 for testing. These end-users successfully trialed the LENZ Level IV threat classification across a variety of applications. It was used by DOC staff to

inform policy and significance assessment for tenure review, by environmental NGOs for information, advocacy and resource consent hearings, and by regional council staff to inform submissions on proposed protected areas. A sample application of the interactive map is depicted in Appendix 4.

Our feedback from this trial suggest that (1) Level IV is an appropriate scale at which to assess the vulnerability of remaining indigenous cover at a regional, district and local (i.e. property) scales and (2) the technical complexity of disseminating threat classification information at Level IV of LENZ (rather than Level II) is more perceived than actual: there was ready uptake and adoption of the threat classification by trial end-users with a range of skill levels and needs. The major limitation to use that we see is the use and uptake of LENZ by end-users; however, LENZ is now widely distributed across local authorities, and remaining software constraints to uptake (e.g. conversion of LENZ for MapInfo users) are being resolved.

5.5 Limitations of the environment threat categories for identifying significant indigenous vegetation

Indigenous vegetation may be significant for its contribution to maintaining a wide range of different value types (i.e. not only biodiversity, but also landscape, recreation, public access, ecosystem services, etc.), and is usually identified by applying a range of criteria (e.g. representativeness, rarity, distinctiveness). Significance is not given only to inherent values that are threatened or rare. For example, the Crown Pastoral Lands Act (1998) definition of significant inherent values uses the terms importance, nature, and quality as well as rarity. An area may also be considered significant at a range of scales (e.g. national, regional, local).

Land environment threat categories can help to identify remaining indigenous cover that is significant (i.e. deserves protection) for the maintenance of indigenous biodiversity (a single value set) at a national scale. Specifically, the environment threat categories can assist by improving the objectivity of the assessment of representativeness. Representativeness (i.e. contribution to the maintenance of the full range) is generally used as the primary criterion for the assessment of significance of ecological values. High representative value (i.e. high significance on the basis of the representativeness criterion) is given to a community or ecosystem that:

1. has large overall areas in a region or district,
2. has been reduced from their former extent, or
3. is poorly represented in reserves (Myers et al. 1987).

Therefore, the representativeness criterion includes communities or ecosystems that have been significantly reduced and/or are poorly protected, but extends beyond these.

Remaining indigenous ecosystems, habitats, and species in the five categories of threatened land environments are parts of the full range of biodiversity that have been significantly reduced and/or are poorly protected, and therefore meet conditions 2. and 3. of the representativeness criterion above. Remaining indigenous vegetation in threatened environments, although typically highly modified, would therefore certainly be considered significant. However, there will be many areas of remaining indigenous vegetation important for maintaining indigenous biodiversity in land environments that are not assigned to any of our five threat categories. For example:

1. Large areas of remaining indigenous vegetation (communities or ecosystems that have large overall areas in a region or district) meeting the first condition of

the representativeness criterion (1. above) will not typically be located in threatened environments. High representative value (i.e. significance) is given to large areas because these are needed to maintain indigenous species, habitats and ecological processes that require large areas to persist (e.g. species that are large-bodied, host-dependent, narrow-range, habitat-specialist, or dependent on large contiguous habitats).

2. Remaining small-scale ecosystems and habitat types such as limestone outcrops (karst), geothermal, and various wetland and floodplain ecosystem types are much reduced and/or poorly protected, but are not consistently identified by LENZ or other databases. These special habitats would meet conditions 2. and 3. of the representativeness criterion, but are not yet consistently mapped in New Zealand.
3. An environment may not have lost more than 70% of its indigenous cover nationally, but remaining cover may be highly modified or disproportionately reduced within a particular region. In these cases it may be judged to be significant, since its protection will contribute to the maintenance of the full range of biodiversity within that region.

6. Conclusions

New Zealand's coastal, lowland, and montane environments have experienced substantial indigenous habitat loss, and what indigenous cover remains in these environments today has little legal protection.

The much-reduced and highly modified areas of indigenous cover remaining in these threatened environments support a disproportionately large percentage of New Zealand's most seriously threatened species, habitats, and ecosystems. The protection of what remains in these environments is essential to halt the decline of New Zealand's indigenous biodiversity.

Clearance and loss of indigenous cover and associated indigenous biodiversity continues across New Zealand. Because the consequences of continued indigenous cover clearance for biodiversity (i.e. biodiversity loss and increased risk to what remains) are most severe in environments where little remains, the current pattern of clearance greatly exacerbates the status of biodiversity in New Zealand.

Although historically clearance of indigenous cover was concentrated on land of high value for agricultural production, it appears that the trend is now for clearance of indigenous cover on more marginal land (i.e. Land Use Capability classes 6, 7 and 8), notably for exotic forestry.

This evidence suggests that public awareness and education, voluntary protection, RMA provisions, and formal legal protection of remaining indigenous biodiversity have not halted the clearance of vulnerable indigenous biodiversity in much reduced and poorly protected ecosystems and habitats.

7. Recommendations

- Two criteria are required to identify biodiversity that is most vulnerable (most likely to be lost). These are (1) poor legal protection (reflected by low percentages legally protected) and (2) past habitat loss (reflected by low percentages of remaining indigenous cover).

- Based on these two criteria, we recommend five categories of threatened environments to identify environments containing indigenous biodiversity at most risk of loss. The biodiversity that remains in these threatened environments is some of the most severely threatened in New Zealand.

- We recommend that Level IV of LENZ is the most appropriate level to identify environments that are most vulnerable to biodiversity loss, in order to effectively protect biodiversity at district and local (property) scales. Information based on a Level IV classification of threatened environments may be summarised to higher levels (e.g. Level I or II) for national or regional summaries.

- Existing databases (e.g. LENZ, LCDB) do not identify many rare and distinctive ecosystems and habitats that are also reduced and poorly protected parts of the full range of New Zealand's biodiversity pattern. We therefore recommend that such rare and distinctive habitats and ecosystems are also regarded as threatened.

- There needs to be some investigation and comparison of the social, economic and regulatory drivers of indigenous vegetation protection and loss in councils where most loss (e.g. Far North, Central Otago and Marlborough districts) and least loss (e.g. Kaikoura District, Waitakere City, Queenstown Lakes District) has occurred. This may help policy makers to understand some of the key factors for successful biodiversity conservation on private land.

- This analysis cannot be repeated in the future, unless further full national updates of the Land Cover Database are produced, using satellite imagery taken over as short a time period as possible (e.g. a single summer). We recommend that the interval between comprehensive national land cover database updates is no less than 5 years, so that progress towards halting the decline in biodiversity can be monitored within relevant time frames.

8. Acknowledgements

The preparation of this report was funded by Landcare Research internal funding (SW and DR), and by the Conservation Policy Division of the Department of Conservation (RP). We thank many colleagues who have made diverse formative contributions to the ideas presented here: in particular Bill Lee, Theo Stephens, Matt McGlone, Jake Overton, Bruce Burns, Deb Wilson, Grant Hunter, Robin MacIntosh, Peter Newsome, John Dymond, John Leathwick, Geoff Rogers, Raphael Didham and Richard Duncan. Major technical contributions were made by Deb Zanders, James Barringer, Peter Newsome and Janice Willoughby. We thank Matt McGlone, Jake Overton, Ian

Whitehouse, Elaine Wright, Theo Stephens and Bill Lee for critical comments on a draft, which substantially improved the report.

The work was possible because of investment by Government agencies in key national spatial databases in recent years. In particular, the Ministry for the Environment was a major funder of the production of Land Environments of New Zealand and the Land Cover Databases. The Department of Conservation, the QEII National Trust, and Nga Whenua Rahui all made substantial contributions towards a national database of protected land, and we thank them for their permission to use their data for this purpose. New Zealand's ability to assess and report on its biodiversity protection performance in the future will depend upon continued, multi-agency support for these key national databases.

9. References

Andrén, H. 1994: Effects of habitat fragmentation on birds and mammals in landscapes with different proportion of suitable habitat: a review. *Oikos 71*: 355–366.

Andrén, H. 1996: Population responses to habitat fragmentation: statistical power and the random sample hypothesis. *Oikos 76*: 235–242.

Atkinson, I.A.E.; Cameron, E.K. 1993: Human influence on the terrestrial biota and biotic communities of New Zealand. *Trends in Evolution and Ecology 8*: 447–451.

Berry, O.; Tocher, M.D., Gleeson, D.M.; Sarre, S.D. 2004: Effect of vegetation matrix on animal dispersal: genetic evidence from a study of endangered skinks. *Conservation Biology*.

Brooks, T.M.; Pimm, S.L.; Collar, N.J. 1997: Deforestation predicts the number of threatened birds in insular southeast Asia. *Conservation Biology 11*: 382–394.

Brooks, T.M.; Pimm, S.L.; Oyugi, J.O. 1999: Time lag between deforestation and bird extinction in tropical forest fragments. *Conservation Biology 13*: 1140–1150.

de Lange, P.J.; Norton, D.A.; Heenan, P.B.; Courtney, S.P.; Molloy, B.P.J.; Ogle, C.C.; Rance, B.D.; Johnson, P.N. 2004: Threatened and uncommon plants of New Zealand. *New Zealand Journal of Botany 42*: 45–76.

Department of Conservation (DOC) & Ministry for the Environment (MfE) 2000: The New Zealand biodiversity strategy. DOC & MfE, Wellington, New Zealand.

Dugdale, J.; Hutcheson, J. 1997: Invertebrate values of kanuka (*Kunzea ericoides*) stands, Gisborne Region. *Science for Conservation 55*, Department of Conservation, Wellington, New Zealand. 30 p.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management 61*: 603–610

Fahrig L. 2002. Effect of habitat fragmentation on the extinction threshold: a synthesis. *Ecological Applications 12*: 346–353.

Faith, D.P.; Walker, P.A. 1996: Integrating conservation and development: incorporating vulnerability into biodiversity-assessment of areas. *Biodiversity and Conservation 5*: 431–446.

Gaston, K.J.; Pressey, R.L.; Margules, C.R. 2002: Persistence and vulnerability: retaining biodiversity in the landscape and in protected areas. *Journal of Biosciences 27 (Suppl. 2)*: 361–384.

Grüner, I.; Gapare, N. 2004: Fieldwork procedures used for LCDB 2. AgriQuality, Palmerston North.

Harrison, S.; Bruna, E.M. 1999: Habitat fragmentation and large scale conservation: what do we know for sure? *Ecography 22*: 225–232.

Heijnis, C.E.; Lombard, A.T.; Cowling, R.M.; Desmet, P.G. 1999: Picking up the pieces: a biosphere reserve framework for a fragmented landscape – The Coastal Lowlands of the Western Cape, South Africa. *Biodiversity and Conservation 8*: 471–496.

Heydenrych, B.J.; Cowling, R.M.; Lombard, A.T. 1999: Strategic conservation interventions in a region of high biodiversity and high vulnerability: a case study from the Agulhas Plain at the southern tip of Africa. *Oryx 33*: 256–269.

Hutcheson, J.; Jones, D. 1999: Spatial variability of insect communities in a homogenous system: Measuring biodiversity using Malaise trapped beetles in a *Pinus radiata* plantation in New Zealand. *Forest Ecology and Management 118*: 93–105.

Kelly, G.C. 1980: Landscape and nature conservation. Pp. 63–88 in Molloy, L.F. (Ed.). Land alone endures: Land use and the role of research. New Zealand. Department of Scientific and Industrial Research Discussion Paper No. 3.

Koh, L.P.; Dunn, R.; Sodhi, N.S.; Colwell, R.K.; Proctor, H.C; Smith, V.S. 2004: Species coextinctions and the biodiversity crisis. *Science 305*: 1632–1634.

Lawler, J.J.; White, D.; Master, L.L. 2003: Integrating representation and vulnerability: Two approaches for prioritizing areas for conservation. *Ecological Applications 13*: 1762–1772.

Leathwick, J.R.; McGlone, M.S.; Walker, S. 2004. New Zealand's potential vegetation pattern. Manaaki Whenua Press, Lincoln, New Zealand.

Leathwick, J.R.; Wilson, G.; Rutledge, D.; Wardle, P.; Morgan, F.; Johnston, K.; McLeod, M.; Kirkpatrick, R. 2003a: Land environments of New Zealand. David Bateman, Auckland, New Zealand.

Leathwick, J.R; Overton, J.McC; McLeod, M. 2003b: An environmental domain classification of New Zealand and its use as a tool for biodiversity management. *Conservation Biology* 17: 1612–1623.

Lee, W.G.; Walker S. 2004: Significance of the remaining indigenous vegetation in Central Otago – protecting biodiversity within the proposed Central Otago District Plan. Landcare Research Contract Report LC0304/012 (unpubl.).

Lee, W.G.; McGlone, M.S.; Wright, E. (Comps) 2004: Biodiversity inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Landcare Research Contract Report prepared for the Department of Conservation (unpubl.).

Margules, C.R.; Pressey, R.L. 2000: Systematic conservation planning. *Nature 405*: 243–253.

Margules C.R.; Nicholls A.O.; Pressey R.L. 1988: Selecting networks of reserves to maximise biological diversity. *Biological Conservation 43*: 63–76.

Margules, C.R.; Pressey, R.L.; Williams, P.H. 2002: Representing biodiversity: data and procedures for identifying priority areas for conservation. *Journal of Biosciences 27 (Suppl. 2)*: 309–326.

Meurk, C.D.; Walker, S.; Gibson R.S.; Espie P. 2002: Changes in vegetation states in grazed and ungrazed Mackenzie Basin grasslands, New Zealand, 1990–2000. *New Zealand Journal of Ecology 26*: 95–104.

Ministry for the Environment (MfE), Department of Conservation (DOC) & Local Government New Zealand (LGNZ) 2004: A snapshot of council effort to address biodiversity on private land. MfE, Wellington, New Zealand.

Ministry of Works and Development 1979: Our land resources. A bulletin to accompany New Zealand Land Resources Inventory Worksheets produced for the National Water and Soil Conservation Organisation. Ministry of Works and Development, Wellington, New Zealand.

Molloy, J.; Bell, B.; Clout, M.; de Lange, P.; Gibbs, G.; Given, D.; Norton, D.; Smith. N.; Stephens, T. 2002: Classifying species according to threat of extinction: A system for New Zealand. *Threatened Species Occasional Publication 22*. Department of Conservation, Wellington, New Zealand.

Moritz, C. 2002: Strategies to protect biological diversity and the evolutionary processes that sustain it. *Systematic Biology 51*: 238–254.

Myers, S.C.; Park, G.N.; Overmars, F.B. 1987: A guidebook for the rapid ecological survey of natural areas. *New Zealand Biological Resources Centre Publication 6*, Department of Conservation, Wellington, New Zealand.

Perley, C.; Moller, H.; Hutcheson, J.; Hamilton W. 2001: Towards safeguarding New Zealand's agricultural biodiversity: research gaps, priorities and potential case studies. A contract report to the Ministry of Agriculture and Forestry: "Biodiversity Policy and Research to meet Convention on Biological Diversity Commitments" (Project EI-30/2000). Ecosystems Consultants Report No. 23.

Pressey, R.L. 1994: Ad hoc reservations: forward or backward steps in developing representative reserve systems? *Conservation Biology 8*: 662–668.

Pressey, R.L.; Taffs, K.H. 2001a: Sampling of land types by protected areas: three measures of effectiveness applied to western New South Wales. *Biological Conservation 101*: 105–117.

Pressey, R.L.; Taffs, K.H. 2001b: Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological Conservation 100*: 355–376.

Pressey, R.L.; Humphries, C.J.; Margules, C.R.; Vane-Wright, R.I.; Williams, P.H. 1993: Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution 8*: 124–128.

Rogers, G.M.; Walker, S. 2002: Taxonomic and ecological profiles of rarity in the New Zealand vascular flora. *New Zealand Journal of Botany 40*: 73–93.

Rogers, G.M.; Walker, S; Lee, W.G. 2004: Is disturbance necessary to restore dryland ecosystems and their threatened plants in eastern New Zealand? Landcare Research Contract Report: LC0304/052 prepared for the Department of Conservation (unpubl.).

Rosenweig, M.L. 1995: Patterns in space: species area curves. Pp. 8–25 in Rosenweig M.L. (Ed.) Species diversity in space and time. Cambridge University Press, Cambridge.

Rouget, M.; Richardson, D.M.; Cowling, R.M. 2003: The current configuration of protected areas in the Cape Floristic Region, South Africa – reservation bias and representation of biodiversity patterns and processes. *Biological Conservation 112*: 129–145.

Rutledge, D.; Price, R.; Heke, H.; Auseill, A.G. 2004: National analysis of biodiversity protection status: methods and summary results. Landcare Research Contract Report: LC0405/042 prepared for the Ministry for the Environment (unpubl.).

Sierra, R.; Campos, F.; Chamberlain, J. 2002: Assessing biodiversity conservation priorities: ecosystem risk and representativeness in continental Ecuador. *Landscape and Urban Planning 59*: 95–110.

Stewart, R.R.; Noyce, T.; Possingham, H.P. 2003: Opportunity cost of ad hoc marine reserve design decisions: an example from South Australia. *Marine Ecology-Progress Series 253*: 25–38.

Terralink 2004: New Zealand Land Cover Database (LCDB2). Terralink International Limited, Wellington, New Zealand.

Thomas, C.D.; Cameron, A.; Green, R.E.; Bakkenes, M.; Beaumont, L.J.; Collingham, Y.C.; Erasmus, B.F.N.; de Siqueira, M.F., Grainger, A.; Hannah, L.; Hughes, L.; Huntley, B.; van Jaarsveld, A.S.; Midgley, G.F.; Miles, L.F.; Ortega-huerta, M.A.; Townsend Peterson, A.; Phillips, O.L.; Williams, S.E. 2004: Extinction risk from climate change. *Nature 427*: 145–148.

Thompson, S; Grüner, I.; Gapare, N. 2003: New Zealand Land Cover Database Version 2. Illustrated guide to target classes. Ministry for the Environment, Wellington, New Zealand

Walker, S.; Lee, W.G. 2004: Significance assessment for biodiversity in the South Island High Country. Landcare Research Contract Report LC0304/111 prepared for Land Information New Zealand (unpubl.).

Walker, S.; Lee, W.G. Willoughby, J.M.; Newsome, P. 2004: Representativeness of protected areas for biodiversity in the South Island high country. Landcare Research Contract Report LC0304/086 prepared for Land Information New Zealand (unpubl.).

World Resources Institute 1992: Global biodiversity strategy. World Resources Institute, Washington, D.C.

Appendix 1. Indigenous and non-indigenous cover classes

Table A1. Categorisation of LCDB1 and LCDB2 cover classes for the purposes of this report. Indigenous = 1, non-indigenous = 0.

Class No.	Class Name	Indigenous
1	Built-up Area	0
2	Urban Parkland / Open Space	0
3	Surface Mine	0
4	Dump	0
5	Transport Infrastructure	0
10	Coastal Sand and Gravel	1
11	River and Lakeshore Gravel and Rock	1
12	Landslide	1
13	Alpine Gravel and Rock	1
14	Permanent Snow and Ice	1
15	Alpine Grass/ Herbfield	1
20	Lake and Pond	1
21	River	1
22	Estuarine Open Water	1
30	Short-rotation Cropland	0
31	Vineyard	0
32	Orchard and Other Perennial Crops	0
40	High Producing Exotic Grassland	0
41	Low Producing Grassland	0
43	Tall-Tussock Grassland	1
44	Depleted Grassland	1
45	Herbaceous Freshwater Vegetation	1
46	Herbaceous Saline Vegetation	1
47	Flaxland	1
50	Fernland	1
51	Gorse and or Broom	0
52	Manuka and or Kanuka	1
53	Matagouri	1
54	Broadleaved Indigenous Hardwoods	1
55	Sub Alpine Shrubland	1
56	Mixed Exotic Shrubland	0
57	Grey Scrub	1
60	Minor Shelterbelts	0
61	Major Shelterbelts	0
62	Afforestation (not imaged)	0
63	Afforestation (imaged, post LCDB 1)	0
64	Forest - Harvested	0
65	Pine Forest – Open Canopy	0
66	Pine Forest – Closed Canopy	0
67	Other Exotic Forest	0
68	Deciduous Hardwoods	0
69	Indigenous Forest	1
70	Mangrove	1

Appendix 2. Level II v. Level IV comparison within Environment F1.

This appendix illustrates differences among Level IV environments within one Level II environment. Environment F1 extends from the western Waikato through inland Taranaki and northern Manawatu to the ranges of Hawke's Bay and Wairarapa, through Wellington and southward to the Marlborough and Tasman regions. On average, 48.4% (886,270 ha) of the total 1,832,582 ha in environment F1 remains in indigenous cover, and 22.8% of the total area is protected (Table A2.1). Therefore F1 is assigned to 'no threat category' if threat classification is carried out at Level II.

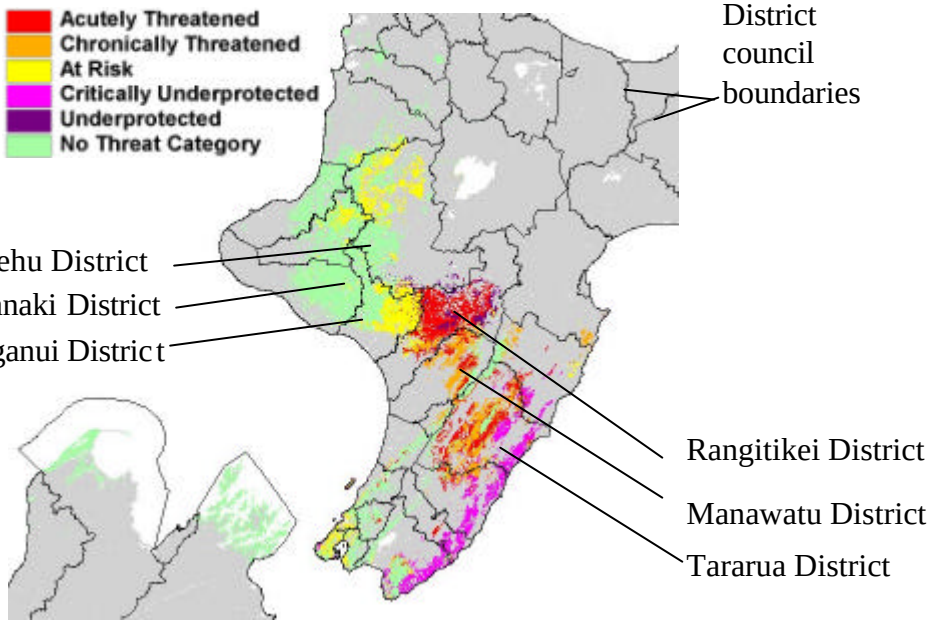
If threat classification is carried out at Level IV, 12 of the 19 Level IV environments in F1 are classified as threatened, and all five threat categories are represented (Map A2-I, Table A2.1). Three environments are Acutely Threatened (F1.3d in central Rangitikei District, F1.1f in north-western Manawatu, Tararua and northern Masterton districts, F1.1g in Tararua District). Indigenous cover in Level IV environments varies between 4.5% (F1.1g in Tararua District) and 78.5% (F1.1a in Tasman District) remaining. The percentage of a Level IV environment protected is strongly correlated with indigenous cover remaining, and ranges from 1.4% to 58.4%.

Map A2-II shows the distribution across environment F1 of broad potential natural vegetation cover classes (20 potential forest types defined using statistical modelling techniques to combine extensive plot data with environmental data layers: Leathwick et al. 2004). This map shows the likely variation in one component of the undisturbed biodiversity pattern across F1 (i.e. the forest canopy). Table A2.1 shows wide variation in the percentage of each predicted forest type across Level IV environments. For example, Rimu-matai-miro-totara/kamahi forest as previously most abundant in the now almost entirely deforested environments F1.1g (Acutely Threatened, 1.1% indigenous forest cover remaining today) and F1.4d (Chronically Threatened, 4.9% indigenous forest cover remaining) in Central Tararua District. A high proportion of Kahikatea-matai/tawa-totara forest was in environment F1.2c (Critically Underprotected, with 4.9% remaining in indigenous forest cover today).

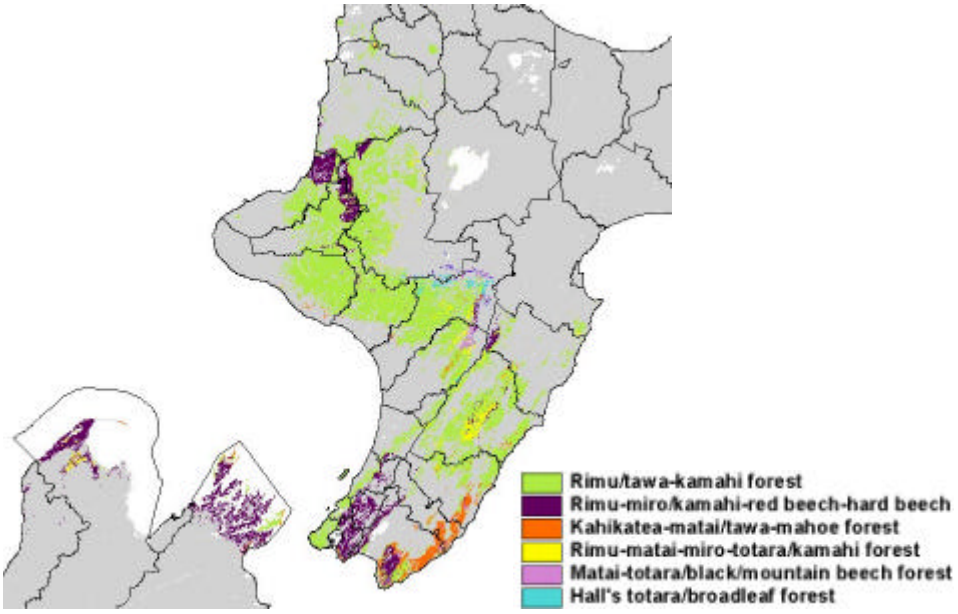
Map A2-III shows the distribution of the major present LCDB2 cover classes across F1. Table A2.1 shows the percentage areas of LCDB2 in each cover class, as well as a selection of environmental characteristics. The land cover on the most fertile soils (indicated by high acid-soluble phosphate in F1.1g), and on sites with little slope (e.g. F1.1e and F1.1f) have generally been converted to pasture. Areas of less fertile soils where early attempts at pastoral farming were frustrated by soil nutrient deficiencies now support regenerating forests and scrub (e.g. F1.2d in South Wairarapa). Extensive areas of indigenous forest still survive, mostly on steeper slopes and in more topgraphically challenging and remote areas (e.g. F1.1d in Ruapehu, South Taranaki and Wanganui districts).

These data demonstrate that environmental differences driving patterns of biodiversity as well as present and past land clearance occur at finer scales than Level II of LENZ (represented here by F1), and that biodiversity and clearance patterns are better depicted at Level IV than at Level II. These patterns also vary considerably between different district council areas containing parts of a Level II environment.

Map A2-I: LENZ Level IV environmental threat categories within Level II environment F1



Map A2-II: Potential forest types (from Leathwick et al. 2004) within Level II environment F1



Map A2-III: Present cover (LCDB2 classes) within Level II environment F1

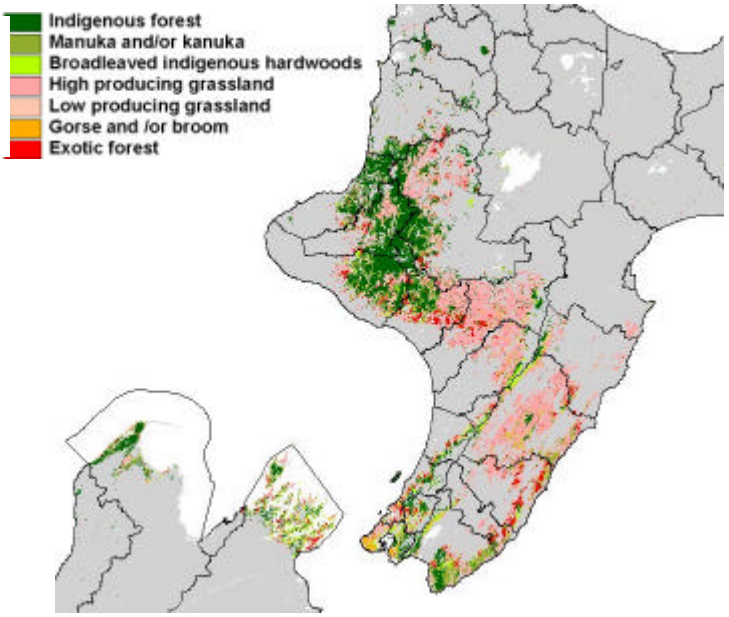


Table A2.1. Distribution of % remaining indigenous cover, % legally protected, environment threat categories, potential dominant natural vegetation, and present LCDB2 cover classes across the 19 Level IV environments within Level II Environment F1.

Threat statistics and category					Potential natural vegetation (6 most widespread forest types): % of environment						Present LCDB2 cover classes (5 most widespread amalgamated categories): % of environment					Environmental characteristics			
Level IV	Total Area (ha)	% Indigenous cover	% Legally protected	Threat Category (threat classification at LENZ Level IV)	Rimu/tawa-kamahi	Rimu-miro/kamahi-red beech-hard beech	Kahikatea-matai/tawa-totara	Rimu-matai-miro-totara/kamahi	Matai-totara/ black/mountain beech	Hall's totara/broadleaf	Indigenous Forest	Scrub (Manuka, Kanuka, Broadleaved Indigenous Hardwoods)	Pasture (High + Low producing)	Gorse and/or Broom	Exotic forestry	Slope (°)	Mean Annual Temperature (°C)	Annual Water Deficit (mm)	Acid soluble Phosphate (1=Low / 5=High)
F1.1a	50,099	78.5	58.4	No Threat Category	3	83	0	11	0	0	51	25	18	1	2	12.3	12.1	0.1	1.7
F1.1b	131,322	70.0	31.9	No Threat Category	77	23	0	0	0	0	57	12	26	1	3	17.5	12.7	1.3	1.7
F1.1c	118,124	29.9	14.2	At Risk	90	6	0	3	0	0	25	5	64	0	5	13.8	12.1	2.4	2.9
F1.1d	411,537	77.9	50.1	No Threat Category	80	11	0	5	2	1	63	14	18	0	4	19.7	11.2	0.5	1.1
F1.1e	18,012	16.8	5.0	Chronically Threatened	90	3	0	4	2	0	11	5	79	0	2	8.7	11.3	13.5	1.7
F1.1f	84,281	9.0	2.4	Acutely Threatened	85	2	3	6	4	0	3	6	85	1	5	9.6	11.3	24.3	1.7
F1.1g	19,451	4.5	1.4	Acutely Threatened	40	9	2	46	0	3	1	3	94	1	1	12.3	10.5	8.9	3.6
F1.2a	126,850	67.7	30.4	No Threat Category	22	69	6	0	1	0	23	43	16	3	12	22.6	11.6	14.8	2.4
F1.2b	16,582	53.9	23.5	No Threat Category	36	46	19	0	0	0	10	38	35	3	7	17.6	12.4	52.6	2.6
F1.2c	154,454	31.3	3.1	Critically Underprotected	62	0	36	0	1	0	5	25	49	3	16	14.8	12.1	78.7	1.0
F1.2d	10,225	68.6	5.0	Critically Underprotected	75	3	21	0	0	0	6	59	29	0	0	12.7	12.5	26.1	1.1
F1.3a	108,210	22.9	4.2	At Risk	95	0	1	1	0	1	13	10	62	2	12	17.5	11.5	33.0	1.8
F1.3b	138,464	68.0	20.2	No Threat Category	97	0	2	0	0	0	43	24	21	1	9	19.6	12.2	18.4	1.0
F1.3c	36,060	34.2	12.2	Underprotected	27	5	0	12	1	30	20	11	62	0	3	16.1	9.4	23.8	1.1
F1.3d	124,070	10.0	2.1	Acutely Threatened	89	1	1	1	2	4	5	4	83	0	6	13.6	10.8	52.1	1.8
F1.4a	112,505	12.0	2.2	Chronically Threatened	89	1	4	4	2	0	3	9	79	1	6	10.0	11.4	39.5	1.1
F1.4b	26,695	27.3	4.5	At Risk	74	24	2	0	0	0	6	21	34	18	9	13.9	12.2	42.4	1.0
F1.4c	110,676	60.7	27.2	No Threat Category	39	53	2	2	2	0	32	28	21	7	10	19.3	11.1	6.4	1.0
F1.4d	34,965	16.8	4.3	Chronically Threatened	62	9	1	25	2	0	5	12	77	3	3	15.2	11.1	18.1	2.0
F1 Total	**1,832,582**	**48.4**	**22.9**	**No Threat Category**	**72**	**16**	**5**	**4**	**1**	**1**	**31**	**17**	**42**	**2**	**7**	13.6	11.5	20.6	1.5

Appendix 3. (a) Threat classification at *Level II* of LENZ. Area of indigenous vegetation not protected (INP) in the 42 of the 100 LENZ Level II environments with less than 20% indigenous vegetation remaining nationally: distribution across *Districts*. 0–10% and yellow shading = area INP (ha) in Acutely Threatened environments, 10–20% = area INP (ha) in Chronically Threatened environments. Data are from LCDB2, and indigenous cover classes are defined as in Appendix 1.

		Area (in ha) of indigenous cover not protected																	
	Percentage remaining	Ashburton District	Auckland City	Banks Peninsula District	Buller District	Carterton District	Central Hawkes Bay District	Central Otago District	Christchurch City	Clutha District	Dunedin City	Far North District	Franklin District	Gisborne District	Gore District	Grey District	Hamilton City	Hastings District	Hauraki District
A5	7.5		393									3149	722	517			44	37	1145
A7	5.6		408									3034	4480	423			220		162
B1	6.3						2254											1993	
B2	6.3						1568							10				1286	
B3	13.0	154		5															
B4	4.5																		
B5	1.5						5							199				380	
B6	1.4			4					6										
B7	3.6						0							0				783	
B9	6.9								9										
C1	12.1				302								6	18					
C2	4.0					139	93											71	
C3	2.1					84	1156											17	
D3	16.3						15						17	51946			0	14781	55
E3	6.6	790		0				90											
F3	15.0	3		11954					308										
F4	7.9					3044	3255											290	
F5	10.3				691														
G3	11.6		187				1					4214	337	3568			4	136	4
G4	8.0		0										370	4					135
G6	10.2													1857				21	2
H3	8.9				7														
I2	3.2					97	167											27	
I3	10.5	9		376					50										
I4	7.8																		
I5	1.4						2							218				210	
I6	7.5													29				26	
J1	6.5																		
J2	6.0	894		331					211										
J3	12.6																		
J4	7.7					333	293											193	
K3	18.5	1						1766											
L1	7.5	120						101		533	485				132				
L2	11.8									445	154								
L4	2.8							118		6792	2678				201				
L5	13.0									59					10				
N1	0.8	267		4				0	75										
N2	0.7	638						5		54	108				0				
N3	5.3	11						11286		15	2401								
N5	2.6							1946											
N7	14.0							959											
N8	5.6							1843											
District totals	0-10%	2719 (1898)	801 (446)	340 (2841)	7 (0)	3696 (2266)	8794 (6458)	15389 (5282)	301 (471)	7395 (9859)	5672 (4290)	6183 (3643)	5572 (4192)	1400 (3815)	332 (743)	0 (0)	264 (285)	5313 (3363)	1442 (1603)
	10-20%	167 (838)	187 (480)	12334 (4863)	993 (711)	0 (1630)	16 (4261)	2725 (28006)	358 (167)	504 (5151)	154 (6694)	4214 (8561)	360 (6145)	57389 (47601)	10 (83)	0 (0)	4 (7)	14938 (17195)	60 (179)

Appendix 3 (a) *Continued*

	Area (in ha) of indigenous cover not protected																		
	Horowhenua District	Hurunui District	Invercargill District	Kaikoura District	Kaipara District	Kapiti Coast District	Kawerau District	Lower Hutt City	Mackenzie District	Manawatu District	Manukau City	Marlborough District	Masterton District	Matamata - Piako District	Napier City	Nelson City	New Plymouth District	North Shore City	Opotiki District
A5					2084						131			227			12	8	180
A7					397		30				347			410			4	96	1050
B1										160		691				212			
B2																			
B3		21064		506					40			439							
B4												60				13			
B5															25				
B6		7		18								356							
B7				159								931			4				
B9				291								797							
C1	0					0				5	6			12			512		49
C2	369					453		595		1139			240						
C3	595					552		77		403			443						
D3														11	25				21
E3		149							828			5							
F3												11							
F4	1					12		7		41			6187						
F5								2				1355				50	5295		
G3					1339		48				21			15	13		45		631
G4											61			524					
G6														0					
H3												141				56			
I2	133					6				53			77						
I3		9										418							
I4				9								25							
I5															36				
I6															113				
J1				7								1530				118			
J2		1344		20					1552			287							
J3		124		1511								1							
J4	1329					310		157		1086			375						
K3									1394										
L1			790						219										
L2																			
L4																			
L5			171																
N1		1861		9					62			2							
N2		122		0					599			14							
N3		15							913										
N5									699										
N7									315										
N8									0										
District totals 0-10%	2428 (1556)	3497 (7226)	790 (274)	513 (770)	2481 (1675)	1332 (1270)	30 (78)	837 (596)	4873 (2440)	2881 (4594)	540 (403)	4838 (3183)	7321 (4621)	1161 (1392)	178 (216)	398 (398)	16 (3960)	104 (51)	1230 (2228)
District totals 10-20%	0 (1166)	21198 (10219)	171 (126)	2017 (1994)	1339 (4397)	0 (300)	48 (58)	2 (310)	1749 (8834)	5 (5311)	27 (163)	2225 (9080)	0 (4808)	38 (114)	38 (0)	50 (213)	5852 (147)	0 (63)	701 (1099)

Appendix 3 (a) *Continued*

	Area (in ha) of indigenous cover not protected																		
	Otorohanga District	Palmerston North City	Papakura City	Porirua City	Queenstown Lakes District	Rangitikei District	Rodney District	Rotorua District	Ruapehu District	Selwyn District	South Taranaki District	South Waikato District	South Wairarapa District	Southland District	Stratford District	Tararua District	Tasman District	Taupo District	Tauranga District
A5	68		18				564	16			45	18						0	238
A7	29		73				1642	75				31							408
B1						1258			0		25		19				1818	1	
B2						43			51									5	
B3					17					449							1		
B4																	45		
B5																			
B6																			
B7																			
B9																			
C1	260					220		172	1449		248	0			10		223	1632	
C2		750		439		1345			30		261		482			1389			
C3		22		45		599					239		609			263			
D3	2					182		1				89						0	
E3					6					226									
F3					21					288									
F4				117		109					4		9129			5726			
F5						2					4519				1235		1602		
G3	23						729	32			7	33						1	
G4			23				0					1							39
G6							0												
H3											44				60		77		
I2		30		6		14							331			15			
I3										457									
I4																			
I5																			
I6																			
J1																	1477		
J2										622									
J3																			
J4		130		16		871			226		445		731			670			
K3					895														
L1					172									5733					
L2																			
L4														989					
L5														3129					
N1					3					207				3					
N2					30					478				105			1		
N3					31									98					
N5					584														
N7					5														
N8					33														
District totals 0-10%	98 (744)	932 (356)	114 (113)	622 (494)	860 (1471)	4238 (11128)	2205 (1006)	91 (1339)	306 (743)	1532 (1940)	1063 (6003)	50 (849)	11301 (6377)	6930 (9132)	60 (1089)	8062 (11237)	3417 (3277)	6 (3715)	685 (628)
District totals 10-20%	284 (773)	0 (1147)	0 (5)	0 (136)	938 (2913)	404 (4929)	730 (2111)	205 (1470)	1449 (2709)	1194 (746)	4774 (146)	122 (164)	0 (5804)	3129 (12146)	1245 (133)	0 (8189)	1827 (6232)	1633 (284)	0 (1)

Appendix 3 (a) *Continued*

	Area (in ha) of indigenous cover not protected																		
	Thames - Coromandel District	Timaru District	Upper Hutt City	Waikato District	Waimakariri District	Waimate District	Waipa District	Wairoa District	Waitakere City	Waitaki District	Waitomo District	Wanganui District	Wellington City	Western Bay of Plenty District	Westland District	Whakatane District	Whangarei District	Total Indigenous Cover Not Protected
A5	387			1688			285	659	9		114			255		104	1164	14,281
A7	1125			1690			529	1048	279		0			2675		140	1302	22,108
B1												2341						10,770
B2												276						3239
B3		17			360													23,051
B4																		117
B5												9						618
B6					2													392
B7												0						1877
B9																		1097
C1			119				60				1214	6		4		214		6741
C2			449									512	324					9080
C3			73									339	62					5577
D3	77			32			31	29858				0				5		97,148
E3		758			687	87												3626
F3					24													12,610
F4			2									123	40					28,085
F5											61	248						15,059
G3				448			122	451	14		0			18		991	2206	15,637
G4	1153			796			79		4					144		71		3403
G6	5							33										1918
H3												6						390
I2													28					984
I3		46			25	62												1451
I4																		34
I5																		467
I6																		168
J1																		3132
J2		346			302					4								5913
J3																		1637
J4			9					2			20	273	34					7502
K3		133				117				1070								5376
L1		265				334				194								9077
L2		106				2				70								777
L4										172								10,951
L5																		3368
N1		24			204	100												2821
N2		204			363	364				179								3264
N3		1642				2840				9489								28,741
N5						47				843								4118
N7						2				235								1515
N8						0				19								1895
District totals 0-10%	2665 (1275)	3239 (2263)	532 (675)	4174 (6124)	1558 (1558)	3771 (2373)	892 (2436)	1710 (1453)	292 (251)	10900 (4145)	134 (1437)	3878 (1995)	488 (446)	3073 (2910)	0 (0)	315 (1628)	2467 (1575)	183,726 (182573)
District totals 10-20%	81 (1366)	302 (1132)	119 (343)	481 (4921)	408 (408)	183 (2630)	214 (287)	30343 (19804)	14 (210)	1375 (14735)	1275 (192)	255 (2614)	0 (15)	22 (4)	0 (0)	1211 (2395)	2206 (3351)	186,287 (285416)

Appendix 3. **(b)** Threat classification at *Level II* of LENZ. Area of indigenous vegetation not protected (INP) in the 42 of the 100 LENZ Level II environments with less than 20% indigenous vegetation remaining nationally: distribution across 16 *Regions.* 0–10% and yellow shading = area INP (ha) in Acutely Threatened environments, 10–20% = area INP (ha) in Chronically Threatened environments. 0–20% = area INP (ha) in Acutely and Chronically Threatened environments. Figures in brackets (Region total rows) are INP area from Level IV analysis (see Appendix 3(c)). Data are from LCDB2, and indigenous cover classes are defined as in Appendix 1.

		Area (in ha) of indigenous cover not protected																
		Auckland	Bay of Plenty	Canterbury	Gisborne	Hawkes Bay	Manawatu-Wanganui	Marlborough	Nelson City	Northland	Otago	Southland	Taranaki	Tasman	Waikato	Wellington	West Coast	Total INP
A5		1252	790		517	697				6398			57		4572			14,281
A7		5875	4375		423	1048				4734			4		5648			22,108
B1						4279	3727	691	212				25	1818	1	19		10,770
B2					10	2873	351								5			3239
B3				22594				439			17			1				23,051
B4								60	13					45				117
B5					199	410	9											618
B6				37				356										392
B7				159		787		931										1877
B9				300				797										1097
C1		12	467		18	10	1680						770	223	3140	119	302	6741
C2						165	5534						261			3121		9080
C3						1173	2189						239			1976		5577
D3		1	27		51946	44862									312			97,148
E3				3526				5			96							3626
F3				12577				11			21							12610
F4						3544	5419						4			19118		28,085
F5							263	1355	50				11036	1602	61	2	691	15,059
G3		1132	1721		3568	601				7758			52		805			15,637
G4		157	253		4										2988			3403
G6					1857	54									6			1918
H3							12	141	56				98	77			7	390
I2						194	244									545		984
I3				1033				418										1451
I4				9				25										34
I5					218	249												467
I6					29	139												168
J1				7				1530	118					1477				3132
J2				5626				287										5913
J3				1636				1										1637
J4						488	4532						446		20	2016		7502
K3				2708							2668							5376
L1				1009							1413	6655						9077
L2				107							669							777
L4											9761	1190						10,951
L5											59	3310						3368
N1				2813				2			3	3						2821
N2				2771				14			372	105		1				3264
N3				6505							22137	98						28,741
N5				1588							2530							4118
N7				552							963							1515
N8				20							1876							1895
Region totals	0-10%	7284 (3464)	5418 (8636)	24368 (25077)	1400 (3815)	16047 (12128)	22017 (30883)	4838 (3183)	398 (398)	11131 (6893)	38189 (23748)	8052 (10149)	1133 (11034)	3417 (3277)	13234 (22484)	26794 (17404)	7 (0)	183,726 (182,573)
	10-20%	1146 (5299)	2214 (5027)	41207 (36836)	57389 (47601)	45527 (41481)	1943 (25878)	2225 (9080)	50 (213)	7758 (16308)	4398 (52494)	3310 (12355)	11858 (307)	1827 (6232)	4325 (12,161)	120 (13,434)	993 (711)	186,287 (285,416)
	0-20%	8430 (8763)	7632 (13663)	65575 (61913)	58788 (51416)	61574 (53609)	23960 (56761)	7062 (12263)	448 (611)	18890 (23202)	42586 (76242)	11362 (22504)	12992 (11341)	5244 (9509)	17558 (34645)	26914 (30838)	1000 (711)	370,014 (467,988)

Appendix 3 (c) Threat classification at *Level IV* of LENZ. Area of indigenous vegetation not protected (INP) in the 232 Level IV environments with less than 20% indigenous vegetation remaining nationally, summarised to show areas in 61 Level II environments across 16 *Regions.* No. Lvl IV = number of Level IV environments; 0–10% and yellow shading = area INP (ha) in Acutely Threatened environments, 10–20% = area INP (ha) in Chronically Threatened environments. 0–20% = area INP (ha) in Acutely and Chronically Threatened environments. Data are from LCDB2, and indigenous cover classes are defined as in Appendix 1.

		Area (in ha) of indigenous cover not protected																
	No. Lvl IV	Auckland	Bay of Plenty	Canterbury	Gisborne	Hawkes Bay	Manawatu-Wanganui	Marlborough	Nelson City	Northland	Otago	Southland	Taranaki	Tasman	Waikato	Wellington	West Coast	Total Area
A1	1	42								1733								1776
A4	1														1			1
A5	9	1118	650		312	697				6397			57		4288			13,519
A6	2	303	75		16					2782					174			3350
A7	7	5875	4375		423	290				4734			4		5644			21,345
B1	8					4279	3727	691	212				25	1818	1	19		10,770
B2	4				10	2873	351								5			3239
B3	4			15814				439			17			1				16,271
B4	2							60	13					45				117
B5	5				199	410	9											618
B6	4			37				356										392
B7	4			159		787		931										1877
B8	1			6				1563						1				1569
B9	3			300				797										1097
C1	3	12	263		18		3						594	223	1545	103	302	3063
C2	5					165	5534						261			3121		9080
C3	7					1173	2189						239			1976		5577
D2	1	41	73			3							94		10216			10,427
D3	8	1	27		46361	34764									295			81,448
E1	2			256				3663	163					3422				7503
E2	1							11						925				937
E3	2			3526				5			96							3626
E4	1			5046				363										5408
F1	6					2203	29147						33		278	3623		35,283
F3	3			7569				3			21							7593
F4	6					3544	5419						4			19118		28,085
F5	4						263	1355	50				8835	535	44	2	56	11,139
F6	2	5	5172		2	42									5069			10,289
F7	3		1155		7	660	4699						1		3133			9655
G1	1	93																93
G3	8	1115	1718		1856	601				7552			52		805			13,699
G4	3	157	63		4										2988			3212
G6	4				1857	54									6			1918
H1	4					15	633			4			599	1061	127	438	354	3231
H2	2		93		104	2									6			203
H3	2						12	141	56				98					307
I2	4					194	244									545		984
I3	5			1033				75										1108
I4	1			9				15										24
I5	3				218	249												467
I6	2				29	139												168
J1	6			7				1530	118					1477				3132
J2	6			3173				250										3423
J3	3			1636				1										1637
J4	9					465	4532						446		20	1895		7358
K3	3			1113							970							2083
K5	1			1														1
L1	9			1009							1178	4913						7099
L2	2			107							36							143
L4	3										9761	1190						10,951
L5	2											3155						3155

Appendix 3 (c) *Continued*

		Area (in ha) of indigenous cover not protected																	
		No. Lvl IV	Auckland	Bay of Plenty	Canterbury	Gisborne	Hawkes Bay	Manawatu-Wanganui	Marlborough	Nelson City	Northland	Otago	Southland	Taranaki	Tasman	Waikato	Wellington	West Coast	Total Area
N1		6			2813				2			3	3						2821
N2		6			2771				14			372	105		1				3264
N3		9			6505							22137	98						28,741
N4		3			4366							17806							22,172
N5		4			1588							2530							4118
N6		1			2255							354							2609
N7		2			552							963							1515
N8		3			20							1876							1895
Q3		1										257	1668						1924
Q4		5			245							17864	11371						29,480
Region totals	0-10%	No. Lvl IV	18	17	46	31	45	36	28	7	7	40	16	20	9	27	27	0	158
		Area	3464	8636	25077	3815	12128	30883	3183	398	6893	23748	10149	11034	3277	22484	17404	0	182,573
	10-20%	No. Lvl IV	12	13	25	15	25	15	13	2	6	17	6	7	9	18	14	3	74
		Area	5299	5027	36836	47601	41481	25878	9080	213	16308	52494	12355	307	6232	12161	13434	711	285,416
	0-20%	No. Lvl IV	30	30	71	46	70	51	41	9	13	57	22	27	18	45	41	3	232
		Area	8763	13663	61913	51416	53609	56761	12263	611	23202	76242	22504	11341	9509	34645	30838	711	467,988

Appendix 4. An example of an interactive GIS application of the threat classification table to assess the threat status of remaining indigenous cover within an area of interest (bold black outline). In this example, statistics for the yellow area are displayed by clicking the crosshair pointer. This area is in Environment K3.2a, and in the 'At Risk' threat category. The environment has 25.02% indigenous cover remaining, and 5.76% protected. No change in indigenous cover was recorded in this environment from 1996/97 to 2001/02. The inset box shows the five-column table of data joined to the LENZ Level IV attribute table.