Representativeness of Protected Areas for biodiversity in the South Island High Country

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Landcare Research Contract Report: LC0304/086

PREPARED FOR:
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DATE: March 2004

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Summary

Project and Client

This report to Land Information New Zealand (LINZ) accompanies maps and tables of the South Island high country, prepared in March 2004 by Landcare Research, Dunedin and Palmerston North. The tables and maps are based on existing digital databases and are intended for use as background information to the land tenure review of pastoral leases.

Objectives

- Part 1: Identify land environments and vegetation cover in the high country using LENZ and interim vegetation cover map data and identify the representation of these in existing protected natural areas.
- This report also addresses some biodiversity aspects of Part 2: Develop a framework for assessing the levels of significance of indigenous vegetation and environments in the high country.

Methods

Spatial data depicting protected land, indigenous vegetation cover, and pastoral leases were overlaid on LENZ Levels IV environments. In Section I, the representation of land environments in protected areas was assessed nationally and in the high country. In Section II, two measures were developed to assess the effectiveness of biodiversity protection, and the significance of biodiversity for protection. Their operational application to assess progress towards Government objective (g) was demonstrated.

Results

The high country contains a diversity of environments and associated biodiversity. Indigenous vegetation remains largely in high elevation environments, and pastoral leases retain more indigenous vegetation within most environments than freehold tenure. Protected areas in the high country currently represent only a portion of the full range of biodiversity, and environments that are most at risk of biodiversity loss are poorly protected.

Conclusions

Two measures (representativeness and vulnerability) can be used to determine effectiveness of and significance for biodiversity protection, and can be applied to assess progress towards biodiversity outcomes in relation to realistic targets.

Lowland and montane environments of the high country are poorly represented in protected areas, and their remaining biodiversity is particularly vulnerable and of high significance for biodiversity protection.

Representativeness and vulnerability appear to be increasing in the high country, i.e. increased representativeness through protection of the least vulnerable environments is being offset by increased susceptibility to loss and vulnerability in more vulnerable lowland and lower montane environments. Thus, Tenure Review may be working against Government objective (g).

Progress on Government objective (g) will require protection of indigenous biodiversity in lowland and montane environments where there is potential for alternative productive uses. Progress on Government objective (h) will generally contribute little to progress on Government objective (g), because these objectives require protection of land in different places.

Recommendations

We recommend the adoption of clear biodiversity protection targets to direct conservation effort and to provide a context for assessing the effectiveness of biodiversity protection. Two measures — representativeness and vulnerability— are required to assess the effectiveness of protection for biodiversity against these targets, to determine the significance of remaining indigenous vegetation for biodiversity protection, and to measure progress towards Government objective (g) for the high country.

We recommend that a full systematic conservation and land use planning framework is customised for the tenure review process. This will require that targets and appropriate measures of progress be defined for each of the 10 Government objectives. Issues of ownership, accountability, and resources for appropriate spatial data standards will need to be addressed to enable consistent assessment of protection effectiveness, significance, and progress towards objectives.

1. Introduction

1.1 Project objectives

In December 2003, the Department of Conservation reported to Cabinet on its evaluation of current methods by which it and the Commissioner identify biodiversity values that are significant inherent values for protection (POL Min (03) 19/7, Appendix 1, Further work proposed, paragraph g). In February 2004, LINZ requested that Landcare Research build on the work completed by the Department of Conservation in its report to Cabinet. The task was to develop a framework and protocols to guide priority setting for protecting land environments and vegetation components of significant inherent values. The framework and protocols developed should be suitable for operational application, in order to ensure that conservation outcomes for the High Country are consistent with the objectives of tenure review.

Two parts of this work were specified in the brief:
Part 1: Identify land environments and vegetation cover in the high country using LENZ and interim vegetation cover map data and identify the representation of these in existing protected natural areas. This extends preliminary analysis of levels of protection of vegetation by land environment and altitude zones undertaken by the Department of Conservation.

Part 2: Develop a framework for assessing the levels of significance of indigenous vegetation and environments in the high country.

Together, the two parts address the identification of significant inherent values of the high country, which are the focus of three Government objectives for the high country (Objectives c, g & h; Table 1; Appendix 1).

Table 1 Government objectives for the high country relevant to this report

Objectives derived from the CPLA 1998
c. Protect significant inherent values on reviewable land by the creation of protective measures [CPLA S.24(b)(i)]; or preferably by the restoration of the land concerned to full Crown ownership and control [CPLA S.24(b)(ii)]
Complementary objectives from POL Min (03) 19/7
g. Ensure that conservation outcomes for the high country are consistent with the New Zealand Biodiversity Strategy (NZBS) h. Progressively establish a network of high country parks and reserves

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We recommend that a full systematic conservation and land use planning framework is customised for the tenure review process. This will require that targets and appropriate measures of progress be defined for each of the 10 Government objectives. Issues of ownership, accountability, and resources for appropriate spatial data standards will need to be addressed to enable consistent assessment of protection effectiveness, significance, and progress towards objectives.

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1.2 Significance criteria: representativeness and vulnerability

Representativeness expresses the extent to which features (biological, landscape, historic) are contained (i.e. represented) in protected areas, and is therefore an indicator of the effectiveness of protection. Representativeness is also the primary criterion in the assessment of significance; features that are less well represented in protected areas are more significant (Myers et al. 1987; Clarkson 1995; Whaley et al. 1995; Norton & Roper-Lindsay 1999; Lee & Walker 2004).

Representativeness is not informative about a second aspect of the effectiveness of protection, i.e. how well a network of protected areas insures against the loss of features (e.g. Faith & Walker 1996c; Gaston et al. 2002; Lawler et al. 2003). In the assessment of significance for protection in New Zealand, the vulnerability of features has been addressed within the criterion 'Fragility and Threat' (Clarkson 1995; Whaley et al. 1995; Lee & Walker 2004). Features that are more vulnerable (i.e. susceptible to loss or degradation) are considered to be more significant, because protection is more urgent if these are to be conserved.

1.3 Criteria for the assessment of significance for biodiversity protection

Biodiversity is a substantial subset of significant inherent values specifically referred to in Government objective (g) (ensure that conservation outcomes for the high country are consistent with the New Zealand biodiversity strategy). *The New Zealand Biodiversity Strategy* (p. 41; Department of Conservation & Ministry for the Environment (DOC & MfE) 2000) directs priority for addition to public conservation lands by the application of two criteria (Objective 1, first Priority Action, Biodiversity on Land):

(a) those habitats and ecosystems important for indigenous biodiversity that are not represented within the existing protected area network (i.e. representativeness), or

(b) those habitats and ecosystems important for indigenous biodiversity that are at significant risk of irreversible loss or decline (i.e. vulnerability).

This priority action identifies (a) representativeness and (b) vulnerability as the two key criteria defining significance for biodiversity protection. Biodiversity that is poorly represented in protected areas is significant, because its protection will be necessary for maintaining and sustaining the full range of indigenous biodiversity. Biodiversity that is vulnerable (i.e. 'at significant risk of irreversible loss or decline') is significant because its urgent protection is necessary to avoid biodiversity loss.

The representativeness of land environments and vegetation cover within the protected area network in the high country is one indicator of the effectiveness of protection for biodiversity, which also determines significance for biodiversity protection (Pressey 1994; Pressey & Logan 1998; Scott et al. 2001; Sierra et al. 2002; Margules et al. 2002). However, a second, complementary measure (vulnerability) is needed, both to assess the effectiveness of protection for biodiversity, and to determine the significance of

biodiversity for protection (e.g. Faith & Walker 1996c; Pressey & Taffs 2001a, b; Sierra et al. 2002; Gaston et al. 2002; Lawler et al. 2003; Rouget et al. 2003b). Both measures are relevant to assessing significance for achieving Government objective (g) for the high country, and for determining progress towards this objective.

1.4 Scope of the report

In Section I of this report, we address Part 1 of the work (above): we identify land environments and vegetation cover in the high country using LENZ and interim vegetation cover map data, and describe the extent to which these are contained (i.e. represented) in protected areas.

The representativeness of land environments and vegetation cover within a protected area network indicates both the adequacy of protection for the full range of biodiversity, and significance of remaining indigenous vegetation for biodiversity protection. In Section II of this report, we build upon the analysis of representation Section I to address aspects of Part 2 of the brief (develop a framework for assessing the levels of significance of indigenous vegetation and environments in the high country) that relate to the protection of biodiversity. We use two complementary measures (representativeness and vulnerability) that describe the effectiveness of biodiversity protection in the high country, and in doing so, identify and rank significance for biodiversity protection.

To be relevant in an operational setting, representativeness and vulnerability must be determined in the context of appropriate targets for biodiversity protection (Pressey 1999a; Pressey et al. 2003a; Margules & Pressey 2000; Cowling & Pressey 2003, Cowling et al. 2003a). We describe a procedure for defining appropriate targets, and apply them here.

Criteria used for the assessment of significance should be suitable for operational application in the Tenure Review process, and sensitive to changes made in the protection of environments and vegetation through that process. We trial the suitability of our measures for assessing changes in the effectiveness of biodiversity protection, and significance for biodiversity protection, using changes in land tenure to date as an example.

In a second report (Walker et al. in prep.), we complete Part 2 of the work brief, placing representativeness and vulnerability within a more comprehensive framework of criteria for assessing the significance of indigenous vegetation and environments in the high country.

2. Background

2.1 High Country environments and indigenous biodiversity

The pastoral high country covers some 25% of New Zealand's land area, encompassing a considerable altitudinal range from valley floors to mountain tops. Productivity follows altitudinal gradients, with factors such as steep relief, short growing seasons, high frost frequency, and low soil fertility all becoming increasingly limiting to primary production with increasing elevation. Indigenous species and communities also follow altitudinal gradients; for example in the absence of human disturbance, shrublands and tall tussock grasslands would dominate above treeline (i.e. in the alpine zone), tall forests would cover mountain slopes (the montane zone), dry, frosty basin floors (the lowland zone) would be occupied by shrublands with diverse understorey herbs and smaller grasses (Leathwick et al. in press).

Lowland and montane areas of the high country have been more intensively developed by topdressing and oversowing with exotic pasture species, as well as by cultivation. This process removes indigenous species and replaces them with exotic species (mainly grasses and forbs). Thus, there has been differential removal of indigenous biodiversity across 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. This altitudinal pattern of land use and habitat loss in the South Island high country is a feature that it shares with all of New Zealand (Leathwick et al. 2003b).

The consequences of intensive land use for indigenous biodiversity are reflected in the altitudinal distribution of New Zealand's most threatened species (e.g. Rogers & Walker 2002). For example, de Lange et al. (in press) estimate that 37.1% of New Zealand's Acutely and Chronically Threatened plant species (the two higher categories of extinction threat in the New Zealand threat classification system) occur in the lowland zone, and a further 30.9% in the montane zone, while the subalpine and alpine zones contain only 7.2 and 5.0%, respectively. Lee and Walker (2004) categorised the Acutely and Chronically Threatened plants of Central Otago District (a part of the high country) by altitudinal zone, and estimated that 80% of the Acutely and Chronically Threatened plant species occurred in the lowland and montane zones (of the remainder, 10% were classified as alpine-montane and 10% as alpine).

2.2 The New Zealand Biodiversity Strategy

New Zealand's indigenous biodiversity is globally distinctive and unique, in part a consequence of evolution through a long period of isolation after separation from other continents some 80 million years ago, but also through recent adaptive speciation in

novel environments. This distinctiveness is seen in high levels of endemism (native only to NZ), presence of ancient and unusual forms, and in the different features of communities.

The loss and deteriorating condition of indigenous biodiversity was described in the *State of New Zealand's Environment 1997* report (Taylor et al. 1997) as the nation's most pervasive environmental issue. *The New Zealand Biodiversity Strategy* (DOC & MfE 2000) was prepared in response to the decline in New Zealand's native biodiversity.

Goal 3 of the Strategy is to:

> Halt the decline in New Zealand's indigenous biodiversity
> Maintain and restore the full range[1] of remaining natural habitats and ecosystems to a healthy functioning state, enhance critically scarce habitats and sustain the more modified ecosystems in production and urban environments; and do what else is necessary to maintain and restore viable populations of all indigenous species and subspecies across their natural range and maintain their genetic diversity (p. 18)

[1] a comprehensive and representative range, that reflects the known diversity of habitats and ecological communities remaining in New Zealand

The Strategy also states (p. 20) that 'maintaining viable populations of indigenous species across their natural range should largely be achieved by maintaining a full range of natural habitats and ecosystems.'

It is recognised in the Strategy (p. 34) that protection for indigenous biodiversity is unevenly distributed across environments. Accordingly, priority for protection is directed to those habitats and ecosystems important for indigenous biodiversity that are not represented within the existing protected area network, or those habitats and ecosystems important for indigenous biodiversity that are at significant risk of irreversible loss or decline (p. 41).

2.3 Opportunities for biodiversity protection through tenure review

Tenure review under the Crown Pastoral Lands Act 1998 (CPLA) is the predominant method by which the Crown achieves conservation outcomes in the South Island high country. The process therefore presents a unique opportunity to improve the protection of ecosystems, habitats and species of the high country. This opportunity is of considerable importance for meeting national biodiversity goals as expressed in the New Zealand biodiversity strategy (DOC & MfE 2000), and international commitments (Convention on Biological Diversity; e.g. Perley et al. 2001).

The importance of tenure review for biodiversity lies firstly in the opportunity to conserve what little remains of seriously threatened biodiversity (habitats, ecosystens and species) associated with lowland and montane environments, that are poorly represented within the existing protected area network, and at significant risk of irreversible loss or decline. Although the indigenous biodiversity that remains in these environments is often reduced and modified, it can be all or most of what remains of its type, presenting the

only opportunity to slow or halt its decline. It will therefore be of major significance for biodiversity conservation.

Geographic characteristics of pastoral leases provide potential (that seldom exists on private land) to create corridors of lands traversing altitudinal sequences that are protected or managed sympathetically. This presents a second important opportunity for tenure review to improve biodiversity protection. Given the inevitability of climate change, elevation sequences must be protected to enable communities and species to migrate up or downslope with environmental changes. Isolated, fragmented reserves may pose expensive and intractable problems for conservation in the future.

Historically, additions to New Zealand's national network of protected areas have largely been opportunistic, expedient, and ad hoc (see Pressey et al. 1993; Pressey 1994; Stewart et al. 2003). As a consequence, the national reserve system is strongly skewed towards higher, wetter, mountainous environments, and there is little provision for the protection of habitats and ecosystems in productive lowland and montane environments, which hold the majority of New Zealand's Acutely and Chronically threatened species. The timely combination of three factors enables tenure review to redress this reservation bias and to improve the protection and status of indigenous species. The three factors are:

1. The New Zealand Biodiversity Strategy now provides clear direction for reservation, stating that priority should be given to those habitats and ecosystems that are poorly represented within the existing protected area network, or at significant risk of irreversible loss or decline. One reason for the current reservation bias, and the threatened status of many New Zealand species, is the absence, in the past, of this overarching direction to guide reserve acquisition policy.
2. Improved technological capability (e.g. spatial information technology such as GIS) has enabled the development of systems for land use planning that optimise the contribution of land tenure decisions to different objectives, and maximise the economic efficiency of land tenure changes. There has been at least two decades of research into the concepts and application of systematic conservation planning. This has built a body of expertise overseas, and resulted in an extensive international literature that describes the application of systematic conservation planning in many countries and regions (e.g. Ferrier et al. 2000; Margules & Pressey 2000; Nix et al. 2000; Margules et al. 2002; Cowling et al. 2003a, b). These planning techniques are of particular relevance to tenure review, and can be customised for the process.
3. Because tenure review applies to large areas of Crown land, the process itself presents perhaps the first opportunity for New Zealand to systematically plan and manage land allocation decisions to optimally and efficiently meet biodiversity goals, in concert with other objectives.

2.4 Threats to biodiversity from tenure review

The Cabinet Policy Committee Report Back on Government Objectives for the High Country states (paragraph 46): "The protection of lowland or valley floor habitats and ecosystems has been difficult to achieve under tenure review. Lowland areas are generally the most modified parts of pastoral properties and generally have the best potential for alternative or more intensive land uses. They are therefore the places that the lessee wants to freehold unencumbered."

Further, the Report Back states (paragraph 47): "It has been even more difficult to achieve protection for complete altitudinal sequences from the lowlands to the alpine zone, but has been relatively easy to protect the highest altitude ecosystems."

Land that has been freeholded may be used for a range of purposes that were not permitted as of right when land was pastoral lease (Report Back paragraph 21) and intensification of production is generally anticipated (Report Back paragraph 22).

These statements suggest that tenure review is:

- largely reinforcing past patterns of reservation bias, i.e. only those habitats and ecosystems with little potential for economic use are being protected;
- failing to protect those habitats and ecosystems that are most poorly represented within the existing protected area network, or at most significant risk of irreversible loss or decline;
- not reducing the fragmentation or reconnecting poorly represented or at-risk ecosystems.

The reason suggested for this bias in land allocation is that these habitats and ecosystems have potential for alternative economic uses, which is given priority over threatened biodiversity in tenure review land allocations.

If the above extracts from the Report Back are correct, then tenure review is likely to exacerbate biodiversity loss, both by extinguishing the last opportunities to protect threatened lowland and montane ecosystems, habitats and species through their addition to public conservation lands, and by missing opportunities to reconnect indigenous ecosystems and reduce fragmentation.

Failure to implement explicit, systematic planning is a contributor to the threat the tenure review process poses for biodiversity. A planning framework, with explicit targets to work towards for all objectives, will enable the best opportunities to balance the different Government objectives to be recognised and taken.

2.5 Representativeness: concept and importance for biodiversity

Protection of representatives of the full range of biological diversity is a central goal of nature conservation, both internationally and in New Zealand (Margules & Pressey 2000).

The aim is to ensure that the complete spectrum of natural ecosystems, together with populations of the species they support, remain in the landscape over the long term. Representativeness is a measure of the extent to which the full range of biological diversity is present. The representativeness of a protected area network is a measure of how well the full range of biological diversity is protected within protected areas. Analysis of the representativeness of a protected area network also allows us to identify those elements that are most poorly protected, and those that are most adequately protected.

Biodiversity conservation depends on *in situ* protection, both within designated reserves, and through a variety of management arrangements that attempt to retain natural values while continuing sympathetic land use. In New Zealand, as elsewhere in the world, the existing network of protected areas contains a biased sample of biodiversity, i.e. predominantly that of remote places and other areas that are unsuitable for commercial activities (Mark 1985). The consequence of biased patterns of reservation for indigenous biodiversity is an elevated risk of extinction in those ecosystems, habitats and species that occur where human impacts are concentrated, and the proportion of land set aside for protection is smallest (e.g. Heydenrych et al. 1999; Heijnis et al. 1999; Gaston et al. 2002).

It is widely recognised, within New Zealand and internationally (Margules et al. 1988, 2002; Lombard et al. 1999; Rouget et al. 2003a, b), 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. In New Zealand, progress towards Goal 3 of *The New Zealand Biodiversity Strategy* (DOC & MfE) depends upon improved representativeness. For example, the Action Plan for Biodiversity on Land sets out the following objective (p. 41):

> Objective 1.1 Protecting indigenous habitats and ecosystems
> a) Enhance the existing network of protected areas to secure a full range of remaining indigenous habitats and ecosystems.

Accordingly, improved representativeness (i.e. 'A more comprehensive range of terrestrial, freshwater and marine environments and habitats is legally protected') is National Priority Outcome 1.3 of the Department of Conservation Statement of Intent 2003–2006. The change in percentage of each environment type under legal protection (i.e. representativeness) is the indicator for this outcome. Similarly, change in representativeness (a measure of how well the full range of biological diversity is protected) will be an appropriate indicator of progress towards the objective 'To ensure that conservation outcomes for the high country are consistent with the New Zealand Biodiversity Strategy.' [Cabinet Policy Minute POL Min (03) 19/7].

2.6 Representativeness: a retreating option

Some natural features are less likely to persist under human land use pressures than others. It follows that over time, realistic opportunities for protection are narrowed down to a diminishing set of features that are safest from clearance, or pest invasion pressures

(Pressey & Taffs 2001a, b; Rouget et al. 2003a, b). Achieving representativeness (i.e. protecting representatives of the full range of biological diversity) is therefore a retreating option. The longer protection is delayed, the greater the likelihood that representativeness will not be achieved.

If representativeness goals are to be met, priority and urgency should be accorded to the protection of the most rapidly retreating opportunities, i.e. those natural features (ecosystems, communities, species) for which there is the greatest likelihood of imminent loss or degradation under current and/or future land uses (World Resources Institute 1992; Pressey 1994; Pressey & Taffs 2001b). Because the total amount of resources for protection is always limited (e.g. financial, human capital, land area), options retreat with time. If land is added first to protected areas in those environments that are under little threat, or those in which targets have already been met, this will increase vulnerability, i.e. the likelihood and/or imminence of biodiversity loss, and opportunities for better biodiversity outcomes will be missed.

The most imminent threats to the persistence of the indigenous ecosystems and species of the high country are in its lowland and montane environments. This is where land use changes (principally intensive agricultural development and urbanisation) and weed invasion are leading to the most rapid loss of indigenous cover, and therefore the most rapid retreat of options and opportunities for biodiversity protection (e.g. Lee & Walker 2004).

Representativeness (i.e. the proportion of environments adequately represented) does not necessarily indicate the likelihood and/or imminence of biodiversity loss; even when overall representativeness is relatively high, a network of protected areas may still systematically exclude those ecosystems that are most at risk of change and loss. A second measure is therefore required to assess the adequacy of biodiversity protection provided by a network of protected areas (Lunney et al. 1997; Pressey & Taffs 2001a). This measure, vulnerability, integrates the degree of protection and the likelihood of biodiversity loss across the landscape. It reflects how well a network of protected areas insures against loss, and indicates the urgency of requirements for additional protection.

2.7 Biodiversity protection targets

Performance and progress towards objectives cannot be assessed without the context of targets, which are required to give direction to effort and to provide a scale for the assessment of progress.

The overall goals of conservation have to be translated into specific, quantitative targets for operational use (e.g. Pressey & Logan 1998; Margules & Pressey 2000; Pressey et al. 2003). Ideally, these targets must be sufficient to achieve desired outcomes and realistic in relation to available opportunities. In the high country, targets for protection of indigenous biodiversity are directed by Government objective (g) for the high country; which requires that outcomes are consistent with the New Zealand biodiversity strategy.

Setting sufficient targets: how much is enough?

The generalised species–area relationship describes the relationship between area of habitat and species number (Rosenweig 1995). It can therefore be used to estimate the effects of levels of protection on biodiversity, to inform the setting of targets that are sufficient to halt the decline in species number in a habitat.

The relationship between the extent of an area and the number of species that it can support is not linear, but a curve, usually described by a power function ($S = aC^z$ where $z<1$), i.e. the number of species contained in any area (be it 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 precise shape of the curve changes depending on the body size and life history of the biotic entities involved, but the general shape of the curve remains the same (Fig. 1).

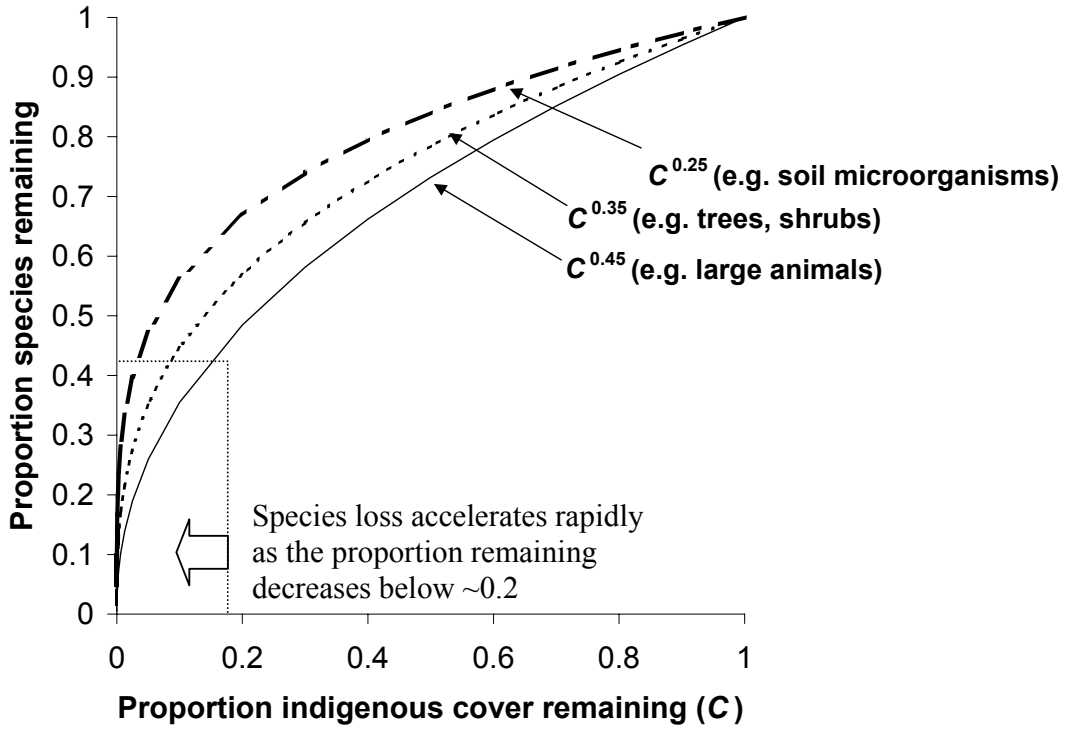


Fig. 1 Generalised species–area relationship applied to the proportion of indigenous cover remaining (*C*), showing curves for biota of different body size (z = 0.25, z = 0.35 and z = 0.45).

Because larger areas are able to support more species, the curve 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. 1), the rate of species loss may be relatively low, and large-bodied biota tend to be most affected. 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. 1). Within any size class, the more vulnerable species are likely to be lost first, and the manner of fragmentation (i.e the retention of large continuous areas *vs* small scattered ones). In general, once the remaining area of an ecosystem, habitat or community has been reduced to less than about 20% of its original area (indicated by the dotted line in the lower left of Fig. 1), the curve indicates that further reductions in area will result in severe depletion of the remaining biodiversity.

The non-linear relationship between area and richness means that the last indigenous remnants in an environment will still contain a proportion of the species associated with that environment, and typically the least vulnerable of these. However, each increment of further loss to those indigenous remnants will result in a greater magnitude of loss of this remaining biodiversity (lower left of the curves in Figure 1). This non-linear relationship may be quantified as the derivative of the curve (i.e. the slope, or instantaneous rate of change at any point). This increases rapidly as proportion of indigenous vegetation cover remaining decreases below about 0.2 on the X-axis at the lower left of the curves in Figure 1 (and indeed increases towards infinity at close to zero).

In Australia and other Commonwealth nations, 15% of original ecosystem extent has been adopted as a pragmatic (and often 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 particularly vulnerable to introduced herbivores, predators and weeds (e.g. Atkinson & Cameron 1993). These ubiquitous pressures reduce the viability and persistence of biological features across the landscape, including protected areas. Therefore, a greater percentage of the original extent is likely to be required to sustain biodiversity. Based on these considerations, we suggest that 20% of original extent may be an appropriate pragmatic minimum level of protection to minimise the loss of biodiversity associated with New Zealand's environments.

Realistic targets

Biodiversity protection targets must be realistic in relation to conservation opportunities. Habitats and ecosystems that are least protected are usually also those that have been most completely modified by human land use, weeds and pests. Therefore, potential to increase representativeness may be low where there is very little indigenous biodiversity remaining.

In the high country, indigenous biodiversity may be scarce in some under-represented environments, so there may be limited potential to increase representativeness by adding indigenous habitats and ecosystems to conservation lands in those environments. Targets for achieving Government objective (g) for the high country must accommodate this limitation.

2.8 Appropriate surrogates for biodiversity pattern

Biodiversity is complex, and knowledge is incomplete, especially for cryptic and microscopic elements. Therefore, conservation planning inevitably depends on surrogates, or partial measures of biodiversity, for decision making (Faith & Walker 1996a; Lombard et al. 2003).

One group of species, or several biotic groups (e.g. plants, butterflies, soil fungi), may not be suitable indicators of biodiversity patterns in other groups (Margules & Pressey 2000). Moreover, the use of national collections or faunas and floras to indicate patterns of biodiversity is notoriously fraught with bias towards more commonly visited, less remote areas (plots of field records from many collections map road networks), and certain, less cryptic biotic groups. This makes it difficult to compare different areas objectively on the basis of similar levels of information on biotic components. New Zealand is no exception: biotic records held in New Zealand datasets (e.g. the National Vegetation Survey Databank (NVS: Wiser et al. 2001) tend to be patchily distributed, with a focus on forests and grasslands in less modified environments.

Theoretical insights and empirical observations suggest that environmental information should provide reasonable estimates of the spatial distributions of species (Faith & Walker 1996a; Margules & Pressey 2000; Pressey et al. 2000). Plants and animal assemblages are strongly influenced by climate and soils; these cause, for example, the distinctive and obvious patterns associated with increasing altitude, rainshadow regions, and limestone outcrops. LENZ (Land Environments of New Zealand, Leathwick et al. 2003a, b; Appendix 10.2) provides an objective, multi-scale classification of New Zealand's environmental pattern, based on the principle determinants of patterns among New Zealand's forest trees. There is growing evidence from empirical studies of the utility and relevance of this classification for other biotic groups (e.g. Lehmann et al. 2003a, b; Overton et al. 2001). While there is no best or ideal surrogate for biodiversity pattern (Margules & Pressey 2000), LENZ provides the most appropriate, quantitative, comprehensive, spatial surrogate for potential biodiversity pattern that is currently available in New Zealand.

We describe the conceptual basis for the defining and mapping the Land Environments in Appendix 10.2. Major high country environments are briefly described in Appendix 10.3.

3. General Methods

3.1 Data sources

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

1. An outline of all high country land. For our purposes, we define 'high country' using the Rural Futures Trust (RFT) boundary clipped to the Main Divide to encompass such land and set the context of the study (cf. Newsome et al. 2003).
2. The boundaries of original and current reviewable pastoral leases were supplied to Landcare Research by the Department of Conservation on 27 February 2004.
3. Map of vegetative cover of the South Island high country, prepared for LINZ in November/December 2003 by Landcare Research, Palmerston North (Newsome et al. 2003).
4. Altitudinal zones were defined using two different classifications. Both are useful surrogates for environmental and biotic variation at the broadest scale.
    (a) Bioclimatic zones: alpine, montane and lowland. These are designed to reflect the major biological zones of the high country, which are driven principally by temperature and daylength, and thus decrease in elevation with increasing latitude. The alpine zone encompasses areas above the climatic upper tree-limit, which is the highest elevation at which summer conditions permit the shoots of tall woody plants to grow and mature sufficiently to withstand winter cold (Tranquillini 1979; Wardle 1985). It is determined by the mean warmest month temperature (MWMT), and by summer daylength, which leads to higher plant productivity at high latitudes (Leathwick et al. in press). Thus, in the South Island, the alpine zone rises from less than 700 m in southern Southland to 1200 m in north-west Nelson. We define the lowland zone in terms of average warmest month temperatures above 14ºC (i.e. those lying below the 14ºC MWMT isotherm; Lee & Walker 2004). Water bodies are also distinguished in this classification.
    (b) Contour zones: a conventional delineation of broad altitudinal zones (<900 m, 900–1200 m, >1200 m; see also Lynn et al. 2003; Newsome et al. 2003). Water bodies were not distinguished in this classification. This classification is a less precise surrogate for environmental and biotic variation with elevation than (a) above, since it does not take account of variation with latitude.
5. Land Environments of New Zealand Level IV (LENZ; Leathwick et al. 2003a, b). The LENZ classification (see Appendices 10.2 & 10.3) explicitly identifies the diversity of New Zealand's terrestrial environments, and therefore defines the likely past (i.e. prehuman) extent of different terrestrial ecosystems and their associated biodiversity. Thus, LENZ provides an appropriate basis for assessing representativeness (Leathwick et al. 2003c), consistent with the goals of the New Zealand biodiversity strategy (e.g. Norton & Roper-Lindsay 1999; detailed updated criteria used for the assessment of significance of inherent values will be given in a second report: Walker et al. in prep). The percentage area of a land environment that is set aside for 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. 2003c). We use it as the principal basis for assessing representativeness.

Land environments are classified at four different national scales: Levels I (20 land environments nationally), II (100 land environments nationally), III (200 land environments nationally) and IV (500 land environments nationally). Each level is nested within each higher level. 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 estimate of the 'full range' of ecosystems, habitats, and biodiversity.

Analyses of representativeness undertaken at Level IV are the most accurate possible. Results at Level IV can be readily summarised to totals and averages for environments at higher levels (e.g. Levels III, II and I) together with estimates of the variance within these higher levels. Levels I, II and III of LENZ average the most detailed information on the 'full range' of ecosystems, habitats, and biodiversity that Level IV provides. If analyses of representativeness are performed at these higher levels, conclusions on how well the 'full range' is represented will be less accurate (and potentially misleading), and estimates of variance will be poor. Therefore, we perform all of our analyses at LENZ Level IV, and summarise results to provide totals and averages for environments at higher levels, unless otherwise stated.

3.2 Data limitations

This work is based on the best available existing large-scale environmental, biological and land tenure datasets. This information has limitations for application at the scale of individual properties. Particular concerns relating to the land tenure and vegetation information are noted below.

Quality of land tenure information

The land tenure databases that are currently held and maintained by DOC are the only resources currently available to enable LINZ to assess the impacts of past, present and proposed changes in tenure upon the effectiveness of protection. In undertaking our analysis, it became apparent that these databases are not appropriately structured to efficiently process this type of analysis, and this can seriously hamper attempts to obtain the information required. Indeed, the databases were not conceived and initiated for this purpose, and database structure and maintenance protocols are far from optimal for it.

Vegetation cover

The vegetation cover map used in this report (Newsome et. al. 2003) was compiled to provide interim information for the high country, using best-available spatial vegetation cover data pending completion of the Land Cover Database 2 (LCDB2). Data sources are dated and unverified by field survey, and there has inevitably been vegetation cover change since they were compiled. Moreover, the classification is necessarily a simplification of the complexity of indigenous and exotic assemblages of plants that are present. Vegetation cover information should be updated as soon as more current data become available, and ideally reviewed frequently thereafter.

4. Section I: Environments, Vegetation and Representation in Protected Areas

4.1 Methods

Summary of methods

First, we summarise the range of land environments, elevation zones, and vegetation cover within the South Island high country. We then quantitatively assess the current representation of environments within protected areas, in New Zealand as a whole, and within the high country.

Environments and vegetation of the high country and pastoral leases

We calculated the land area of bioclimatic zones (lowland, montane, alpine, and water) and contour zones (<900 m, 900–1200 m, >1200 m) contained within the high country, and within reviewable pastoral leases.

For each Level IV land environment that is partly or wholly included in the high country, we calculated the total land area across all of New Zealand, the area contained within the high country, and the area contained within reviewable pastoral leases.

Finally, we merged the 20 categories of land cover in the map of Newsome et al. (2003) into four categories (Appendix 10.4): (1) predominantly indigenous cover (hereafter 'IVeg' or 'indigenous vegetation cover remaining'), (2) predominantly exotic (hereafter exotic cover), (3) water bodies, and (4) bare soil. Because this fourth category was derived by combining naturally bare ground with mine dumps and other anthropogenic categories, we could not define it as either indigenous or exotic. We calculated the area of each land environment within each of these four combined categories of cover (1 to 4), within the high country as a whole, as well as within reviewable pastoral leases, protected Department of Conservation land (see following paragraph), and remaining freehold land.

Representation of New Zealand and high country environments in protected areas

Protected and non-conservation areas in the DOC land inventory

The database of land administered by DOC contains many areas of Crown land that are not managed principally for biodiversity conservation (e.g. buildings, gravel reserves, racecourses, cemeteries, marginal strips). These non-conservation areas are characteristically small in extent and occur in lowland environments. Because so little land is set aside for protection in some in poorly protected environments, non-conservation areas can inflate estimates of representativeness by orders of magnitude.

We identified and removed some of these non-conservation areas from DOC estate data to create a 'cleaned' protected dataset that better reflects land managed principally for biodiversity conservation in New Zealand. However, we were not able to identify and remove all non-conservation areas. Consequently some bias remains in the data that will tend to inflate estimates of representativeness in this report, particularly in lowland environments. Our deletions from the estate data supplied by DOC are provided in a digital annex to this report. The cleaned protected data includes those covenants available as digital data (both Department of Conservation and QEII), and some other protected private land in addition to public conservation lands.

Representation of New Zealand and high country environments in protected areas
Representativeness is a measure of how well the full range of biodiversity is protected. Using the cleaned protected data, we calculated the area (and percentage) protected for each of our three bioclimatic zones, and each of our contour zones within the high country.

Representativeness of land environments was calculated in relation to their total national area. We first calculated the area of each Level IV land environment that is currently protected, and expressed this as a percentage of the total area of that environment in New Zealand. We then calculated the area that is currently protected in the high country, and assessed the contribution this makes to the total percentage of that environment protected nationally.

4.2 Results

Environments and vegetation of the high country and pastoral leases

About a third (32%) of the horizontal area of land mapped as 'high country' lies in the alpine bioclimatic zone above the treeline, where summer temperatures are too cold to support the growth of indigenous trees (Table 2). The largest portion of the high country (44%) lies within the montane bioclimatic zone, and over one-fifth (22%) is classified as lowland (i.e. experiences mean warmest month temperatures above 14ºC).

Table 2 Bioclimatic zones of the high country and pastoral lease land

Bioclimatic zone	High country		Pastoral lease	
	Area (km^2)	% of high country	Area (km^2)	% of high country
Lowland	21140	21.8	5173	7.7
Montane	29732	44.4	11624	17.4
Alpine	14594	31.6	5702	8.5
Water	1458	2.2	25	0.0
Total	66925	100.0	22524	33.7

The 900- and 1200-m contours divide the high country into three contour zones that are broadly analogous to the lowland, montane and alpine zones but do not take account of latitudinal trends in environment (Table 3). The largest contour zone lies below 900 m (59% of the land area), a further 24% lies between the 900- and 1200-m contours, and the smallest portion (18%) lies above 1200 m.

Table 3 Contour zones of the high country and pastoral lease land

Contour zone	High country		Pastoral lease	
	Area (km^2)	% of high country	Area (km^2)	% of high country
<900 m	39324	58.8	10418	15.6
900–1200 m	11732	23.7	5453	8.1
>1200 m	15869	17.5	6653	9.9
Total	66925	100.0	22524	33.6

A total of 214 Level IV environments have land within the high country boundary (these are referred to hereafter as the 214 Level IV high-country environments). These Level IV environments fall within fifteen Level I environments (Table 4). Of these, Environments Q (33% of the high country), P (17%), E (16%) and N (15%) are the most extensive in the high country (Table 4). Fifty-eight Level II environments occur in the high country, of which 34 have more than 10% of their national area in the high country (Table 5); these together account for 93.4% of the total high country area. Environments P1, Q1 and E1 are the most extensive Level II environments in the high country, accounting for about 14%, 13% and 10%, respectively.

Thirteen Level I environments occur on reviewable pastoral leases, of which Environment Q accounts for by far the largest area (Table 4). Thirty-one of the 34 Level II high country environments in Table 5 occur on pastoral leases, of which the largest total areas are in Q1, P1 and Q2.

Table 4 Statistics for the 214 Level IV high-country environments (summed within the 15 Level I environments that occur in the high country). Total areas in the high country and in pastoral lease are compared with the total area of those Level IV enviornments in all of New Zealand. NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level I (*Number of Level IV environments summed*)	**New Zealand**		**High country**		**Pastoral lease**	
	Mean elevation	**Total area**	**Area**	**Percentage of high country**	**Area**	**Percentage of high country**
	(m)	**(km^2)**	**(km^2)**	**(%)**	**(km^2)**	**(%)**
B (*n = 18*)	226	3678	1265	1.9	112	0.2
E (*n = 19*)	654	11975	10721	16.0	3326	5.2
F (*n = 4*)	356	571	49	0.1	1	0.0
I (*n = 3*)	45	21	3	0.0	0	-
J (*n = 11*)	108	1077	77	0.6	81	0.1
K (*n = 20*)	691	1269	1162	1.7	550	0.9
L *(n = 15)*	131	6528	933	1.4	74	0.1
M *(n = 12)*	163	1935	222	0.3	68	0.1
N *(n = 38)*	279	20303	9855	14.7	1902	3.0
O *(n = 15)*	301	10976	462	0.7	44	0.1
P *(n = 17)*	974	22097	11598	17.3	4487	7.0
Q *(n = 28)*	669	31593	22281	33.3	10524	16.3
R *(n = 11)*	1064	11289	4724	7.1	1193	1.9
S *(n = 2)*	915	70	49	0.1	0	-
T *(n = 1)*	1859	1574	766	1.1	56	0.1
Subtotal			64467	96.3	22419	33.5
Water			1458	2.2	41	0.1
Unclassified			1000	1.5	64	0.1
Total			66925	100.0	22524	33.7

Table 5 Statistics for the 214 Level IV high-country environments averaged for Level II environments (for brevity, we tabulate only those 34 Level II environments that have >10% of their area in the high country, which contain 146 Level IV environments). Total areas in the high country and in pastoral lease are compared with the total area of those Level IV enviornments in all of New Zealand. 'Other' = 24 Level II environments that have <10% of their area in the high country. NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level II (*Number of Level IV environments summed*)	**New Zealand**		**High country**		**Pastoral lease**	
	Mean elevation	**Total area**	**Area**	**Percentage of high country**	**Area**	**Percentage of high country**
	(m)	**(km^2)**	**(km^2)**	**(%)**	**(km^2)**	**(%)**
B3 *(n=5)*	300	1876	787	1.2	29	0.0
B8 *(n=2)*	350	760	398	0.6	77	0.1
E1 *(n=10)*	639	7955	6988	10.4	1554	2.3
E3 *(n=2)*	466	688	582	0.9	45	0.1
E4 *(n=4)*	747	3167	3149	4.7	1727	2.6
F2 *(n=1)*	216	43	43	0.1	0	-
I4 *(n=2)*	62	5	1	0.0	0	-
J2 *(n=5)*	135	620	205	0.3	80	0.1
J3 *(n=3)*	82	151	129	0.2	1	0.0
K1 *(n=5)*	749	638	537	0.8	250	0.4
K2 *(n=3)*	790	110	110	0.2	42	0.1
K3 *(n=5)*	535	313	307	0.5	166	0.2
K4 *(n=5)*	605	161	160	0.2	84	0.1
K5 *(n=2)*	626	48	48	0.1	9	0.0
L1 *(n=8)*	154	1728	571	0.9	33	0.0
L3 *(n=1)*	97	124	82	0.1	15	0.0
M2 *(n=5)*	228	747	197	0.3	60	0.1
M3 *(n=2)*	695	4	4	0.0	2	0.0
N2 *(n=6)*	215	4867	1213	1.8	51	0.1
N3 *(n=9)*	294	5933	3035	4.5	227	0.3
N4 *(n=5)*	493	2437	2434	3.6	981	1.5
N5 *(n=4)*	422	1627	1626	2.4	126	0.2
N6 *(n=3)*	489	928	928	1.4	474	0.7
N7 *(n=2)*	413	120	120	0.2	17	0.0
N8 *(n=3)*	247	362	362	0.5	22	0.0
P1 *(n=5)*	1281	10889	9582	14.3	3770	5.6
P2 *(n=2)*	1468	1714	1246	1.9	316	0.5
Q1 *(n=6)*	1154	9154	8965	13.4	5308	7.9
Q2 *(n=5)*	672	6492	6259	9.4	3254	4.9
Q3 *(n=7)*	860	4194	3828	5.7	1700	2.5
Q4 *(n=10)*	264	11754	3229	4.8	262	0.4
R1 *(n=7)*	1344	9808	4566	6.8	1193	1.8
S2 *(n=1)*	1120	49	46	0.1	0	-
T1 *(n=1)*	1859	1574	766	1.1	56	0.1
Subtotal			62503	93.4	21929	32.8
Other (*n=68*)			1964	2.8	490	0.7
Water			1458	2.2	41	0.1
Unclassified			1000	1.5	64	0.1
Total			66925	100.0	22524	33.7

Tables 6 and 7 below present data for those 214 Level IV LENZ Environments that occur in the high country, which we sum and average within their higher order Level I and II environments. The high country contains high proportions of some of these environments, which can therefore be said to be characteristic of the high country. For example, about 92% of 20 of New Zealand's Level IV K environments and about 90% of 19 of New Zealand's Level IV E environments (Table 6) occur in the high country. Reviewable pastoral leases contain 43% of the national extent of those 20 Level IV K environments, and 28% of those in E. Table 7 shows that these characteristic land environments are clustered within several Level II environments (particularly those in the Level I environments E, K, N, and Q).

Table 6 Areas of high country and pastoral lease land in the 214 Level IV high country environments, summed for each of the 15 Level I environments represented in the high country, and as a percentage of the New Zealand total for those 214 Level IV environments. NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level I ***(Number of Level IV environments summed)***	**New Zealand**		**High country**		**Pastoral lease**	
	Mean elevation	**Total NZ land area**	**Area in high country**	**Percentage of NZ land area**	**Area in pastoral lease**	**Percentage of NZ land area**
	(m)	**(km^2)**	**(km^2)**	**(%)**	**(km^2)**	**(%)**
B (*n = 18*)	226	3678	1265	34.4	112	3.0
E (*n = 19*)	654	11975	10721	89.6	3326	27.8
F (*n = 4*)	356	571	49	8.6	1	0.2
I (*n = 3*)	45	21	3	15.6	0	0.0
J (*n = 11*)	108	1077	377	35.0	81	7.6
K (*n = 20*)	691	1269	1162	91.6	50	43.4
L *(n = 15)*	131	6528	933	14.2	74	1.2
M *(n = 12)*	163	1935	222	11.4	68	3.4
N *(n = 38)*	279	20303	9855	48.6	1902	9.4
O *(n = 15)*	301	10976	462	4.2	44	0.4
P *(n = 17)*	974	22097	11598	52.4	4487	20.4
Q *(n = 28)*	669	31593	22281	70.6	10524	33.4
R *(n = 11)*	1064	11289	4724	41.8	1193	10.6
S *(n = 2)*	915	70	49	69.6	0	0.6
T *(n = 1)*	1859	1574	766	48.6	56	3.6
Subtotal			64467		22419	
Water			1458		41	
Null			1000		64	
Total			66925		22524	

Table 7 Areas of high country and pastoral lease land in the 214 Level IV high country environments (for brevity, shown only for each of 34 Level II environments that have >10% of their area in the high country) and as a percentage of the New Zealand total for those 214 Level IV environments. NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

	New Zealand		High country		Pastoral lease	
LENZ Level II (*Number of Level IV environments summed*)	**Mean elevation** (m)	**Total NZ land Area** (km^2)	**Area in high country** (km^2)	**Percentage of NZ land area** (%)	**Area in pastoral lease** (km^2)	**Percentage of NZ land area** (%)
B3 *(n=5)*	300	1876	787	42.0	29	1.6
B8 *(n=2)*	350	760	398	52.4	77	10.0
E1 *(n=10)*	639	7955	6988	87.8	1554	19.6
E3 *(n=2)*	466	688	582	84.6	45	6.4
E4 *(n=4)*	747	3167	3149	99.4	1727	54.6
F2 *(n=1)*	216	43	43	99.6	0	-
I4 *(n=2)*	62	5	1	32.2	0	-
J2 *(n=5)*	135	620	205	33.2	80	12.8
J3 *(n=3)*	82	151	129	85.4	1	0.8
K1 *(n=5)*	749	638	537	84.2	250	39.2
K2 *(n=3)*	790	110	110	100.0	42	37.8
K3 *(n=5)*	535	313	307	98.0	166	53.0
K4 *(n=5)*	605	161	160	100.0	84	52.0
K5 *(n=2)*	626	48	48	100.0	9	19.0
L1 *(n=8)*	154	1728	571	33.0	33	2.0
L3 *(n=1)*	97	124	82	66.2	15	12.2
M2 *(n=5)*	228	747	197	26.4	60	8.0
M3 *(n=2)*	695	4	4	96.6	2	39.8
N2 *(n=6)*	215	4867	1213	25.0	51	1.0
N3 *(n=9)*	294	5933	3035	51.2	227	3.8
N4 *(n=5)*	493	2437	2434	99.8	981	40.2
N5 *(n=4)*	422	1627	1626	100.0	126	7.8
N6 *(n=3)*	489	928	928	100.0	474	51.2
N7 *(n=2)*	413	120	120	100.0	17	13.8
N8 *(n=3)*	247	362	362	100.0	22	6.0
P1 *(n=5)*	1281	10889	9582	88.0	3770	34.6
P2 *(n=2)*	1468	1714	1246	72.8	316	18.4
Q1 *(n=6)*	1154	9154	8965	98.0	5308	58.0
Q2 *(n=5)*	672	6492	6259	96.4	3254	50.2
Q3 *(n=7)*	860	4194	3828	91.2	1700	40.6
Q4 *(n=10)*	264	11754	3229	27.4	262	2.2
R1 *(n=7)*	1344	9808	4566	46.6	1193	12.2
S2 *(n=1)*	1120	49	46	96.0	0	-
T1 *(n=1)*	1859	1574	766	48.6	56	3.6
Subtotal			62503		21929	
Other (*n=68*)			1964		490	
Water			1458		41	
Unclassified			1000		64	
Total			66925		22524	

A subset of Level I environments (O, P, R, S, T) retain >97% indigenous vegetation cover within the high country (Table 8). Areas of Level I Environment Q in the high country retain about 89% indigenous cover on average, and areas in Environment E retain about 85%. Environments B, F, K and M all have >50% indigenous cover in the high country at Level I, and loss of indigenous cover in the high country has been greatest in Environments N (39%), J (36%), L (24%) and I (10%). There is considerable variation in percentage indigenous vegetation cover retained among those portions of Level II environments that occur in the high country (Table 9), especially within the more modified Level I environments (e.g. in the seven major Level II N environments of the high country, %IVeg ranges from 5% to 74%).

Table 8 Vegetation of Level I land environments of the high country. Data are total areas in four cover categories adapted from Newsome et al. (2003) and the average percentage remaining indigenous vegetation cover at Level I. EVeg = exotic vegetation, IVeg = indigenous vegetation, BS = bare soil, WB = water bodies, Unclass. = unclassified in LENZ. Percentage indigenous vegetation cover (% IVeg) is calculated from the areas of EVeg and IVeg at Level I (bare soil and water bodies cannot be attributed to indigenous or exotic categories). NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level I (*Number of Level IV environments summed*)	**All high country**					**Pastoral lease**				
	EVeg	**Iveg**	**BS**	**WB**	**IVeg**	**Eveg**	**IVeg**	**BS**	**WB**	**Iveg**
	(km^2)				**(%)**	**(km^2)**				**(%)**
B (*n = 18*)	612	634	18	1	51	26	82	4	>1	76
E (*n = 19*)	1555	8850	306	10	85	191	3023	109	2	94
F (*n = 4*)	18	29	1	>1	61	>1	1	>1	>1	70
I (*n = 3*)	3	>1	>1	>1	10	>1	>1	>1	>1	-
J (*n = 11*)	227	128	20	1	36	12	65	5	>1	85
K (*n = 20*)	328	738	93	4	69	114	399	36	1	78
L *(n = 15)*	697	218	15	2	24	50	23	2	>1	31
M *(n = 12)*	91	111	18	2	55	30	34	3	1	53
N *(n = 38)*	6032	3772	41	11	39	496	1398	7	1	74
O *(n = 15)*	9	445	8	>1	98	1	43	0	>1	97
P *(n = 17)*	96	7962	3539	1	99	57	3015	1414	>1	98
Q *(n = 28)*	2371	19215	673	6	89	397	9793	333	1	96
R *(n = 11)*	3	3401	1282	1	100	>1	884	308	>1	100
S *(n = 2)*	1	44	4	>1	98	>1	>1	>1	>1	38
T *(n = 1)*	>1	529	230	7	100	>1	29	27	>1	100
Subtotal	12045	46076	6247	45	79	1376	18787	2249	6	93
Water	29	39	53	1473		2	8	4	27	
Unclass.	162	200	533	23		10	29	24	1	
Total	12235	46315	6834	1542		2754	37583	4503	40	

Table 9 Vegetation of Level II land environments of the high country (for brevity, data are shown for only those 34 Level II environments that have >10% of their area in the high country). Data are total areas in four cover categories adapted from Newsome et al. (2003) and the average percentage remaining indigenous vegetation cover at Level II. Other = the remaining 24 Level II high country environments. Remaining abbreviations as in Table 8.

LENZ Level II (*Number of Level IV environments summed*)	**All high country**					**Pastoral lease**				
	EVeg	**IVeg**	**BS**	**WB**	**% IVeg**	**EVeg**	**IVeg**	**BS**	**WB**	**% IVeg**
	(km^2)				**(%)**	**(km^2)**				**(%)**
B3 *(n=5)*	412	367	8	1	47	3	25	1	0	88
B8 *(n=2)*	130	259	9	0	67	18	56	2	0	76
E1 *(n=10)*	892	5856	237	2	87	53	1413	87	0	96
E3 *(n=2)*	353	228	1	0	39	13	32	0	0	71
E4 *(n=4)*	310	2765	67	7	90	125	1577	22	2	93
F2 *(n=1)*	15	27	1	0	64	0	0	0	0	-
I4 *(n=2)*	1	0	0	0	23	0	0	0	0	-
J2 *(n=5)*	80	108	17	1	58	11	64	4	0	86
J3 *(n=3)*	107	18	3	0	15	1	0	0	0	17
K1 *(n=5)*	101	362	73	1	78	31	191	28	0	86
K2 *(n=3)*	14	91	5	0	87	6	34	2	0	86
K3 *(n=5)*	141	153	13	1	52	51	109	5	0	68
K4 *(n=5)*	56	101	3	1	64	26	56	1	1	69
K5 *(n=2)*	16	31	0	0	66	0	9	0	0	100
L1 *(n=8)*	450	105	15	1	19	27	4	2	0	13
L3 *(n=1)*	16	64	0	2	80	1	14	0	0	90
M2 *(n=5)*	78	101	17	1	57	25	32	3	0	57
M3 *(n=2)*	1	2	0	0	66	0	1	0	0	81
N2 *(n=6)*	1088	117	8	1	10	21	29	1	0	58
N3 *(n=9)*	2020	1005	9	1	33	93	134	0	0	59
N4 *(n=5)*	622	1806	4	2	74	189	789	2	0	81
N5 *(n=4)*	1495	128	2	1	8	93	32	0	0	26
N6 *(n=3)*	257	654	13	4	72	71	399	3	1	85
N7 *(n=2)*	81	37	0	1	31	7	9	0	0	55
N8 *(n=3)*	340	17	4	1	5	18	4	0	0	17
P1 *(n=5)*	35	6489	3058	0	100	14	2475	1280	0	99
P2 *(n=2)*	0	783	463	0	100	0	186	131	0	100
Q1 *(n=6)*	73	8248	627	1	99	42	4955	311	0	99
Q2 *(n=5)*	650	5593	15	1	90	231	3014	9	0	93
Q3 *(n=7)*	159	3637	29	3	96	59	1628	13	0	97
Q4 *(n=10)*	1489	1737	1	2	54	65	196	0	0	75
R1 *(n=7)*	3	3289	1243	1	100	0	884	308	0	100
S2 *(n=1)*	1	42	4	0	99	0	0	0	0	-
T1 *(n=1)*	0	529	230	7	100	0	29	27	0	100
Subtotal	11485	44750	6178	43	80	1297	18381	2245	6	93
Other (*n=68*)	560	1326	70	2	70	79	406	4	0	84
Water	29	39	53	1473		2	8	4	27	
Unclass.	162	200	533	23		10	29	24	1	
Total	12235	46315	6834	1542		1387	18824	2278	34	

Portions of Level IV environments on reviewable pastoral leases generally retain higher percentages of indigenous cover than those on freehold land in the high country (e.g. Table 10). This is particularly marked within the extensive environment N that has undergone considerable loss of indigenous vegetation cover. The average percentage indigenous vegetation cover across the 38 Level IV environments of Environment N that occur within high country is 42% on pastoral leases vs 24% on freehold land.

Table 10 Indigenous vegetation in Level I environments of the high country by type of tenure (DOC = Department of Conservation). The data are the total areas of indigenous vegetation, and percentage of indigenous vegetation cover across the *n* Level IV environments. Note that average percentages across the *n* Level IV environments in this table differ from the average percentage calculated on the basis of total area at Level I in Table 8. NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level I (*Number of Level IV environments summed*))	**Area (km^2)**				**Percentage indigenous vegetation (%)** *Average for n Level IV environments*			
	DOC	**Pastoral lease**	**Freehold**	**All high country**	**DOC**	**Pastoral lease**	**Freehold**	**All high country**
B (*n = 18*)	21	82	531	634	42	37	31	32
E (*n = 19*)	1479	3023	4348	8850	91	82	65	74
F (*n = 4*)	1	1	27	29	48	42	41	47
I (*n = 3*)	>1	>1	>1	>1	0	0	17	17
J (*n = 11*)	2	65	62	128	38	42	24	27
K (*n = 20*)	82	399	257	738	69	65	61	66
L *(n = 15)*	23	23	173	218	35	29	22	23
M *(n = 12)*	52	34	24	111	67	40	65	68
N *(n = 38)*	62	1398	2312	3772	33	42	24	28
O *(n = 15)*	389	43	14	445	94	66	68	89
P *(n = 17)*	3653	3015	1294	7962	99	84	65	92
Q *(n = 28)*	3510	9793	5912	19215	91	75	68	74
R *(n = 11)*	2470	884	48	3401	91	64	64	91
S *(n = 2)*	43	>1	1	44	96	19	71	90
T *(n = 1)*	498	29	2	529	100	100	100	100

Representation of New Zealand and high country environments in protected areas

Protected and non-conservation areas in the DOC land inventory

The 'cleaned' DOC land inventory covers approximately 79 878 km^2, of which 78 247 km^2 is classified by LENZ. This accounts for approximately 30.1 % of the total land area of New Zealand that is classified in LENZ.

Representation of New Zealand and high country environments in protected areas
Approximately 23.6% of the area of the New Zealand high country (15 615 km^2) is classified as public conservation land today. This is less than the national average of 30.1% for New Zealand.

Protection in the high country is strongly biased towards higher elevations (Map 1). The highest bioclimatic and contour zones (Table 11) and land environments (Tables 12 and 13; Fig. 4) contain the majority of protected lands. The ecosystems and biodiversity of the lowland bioclimatic zone (5%), and the zone below the 900-m contour (11%) are relatively poorly represented in protected areas (Table 11). All Level I and II high country land environments with mean elevation below about 700 m are poorly protected (Fig. 4; Map 1).

Table 11 Representation of bioclimatic and contour zones in protected areas within the high country

Bioclimatic zone	Total area	Area protected	Protected	Contour zone	Total area	Area protected	Protected
	(km^2)	(km^2)	(%)		(km^2)	(km^2)	(%)
Lowland	21140	1095	5.2	<900m	39324	4360	11.1
Montane	29732	7227	24.3	900–1200m	11732	3863	32.9
Alpine	14594	7403	50.7	>1200m	15869	7556	47.6
Water	1458	55	3.7				
Total	66925	15780	23.6		66925	15780	23.6

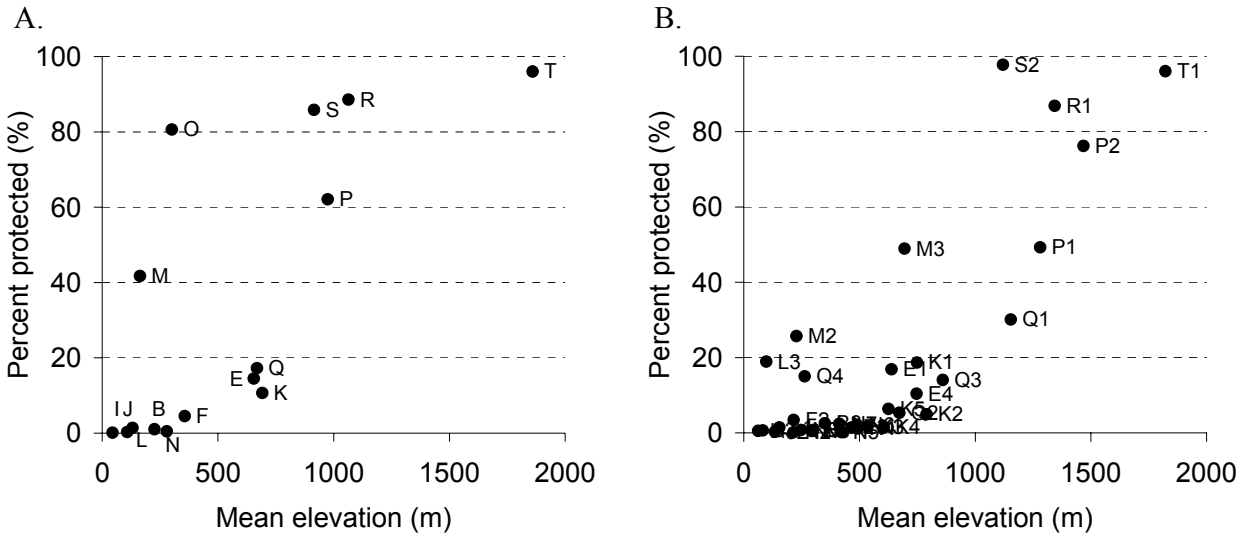


Fig. 4 Percentage of high country environments protected in New Zealand and mean elevation of the environment. A. Average for Level IV environments across each of 15 Level I environments that occur in the high country (upper left outliers M and O have small areas within the western high country (Table 12), but are predominantly centred on Westland, Western Southland and Stewart Island), and B. Average for 214 Level IV environments across each of 34 'Core' Level II land environments that have >10% of their area within the high country.

Table 12 Representation of the 214 Level IV high country environments in protected areas within New Zealand and the high country (summed for each of the 15 Level I environments that occurs in the high country). NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level I (*Number of Level IV environments summed*)	**New Zealand**				**High country**		
	Mean elevation	**Total area**	**Area protected**	**Percentage protected**	**Total area**	**Area protected**	**Percentage protected**
	(m)	**(km2)**	**(km2)**	**(%)**	**(km2)**	**(km2)**	**(%)**
B (*n = 18*)	226	3678	38	1.0	1265	24	0.6
E (*n = 19*)	654	11975	1732	14.5	10721	1604	13.4
F (*n = 4*)	356	571	26	4.5	49	1	0.3
I (*n = 3*)	45	21	0	0.1	3	0	0.0
J (*n = 11*)	108	1077	3	0.3	377	2	0.2
K (*n = 20*)	691	1269	135	10.7	1162	114	9.0
L *(n = 15)*	131	6528	92	1.4	933	27	0.4
M *(n = 12)*	163	1935	807	41.7	222	68	3.5
N *(n = 38)*	279	20303	96	0.5	9855	84	0.4
O *(n = 15)*	301	10976	8850	80.6	462	396	3.6
P *(n = 17)*	974	22097	13723	62.1	11598	5228	23.7
Q *(n = 28)*	669	31593	5454	17.3	22281	3862	12.2
R *(n = 11)*	1064	11289	9998	88.6	4724	3453	30.6
S *(n = 2)*	915	70	60	85.9	49	47	67.4
T *(n = 1)*	1859	1574	1512	96.1	766	704	44.7
Subtotal						15615	
Unclassified						165	
Total						15780	

Table 13 Representation of Level IV high country environments in protected areas within New Zealand and the high country (for brevity, we tabulate only the 34 Level II environments that have >10% of their area in the high country. These contain 146 of the 214 Level IV environments that occur in the high country). NB percentages reflect analyses of raw land area data (in ha) rather than rounded area data (in km^2) presented in the table.

LENZ Level II (*Number of Level IV environments summed*)	**New Zealand**				**High country**		
	Mean elevation	**Total area**	**Area protected**	**Percentage protected**	**Total area**	**Area protected**	**Percentage protected**
	(m)	**(km2)**	**(km2)**	**(%)**	**(km2)**	**(km2)**	**(%)**
B3 *(n=5)*	300	1876	14	0.8	787	10	0.5
B8 *(n=2)*	350	760	19	2.6	398	14	1.8
E1 *(n=10)*	639	7955	1343	16.9	6988	1276	16.0
E3 *(n=2)*	466	688	10	1.4	582	8	1.2
E4 *(n=4)*	747	3167	329	10.4	3149	319	10.1
F2 *(n=1)*	216	43	1	3.4	43	1	3.4
I4 *(n=2)*	62	5	0	0.5	1	0	0.0
J2 *(n=5)*	135	620	2	0.3	205	1	0.2
J3 *(n=3)*	82	151	1	0.7	129	1	0.6
K1 *(n=5)*	749	638	119	18.7	537	98	15.4
K2 *(n=3)*	790	110	5	4.9	110	5	4.9
K3 *(n=5)*	535	313	5	1.6	307	5	1.6
K4 *(n=5)*	605	161	2	1.5	160	2	1.5
K5 *(n=2)*	626	48	3	6.4	48	3	6.4
L1 *(n=8)*	154	1728	25	1.5	571	13	0.8
L3 *(n=1)*	97	124	23	18.9	82	13	10.8
M2 *(n=5)*	228	747	192	25.7	197	63	8.4
M3 *(n=2)*	695	4	2	48.9	4	2	45.5
N2 *(n=6)*	215	4867	6	0.1	1213	4	0.1
N3 *(n=9)*	294	5933	28	0.5	3035	22	0.4
N4 *(n=5)*	493	2437	29	1.2	2434	29	1.2
N5 *(n=4)*	422	1627	3	0.2	1626	3	0.2
N6 *(n=3)*	489	928	20	2.2	928	20	2.2
N7 *(n=2)*	413	120	3	2.4	120	3	2.4
N8 *(n=3)*	247	362	3	0.8	362	3	0.8
P1 *(n=5)*	1281	10889	5364	49.3	9582	4067	37.3
P2 *(n=2)*	1468	1714	1306	76.2	1246	839	48.9
Q1 *(n=6)*	1154	9154	2755	30.1	8965	2601	28.4
Q2 *(n=5)*	672	6492	347	5.3	6259	322	5.0
Q3 *(n=7)*	860	4194	589	14.1	3828	576	13.7
Q4 *(n=10)*	264	11754	1763	15.0	3229	363	3.1
R1 *(n=7)*	1344	9808	8520	86.9	4566	3296	33.6
S2 *(n=1)*	1120	49	47	97.8	46	45	93.8
T1 *(n=1)*	1859	1574	1512	96.1	766	704	44.7

5. Section II: Measures of biodiversity protection effectiveness as significance criteria, and their operational application

5.1 Methods

Summary of methods

In this section, we set explicit targets for biodiversity protection in the high country through the tenure review of pastoral leases, based on the adequacy of levels of protection for land environments across all of New Zealand. These targets reflect realistic potential (based on estimates of remaining indigenous vegetation cover) to add to the protection of under-represented environments through the tenure review of pastoral leases. We then use these targets to evaluate the effectiveness of biodiversity protection for ecosystems and habitats across the whole high country, in terms of our measures. Finally, we demonstrate the application of these methods to evaluate changes in representativeness and vulnerability that arise from land tenure changes.

Effectiveness of protection

As discussed in Sections 2.5 and 2.6, two measures (representativeness and vulnerability, respectively) are needed to assess the effectiveness of the protection of biodiversity, and therefore also significance for biodiversity protection. Calculation of these measures requires explicit and realistic targets to be set in relation to relevant biodiversity objectives. In this section, we set targets for biodiversity protection in the high country designed to meet Government objective (g) through the process of tenure review of pastoral leases. We then use these targets to calculate context-specific measures of representativeness and vulnerability for the high country.

Biodiversity protection targets

Targets are based on the considerations described in the Background to this report (Section 2.7). Twenty percent of the total land area of each LENZ Level IV environment is suggested as a minimum baseline for protection, to avoid the rapid loss of biodiversity anticipated when indigenous vegetation is reduced below this percentage within an environment. However, this is no longer possible (at least without restoration) in environments where indigenous vegetation cover has been reduced below 20%.

We therefore set realistic targets for the protection of each high country land environment through tenure review, based on opportunities for protection on reviewable pastoral leases, as follows (all targets were set at Level IV of LENZ):

In those environments where representation presently **exceeds 20%** nationally, the biodiversity protection target for the high country equals the current protected area within the high country. In these cases, the *unmet* biodiversity protection target in the high country is zero.

Where representation is **equal to or less than 20%** nationally, we set biodiversity protection targets for the high country according to (1) the current extent of protected areas (nationally) and (2) remaining indigenous cover on reviewable pastoral leases.

Where the total area protected in New Zealand plus the area remaining in indigenous cover on reviewable pastoral leases **exceeds 20%** of the national land area, we set the biodiversity protection target at the sum of the current protected area, plus the area of indigenous cover required to ensure that 20% of the land environment is protected nationally. Thus the *unmet* biodiversity protection target is the portion of the area of indigenous cover on reviewable pastoral leases that is required to ensure that 20% of the land environment is protected nationally.

Where the total area protected in New Zealand plus areas remaining in indigenous cover on reviewable pastoral leases sum to **less than 20%** of the national land area, we set the pragmatic target for protection as the sum of the current protected area and the area of indigenous cover on reviewable pastoral leases. In this case, the *unmet* target in the high country is the area remaining in indigenous vegetation cover on reviewable pastoral leases.

Representativeness measure
An overall measure of representativeness in the high country was calculated as the percentage of all categories (Level IV land environments) in which targets are met. We also calculated the number and percentage of targets met in Level IV environments within higher-level land environments (Levels I and II of LENZ).

Vulnerability measure and components
Our measure of **vulnerability** (**VUL**) is the product of two components: firstly, the susceptibility of the environment to biodiversity loss (**SBL or susceptibility to biodiversity loss**), and secondly, the proportion of the biodiversity protection target for that environment that is not currently protected (**PTU** or **protection target unmet**). The overall vulnerability measure (VUL) is calculated as the product of susceptibility to loss and the proportion of the representation target unmet, i.e.

$$\mathrm{VUL} = \mathrm{SBL} \times \mathrm{PTU}.$$

The derivation of the vulnerability measure is illustrated in Fig. 2. The most vulnerable environments are those in the top right corner of the scattergram. These are environments that have been extensively cleared or altered (i.e. are most susceptible to biodiversity loss) **and** have little of their remaining area of indigenous vegetation under formal protection (have high proportions of their protection targets unmet).

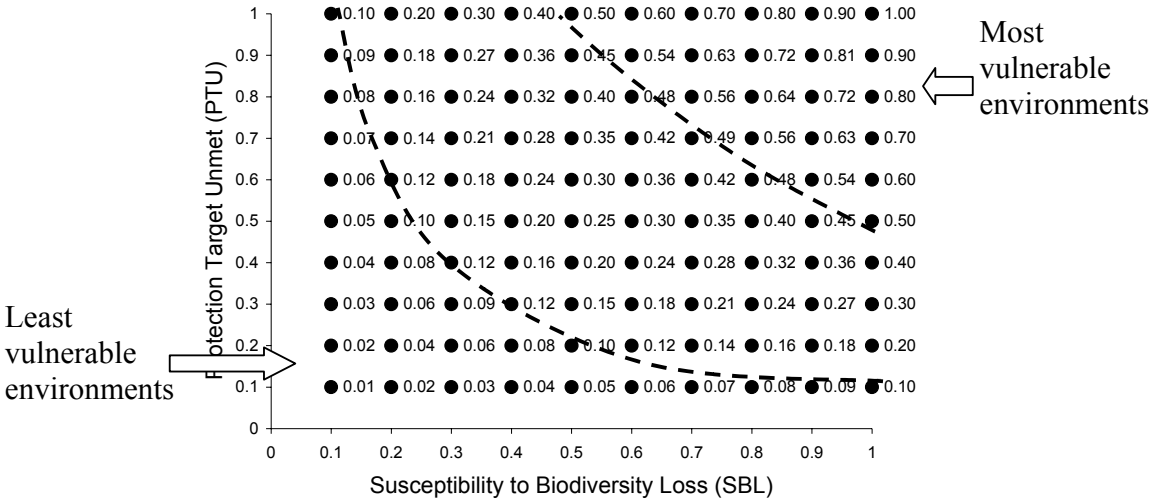


Fig. 2 Vulnerability values (labelled for each of 100 hypothetical environments represented by black dots) in relation to susceptibility to biodiversity loss (SBL, X–axis) and proportion of protection targets unmet (PTU, Y–axis).

The least vulnerable environments are those in the lower left corner of the scattergram (Fig. 2). These have undergone little reduction in indigenous vegetation cover, and have high levels of protection. Moderately vulnerable environments have either (a) relatively intact indigenous vegetation cover but are poorly protected (top left), or (b) moderately intact indigenous vegetation cover and moderate protection (middle), or (c) little intact indigenous vegetation cover but much of their remaining extent is protected (bottom right).

Pressey & Taffs (2001a, b) suggested remaining indigenous land cover, or land use capability, as alternative indicators of high suitability for development, and hence the imminence of potential loss within an area. Accordingly, we use the proportion of remaining indigenous land cover (Newsome et al. 2003) to estimate the susceptibility of each Level IV land environment to biodiversity loss.
We base our estimate of susceptibility to biodiversity loss (SBL) on the complement of the species area curve (Fig. 3a), i.e.

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

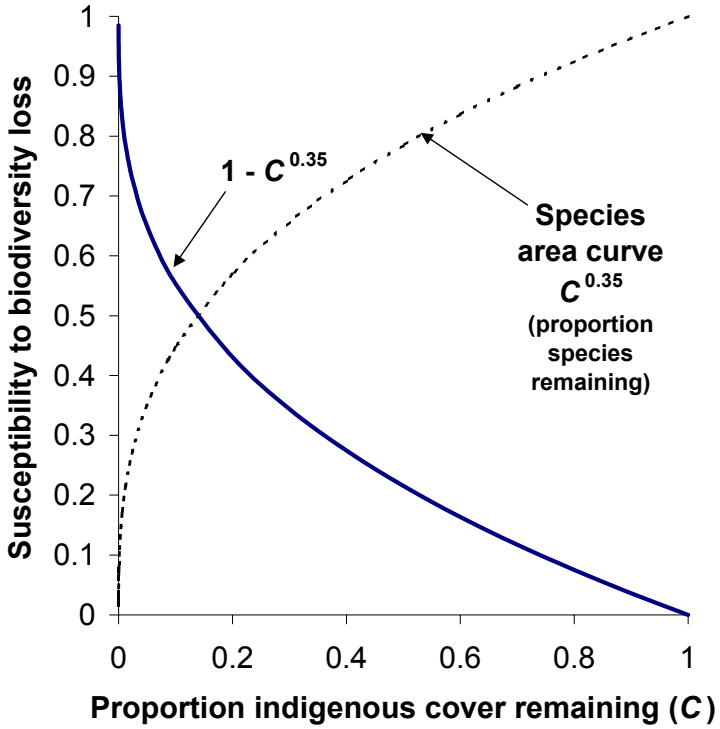


Fig. 3a Method for calculating susceptibility to loss (SBL) for each high country land environment. SBL (solid line) is estimated as the complement of the species area curve (represented dotted line) where z = 0.35. Proportion of indigenous cover remaining (*C*) is derived from categories of Newsome et al. (2003).

Strictly, susceptibility to biodiversity loss may be best represented by the instantaneous rate of change at any point of the species area curve (i.e. the derivative). Where z = 0.35:

$$SBL_{DERIV} = 0.35 \times (\text{proportion remaining indigenous vegetation cover}^{(0.35-1)})$$

SBL_{DERIV} increases to infinity as proportion indigenous vegetation cover remaining decreases to zero (Fig. 3b, below). Our index (SBL) is more computationally simple, but returns lower estimates of susceptibility to biodiversity loss than SBL_{DERIV} where proportions of remaining indigenous vegetation cover are low. The difference becomes marked below about 0.2 (20% of indigenous vegetation cover remaining) and extreme below about 0.1 (10% of indigenous vegetation cover remaining). Thus, our index is a conservative underestimate of actual susceptibility to biodiversity loss where low proportions of indigenous vegetation cover remain.

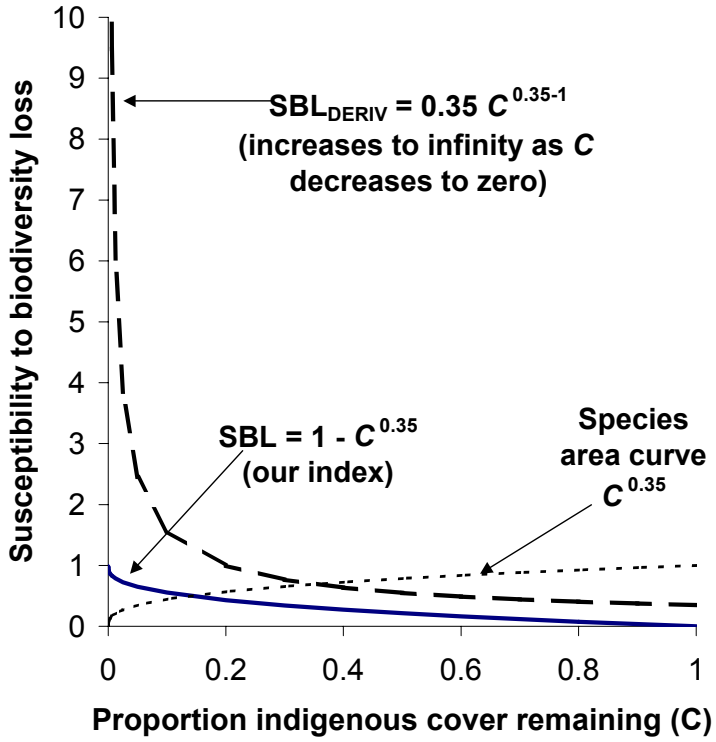


Fig. 3b Susceptibility to biodiversity loss represented by the instantaneous rate of change at any point of the species area curve where z = 0.35. This is the derivative of the species area curve ($0.35C^{0.35-1}$, indicated by the heavy dashed line), which varies from 0.35 to infinity. Our index is the complement of the species area curve $1 - C^{0.35}$, indicated by the solid line, and ranges from zero to 1.0. Note that Y-axis scales differ between Fig. 3a and Fig. 3b.

The complement of the species-area curve ($1 - C^{0.35}$) is used as generalisation to express the susceptibility of an environment to biodiversity loss as a function habitat loss. The generalisation averages across many complexities that are beyond the scope of this contract to research and address. For example, use of the curve assumes that the three major components of biodiversity (genetic, species and ecosystem) behave in the same way as species, and the chosen average z value of 0.35 simplifies across biodiversity components utilising space in different ways. Land environments are used as surrogates representing the range of biodiversity, but these are actually non-discrete, and contain biota with different spatial turnover. Nevertheless, we consider that although probably conservative, our index is a relatively robust and appropriate expression the non-linearity of biodiversity response to habitat loss.

The proportion of the biodiversity protection target unmet (PTU) equals zero in any environment that is protected at, or in excess of, the biodiversity protection target (see Methods Section 3.5 Targets). In underrepresented environments, the proportion of the protection target unmet is calculated as:

$$\text{PTU} = \frac{\text{target area} - \text{protected area}}{\text{target area}}$$

Where there is no indigenous vegetation cover remaining to protect within a land environment on pastoral leases, target area = protected area and the PTU is zero. In this case, it is given a null value, and the vulnerability measure (VUL) is also assigned a null value, on the basis that threats are meaningless after extinction has occurred.

We calculated averages of SBL, PTU and VUL across all high country Level IV environments. We also calculated averages for Level IV environments within each higher-level environment at Levels I and II of LENZ. Null values for PTU and VUL were excluded when calculating averages across Level IV environments.

Operational application

To demonstrate the operational application of these measures of the performance of tenure review towards Government's high country objective (g), we assess changes in representativeness and vulnerability of high country environments that occurred as a consequence of the first 37 tenure reviews of pastoral leases (i.e. to the end of January 2004).

In applying these measures to assess biodiversity protection performance, it is necessary to define a single starting point, and to set fixed targets to work towards.

Because our application is retrospective, it was necessary to adjust protection and pastoral lease data to reflect the earlier state of land tenure (hereafter termed 'original' for convenience). We used the indigenous vegetation cover map for the high country (Newsome et al. 2003) to represent the original state of vegetation. We then set targets and estimated changes in vegetation cover from the original state. We describe the steps and explicit assumptions in our adjustments and calculations below.

Adjustments

1. Protection

To estimate the 'original' extent of protected areas we first removed from the cleaned protected database areas of DOC land protected through tenure review.
For each Level IV land environment, we then calculated totals of (a) original national land area protected, and (b) original high country land area protected. Current land areas protected were retained as in our present cleaned protected data.

2. Indigenous vegetation

We first calculated original area of indigenous vegetation cover remaining

(a) in the high country. For this, we added areas of exotic cover transferred to protected land to present totals for indigenous vegetation cover in the high country
(b) on pastoral leases. This is the present total area of indigenous vegetation cover on pastoral leases, plus areas of exotic and indigenous cover that were previously on pastoral lease but have been transferred to protected land, plus areas of indigenous cover that had been on pastoral lease but have been transferred to freehold.

Both of adjustments (a) and (b) above are based on the assumption that areas defined as exotic cover but protected through tenure Review are misclassified in the vegetation map (Newsome, 2003).

We next calculated the 'current' area of indigenous vegetation remaining
(a) in the high country. For this, we subtracted land areas of indigenous vegetation cover transferred from pastoral lease to freehold from present-day totals.

The assumption here is that freeholding removes these areas from land use constraints of the CPLA, resulting in gradual to rapid intensification of land use development and conversion from indigenous to exotic cover. This is consistent with data showing less indigenous vegetation cover remaining on other tenures, relative to pastoral leases in the high country.

Current areas of indigenous vegetation remaining on pastoral leases were set at the present levels indicated by our pastoral lease and vegetation cover databases, on the assumption that no change in cover had occurred while the tenure remained unchanged.

3. Targets

We next set new targets ('original' targets) for representativeness, based on 'original' levels of protection and 'original' indigenous vegetation cover remaining on pastoral leases, as adjusted above.

4. Calculation of 'original' and 'current' measures

Finally, we calculated 'original' and 'current' representativeness, susceptibility to biodiversity loss (SBL), proportion of the protection target unmet (PTU) and vulnerability (VUL), based on 'original' targets, using the methods described in Section 3.5.

Assessment of progress

Change in representativeness may be zero or positive. Positive change indicates that a more complete range of indigenous biodiversity is protected to target levels.

Vulnerability (VUL) can decrease, increase, or remain unchanged. A decrease (negative change) in vulnerability means that progress towards protection targets (PTU) outweighs the anticipated increase in susceptibility to biodiversity loss (SBL) resulting from the freeholding of areas of remaining indigenous vegetation in that environment. It represents net progress towards halting the decline in indigenous biodiversity. An increase in vulnerability (positive change) means that progress towards protection targets is outweighed by the anticipated increase in susceptibility of the environment to biodiversity loss through the freeholding of other remaining indigenous vegetation in that environment.

The properties of the vulnerability measure (VUL = SBL × PTU) weight it in favour of showing favourable (i.e. positive) change. This is because susceptibility to biodiversity loss (SBL) is calculated in relation to the whole high country (any transferred to freehold is a portion of that remaining in that environment in the high country, so proportional increases in susceptibility to loss are likely to be modest). Moreover, our SBL index will tend to underestimate likely susceptibility to biodiversity loss where indigenous

vegetation cover has been reduced to low levels (See 5.1 Methods *Vulnerability measure and components*). On the other hand, progress towards protection targets (PTU) is calculated in relation to indigenous vegetation remaining on reviewable leases only. Therefore, progress towards protection targets can be rapid, particularly where the target is a small area of land, so that small increases in area protected represent large proportional gains.

5.2 Results

Effectiveness of current levels of protection

Biodiversity protection targets

The land area of unmet biodiversity protection targets for the high country was null or zero in 85 Level IV land environments. These are either

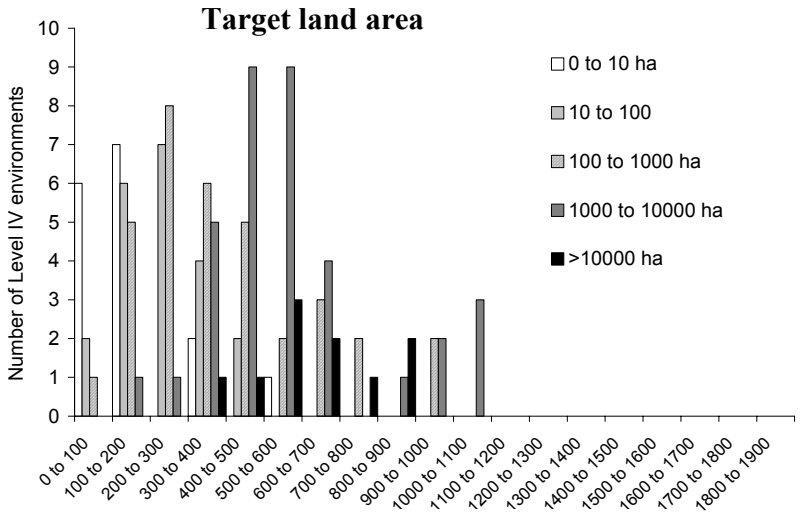
- environments with no mapped indigenous vegetation on pastoral leases (i.e. null values where there is no remaining indigenous vegetation to protect —14 Level IV environments). Areas of indigenous vegetation that are not mapped may be revealed in these environments by field survey, or
- those that have >20% of their land area protected nationally (i.e. no additional protection for biodiversity required — 71 Level IV environments). The latter includes all Level IV environments with mean elevation >1100 m.

The characteristics of unmet biodiversity protection targets for protection in the high country are strongly influenced by elevation (Fig. 5A, B and C):

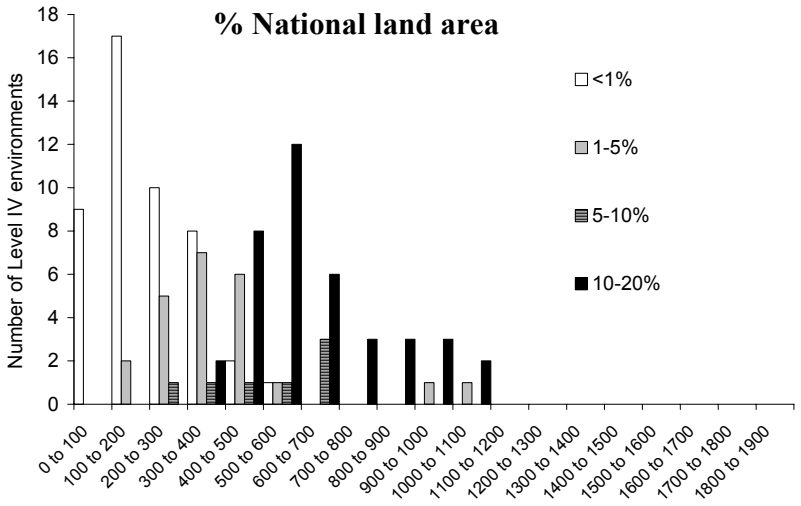
Many unmet biodiversity protection targets in low-elevation environments are small in area (e.g. <100 ha; Fig. 5A), typically account for a small percentage of the total national land area of the environment (<5%; Fig. 5B), and represent high portions of the area of that environment that remains in indigenous cover on pastoral leases (often 100%; Fig. 5C).

Since more indigenous vegetation remains in higher-elevation land environments (those with average elevations up to 1100 m), unmet biodiversity protection targets are larger in land area (up to >10 000 ha; Fig. 5A) and represent greater portions of total national land area (up to 20% Fig. 5B). However, the portion of land on pastoral leases that would be needed to meet these biodiversity protection targets is smaller (in some this is <20%; Fig. 5C).

A.



B.



C.

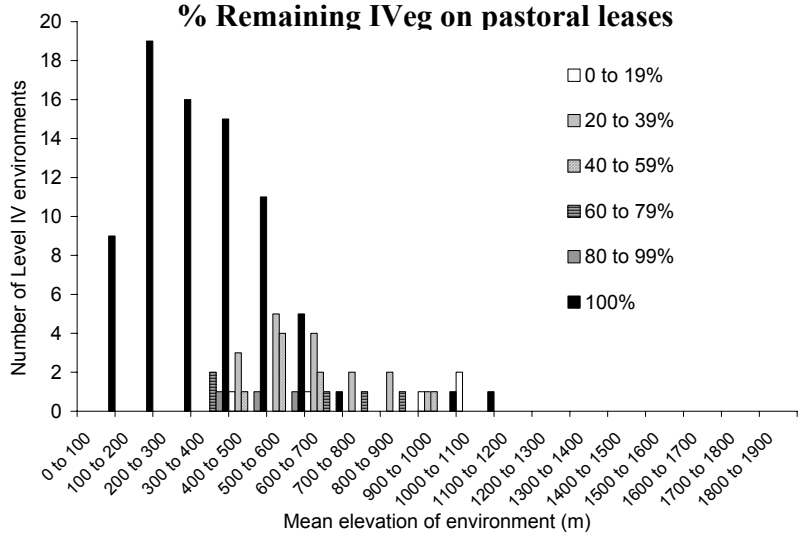


Fig. 5 Unmet biodiversity protection targets in high country Level IV environments grouped into 19 categories of mean elevation. Data are the number of targets in: A. five categories of land area, B. four categories of percentage of national area, C. six categories of percentage remaining area in indigenous vegetation on pastoral leases.

Representativeness
Protected areas equal or exceed biodiversity protection targets in 71 (33.2%) of all high country Level IV environments (Table 14; Map 2).

All 46 Level IV environments within the Level I environments O, P, R, S and T are protected at or in excess of biodiversity protection levels (Tables 14 and 15).
In six Level I environments (B, F, I, J, L, N), none of the 89 Level IV environments are protected to biodiversity protection target level. The remaining environments had two (K: 10%), five (E: 26%), and nine (M: 75%)(Q: 32%) of their Level IV environments protected to biodiversity protection target levels. When using representativeness as a primary criterion in the assessment of significance, areas of indigenous vegetation within these poorly represented environments will be more significant.

Table 14 Representativeness of protected areas in the high country: Level IV environments within Level I environments

Level II environment ***(Number of Level IV environments)***	**Mean elevation**	**Protected areas equal or exceed biodiversity protection targets**
	(m)	**No. (%) Level IV environments**
B *(n = 18)*	226	0
E *(n = 19)*	654	5(26%)
F *(n = 4)*	356	0
I *(n = 3)*	45	0
J *(n = 11)*	108	0
K *(n = 20)*	691	2(10%)
L *(n = 15)*	131	0
M *(n = 12)*	163	9(75%)
N *(n = 38)*	279	0
O *(n = 15)*	301	15(100%)
P *(n = 17)*	974	17(100%)
Q *(n = 28)*	669	9(32%)
R *(n = 11)*	1064	11(100%)
S *(n = 2)*	915	2(100%)
T *(n = 1)*	1859	1(100%)
Total (*n = 214*)		71(33%)

Table 15 shows a lower percentage of targets met in the subtotal (146 Level IV environments within the 34 'core' Level II environments) than in the total (214 Level IV environments, 58 Level II environments). This indicates the core high country environments (i.e. those that are characteristic of and largely confined to the high country) are relatively poorly protected (see also Section 4.2 and Table 11).

Table 15 Representativeness of protected areas in the high country in the 34 major Level II environments of the high country.

Level II environment ***(Number of Level IV environments)***	**Mean elevation**	**Protected areas equal or exceed biodiversity protection targets**
	(m)	**No. (%) Level IV environments**
B3 *(n =5)*	300	0
B8 *(n =2)*	350	0
E1 *(n =10)*	639	2(20%)
E3 *(n =2)*	466	0
E4 *(n =4)*	747	1(25%)
F2 *(n =1)*	216	0
I4 *(n =2)*	62	0
J2 *(n =5)*	135	0
J3 *(n =3)*	82	0
K1 *(n =5)*	749	2(40%)
K2 *(n =3)*	790	0
K3 *(n =5)*	535	0
K4 *(n =5)*	605	0
K5 *(n =2)*	626	0
L1 *(n =8)*	154	0
L3 *(n =1)*	97	0
M2 *(n =5)*	228	2(40%)
M3 *(n =2)*	695	2(100%)
N2 *(n =6)*	215	0
N3 *(n =9)*	294	0
N4 *(n =5)*	493	0
N5 *(n =4)*	422	0
N6 *(n =3)*	489	0
N7 *(n =2)*	413	0
N8 *(n =3)*	247	0
P1 *(n =5)*	1281	5(100%)
P2 *(n =2)*	1468	2(100%)
Q1 *(n =6)*	1154	4(67%)
Q2 *(n =5)*	672	0
Q3 *(n =7)*	860	2(29%)
Q4 *(n =10)*	264	3(30%)
R1 *(n =7)*	1344	7(100%)
S2 *(n =1)*	1120	1(100%)
T1 *(n =1)*	1822	1(100%)
'Core' Subtotal (*n = 146)*		34(23%)
Total (*n = 214*)		71(33%)

Protection to target level is strongly associated with elevation (Map 2; Fig. 6). In most low-elevation environments (<700 m) protection targets are unmet. In most high-elevation environments (>1100 m), protection targets are met. Targets are met in all land environments with average elevation greater than 1100 m. Thus, indigenous vegetation remaining within low-elevation environments in the high country will be significant for biodiversity protection since it is poorly represented in the protected area network.

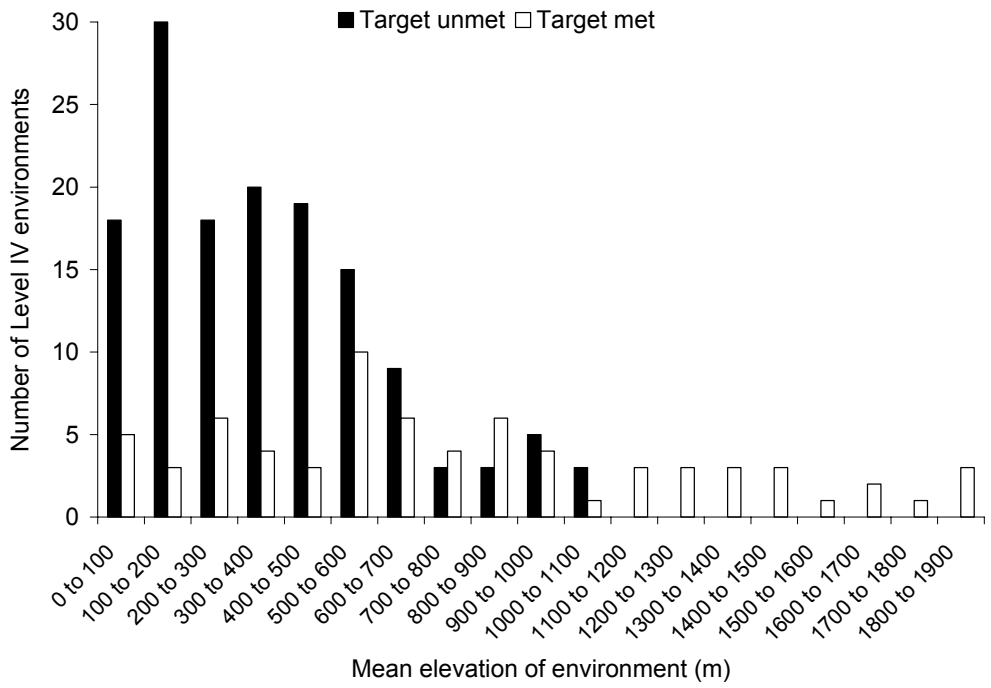


Fig. 6 Number of met and unmet targets in Level IV high country environments. Level IV environments are grouped into 19 categories of mean elevation in New Zealand.

Vulnerability

The spatial distribution of susceptibility to biodiversity loss in the high country is illustrated in Map 3. The scattergram in Fig. 7 shows the susceptibility of high country environments to biodiversity loss. Three features are notable:

There are two clusters of points. The group at upper left has little indigenous vegetation cover remaining and high susceptibility to biodiversity loss; the group at lower right has a high proportion of indigenous vegetation cover remaining and low susceptibility to biodiversity loss.

Standard deviations in both indigenous vegetation cover remaining and susceptibility to biodiversity are large in the first group (upper left). This indicates much variation in the remaining indigenous vegetation cover within Level IV environments in this group. Standard deviations are smaller in the second group (lower right), indicating the general intactness of indigenous cover in these Level IV environments.

The points all lie above the curve relating remaining indigenous vegetation cover to susceptibility to biodiversity loss, and this is most obvious where there is little remaining indigenous vegetation cover (at upper left of the scattergram). This is because susceptibility to biodiversity loss accelerates as indigenous vegetation cover decreases to low levels (See Methods Section 3.5: Vulnerability measures).

It is worth noting again that our index (SBL, calculated as the complement of the species area curve) will underestimate susceptibility to loss where proportions of remaining indigenous vegetation cover are low, relative to the derivative of the species area curve, which would be a more accurate (though computationally more complex) index.

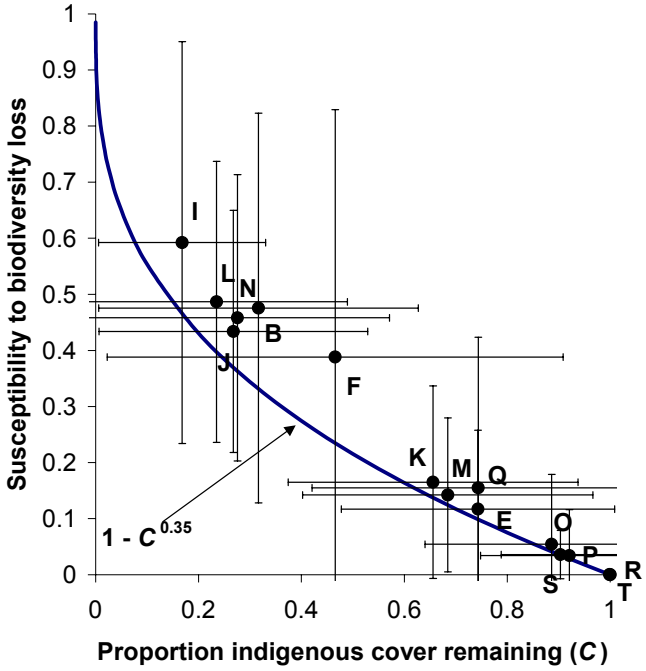


Fig. 7 Average susceptibility to biodiversity loss (SBL) in relation to the average proportion of remaining indigenous cover. The points are averages for all Level IV environments within each of the 15 Level I environments of the high country. Horizontal and vertical error bars represent standard deviations (i.e. variation in indigenous cover and susceptibility to loss among Level IV environments within Level I environments).

Proportions of protection targets unmet (PTU) at Level IV are illustrated in Map 4. Average proportions of protection targets unmet (PTU) vary widely among Level I environments (Tables 16 and 17). The average PTU is zero in Level I Environments O, P, R, S and T, indicating that national protection targets are met in all the Level IV environments within them. Level I Environments N, J and K have the highest average PTUs at Level I (>70% of targets unmet on average in Level IV environments). Average PTU exceeds 0.9 in six of the 34 core high country Level II environments (J2, K3, K4, N4, N5, N6; Table 17).

Table 16 Vulnerability of Level IV high country environments: averages for Level I environments

Level I environment *(Number of Level IV environments)*	Indigenous vegetation cover remaining in high country (IVeg)	Susceptibility to biodiversity loss (SBL = 1 − IVeg0.35)	Protection target unmet (PTU)	Vulnerability (VUL = SBL × PTU)
B *(n = 18)*	0.32	0.48	0.66	0.18
E *(n = 19)*	0.74	0.12	0.38	0.04
F *(n = 4)*	0.47	0.39	1.00	0.20
I *(n = 3)*	0.17	0.59	–	–
J *(n = 11)*	0.27	0.43	0.73	0.24
K *(n = 20)*	0.66	0.16	0.73	0.13
L *(n = 15)*	0.23	0.49	0.63	0.27
M *(n = 12)*	0.68	0.14	0.09	0.02
N *(n = 38)*	0.28	0.46	0.79	0.30
O *(n = 15)*	0.89	0.05	0.00	0.00
P *(n = 17)*	0.92	0.03	0.00	0.00
Q *(n = 28)*	0.74	0.15	0.36	0.03
R *(n = 11)*	1.00	0.00	0.00	0.00
S *(n = 2)*	0.90	0.04	0.00	0.00
T *(n = 1)*	1.00	0.00	0.00	0.00
Average (*n = 214*)	0.58	0.25	0.43	0.12

The spatial distribution of biodiversity vulnerability across Level IV high country environments is illustrated in Map 5. At Level I of LENZ, average vulnerability (VUL) of these Level IV high country environments varies from zero in Environments O, P, R, S and T, to 0.30 in Environment N, 0.27 in Environment L, and 0.24 in Environment J (Table 16). At Level II, average vulnerability of Level IV environments varies from zero in most higher elevation environments to 0.58 in N5, 0.42 in N2 and 0.40 in N8 environments (Table 17). These are the environments that are most at risk of further biodiversity loss, and most urgently require protection. Remaining indigenous vegetation in these environments would be most highly ranked in terms of significance for biodiversity protection.

Average susceptibility to biodiversity loss (SBL) is marginally lower within the 146 'core' Level IV environments (i.e. those within the 34 Level II environments that have >10% of their land area in the high country), than across all 214 Level IV environments. However, the average proportion of targets unmet (PTU) is higher in those core environments, and average vulnerability (VUL) is also higher. This reflects less effective biodiversity protection, and more urgent need for greater biodiversity protection within core high country environments relative to those that are marginal to the high country (e.g. the high-rainfall environments M and O, which have small areas overlapping into the western high country, but are predominantly centred on Westland, Western Southland and Stewart Island).

Table 17 Vulnerability of Level IV high country environments: averages for major Level II high country environments. Data are expressed as proportions of 1.0 or as null values (-)

Level I environment ***(Number of Level IV environments)***	**Indigenous vegetation cover remaining in high country (IVeg)**	**Susceptibility to biodiversity loss (SBL = 1 − IVeg0.35)**	**Protection target unmet (PTU)**	**Vulnerability (VUL = SBL × PTU)**
B3 *(n = 5)*	0.45	0.26	0.46	0.10
B8 *(n = 2)*	0.67	0.14	0.67	0.08
E1 *(n = 10)*	0.72	0.13	0.29	0.02
E3 *(n = 2)*	0.39	0.30	0.68	0.18
E4 *(n = 4)*	0.91	0.03	0.64	0.03
F2 *(n = 1)*	0.64	0.15	–	–
I4 *(n = 2)*	0.25	0.39	–	–
J2 *(n = 5)*	0.41	0.32	0.95	0.30
J3 *(n = 3)*	0.16	0.48	0.17	0.09
K1 *(n = 5)*	0.64	0.16	0.39	0.06
K2 *(n = 3)*	0.88	0.04	0.69	0.04
K3 *(n = 5)*	0.51	0.24	0.90	0.21
K4 *(n = 5)*	0.77	0.10	0.94	0.11
K5 *(n = 2)*	0.43	0.35	0.81	0.33
L1 *(n = 8)*	0.16	0.54	0.53	0.26
L3 *(n = 1)*	0.80	0.07	0.09	0.01
M2 *(n = 5)*	0.80	0.09	0.26	0.05
M3 *(n = 2)*	0.52	0.21	0.00	0.00
N2 *(n = 6)*	0.07	0.65	0.74	0.42
N3 *(n = 9)*	0.24	0.46	0.66	0.23
N4 *(n = 5)*	0.69	0.13	0.95	0.12
N5 *(n = 4)*	0.07	0.62	0.93	0.58
N6 *(n = 3)*	0.60	0.18	0.92	0.18
N7 *(n = 2)*	0.34	0.41	0.42	0.06
N8 *(n = 3)*	0.07	0.62	0.66	0.40
P1 *(n = 5)*	1.00	0.00	0.00	0.00
P2 *(n = 2)*	1.00	0.00	0.00	0.00
Q1 *(n = 6)*	0.99	0.00	0.14	0.00
Q2 *(n = 5)*	0.84	0.06	0.78	0.05
Q3 *(n = 7)*	0.93	0.03	0.42	0.02
Q4 *(n = 10)*	0.42	0.38	0.21	0.05
R1 *(n = 7)*	1.00	0.00	0.00	0.00
S2 *(n = 1)*	0.98	0.01	0.00	0.00
T1 *(n = 1)*	1.00	0.00	0.00	0.00
'Core' average (*n = 146*)	0.58	0.24	0.49	0.13
Average (*n = 214*)	0.58	0.25	0.43	0.12

Operational application

To illustrate the relevance of the proposed measures, we have applied them to a worked example, using the results of tenure review to date. Our data show that 85 of the 214

Level IV environments of the high country were affected by tenure review to January 2004 (Table 18). Of these, 'original' targets indicate that 65 were under-represented in public conservation lands, and the remaining 20 (23.53%) were already protected at or in excess of these biodiversity protection targets.

Comparison of 'current' with 'original' measures show that biodiversity protection targets were met in two environments through tenure review, resulting in an increase in representativeness (i.e. a higher percentage of Level IV environments protected to target levels). An increase to twenty two Level IV environments protected to target levels from an original total of twenty represents a 10% increase in representativeness. Remaining indigenous vegetation in sixty three Level IV environments would be significant for biodiversity protection on the basis of the representativeness criterion, compared with 65 in the original state.

Our calculations show an increase in average susceptibility to biodiversity loss (SBL) of 4.56% across these 85 environments, and a decrease in the average proportion of protection targets unmet (PTU) of 6.00%. An increase in average vulnerability (reflecting urgency of protection) of 3.40% is also shown.

Table 18 Original and current representativeness and vulnerability of environments, and percentage change relative to original, based on 'original' targets. The representativeness measure is the proportion of Level IV environments in which protected areas equal or exceed targets. The vulnerability measures are the averages for SBL, PTU, and VUL across all Level IV environments.

	Representativeness measure	**Vulnerability measures**		
	Protected areas equal or exceed targets (%)	**Susceptibility to biodiversity loss (SBL = 1 − $IV^{0.35}$)**	**Protection target unmet (proportion) (PTU)**	**Vulnerability (VUL = SBL × PTU)**
Level IV environments affected by Tenure Review *(n = 85)*				
Current	0.2588	0.2190	0.5647	0.1624
Original	0.2353	0.2095	0.6007	0.1571
% change relative to original	+10.00%	+4.56%	–6.00%	+3.40%
All Level IV environments in the high country *(n = 214)*				
Current	0.3318	0.2626	0.4095	0.1164
Original	0.3224	0.2588	0.4248	0.1142
% change relative to original	+2.90%	+1.47%	–3.60%	+1.99%

Figure 8 displays changes in the three vulnerability measures for each of the 85 Level IV environments affected by tenure review, in relation to the original vulnerability of environments. Susceptibility to biodiversity loss (SBL) increased in 58 Level IV environments and was unchanged in 27 environments. The proportion of the protection target unmet (PTU) decreased in 32 Level IV environments and remained unchanged in 53 environments. Vulnerability (VUL) increased in 49, decreased in 9, and remained unchanged in 27 Level IV environments. On the basis of the vulnerability criterion, remaining indigenous vegetation cover in those 49 more vulnerable Level IV environments would currently be assessed as more significant for biodiversity protection than before tenure review commenced.

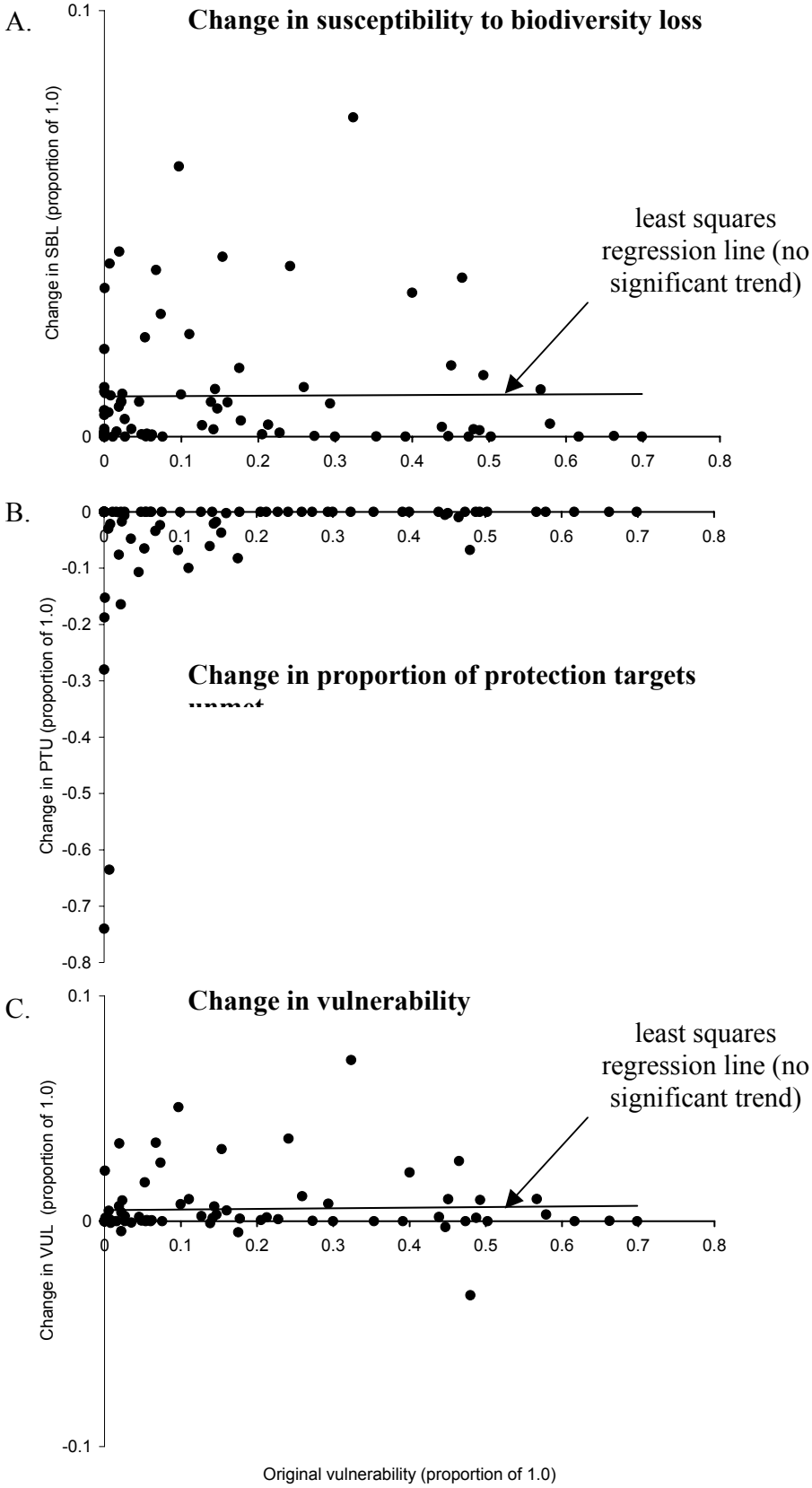


Fig. 8 Changes in A. susceptibility to biodiversity loss, B. proportion of protection target unmet, and C. vulnerability, in relation to original vulnerability, among the 85 Level IV high country environments affected by tenure review.

Figs 8A and 8C show that changes in SBL and VUL are not related to the original vulnerability of the environment. In other words, susceptibility to biodiversity loss and vulnerability have increased in environments irrespective of how vulnerable these environments were originally (i.e. before tenure review). However, there is a clear relationship between changes in protection targets unmet (PTU) and the original vulnerability of an environment (Fig. 8B): this indicates that progress towards protection targets was made mainly in least vulnerable environments.

6. Discussion

6.1 Environments and vegetation of the high country

The high country accounts for 25% of the land area of New Zealand but contains a high diversity of its environments (43% of New Zealand's 500 Level IV land environments). Many environments are restricted to the high country, so that the high country represents the only opportunity to protect the biodiversity associated with those environments.

Human-induced loss of indigenous vegetation cover has been uneven across high country environments. Little indigenous vegetation cover remains in low-elevation environments today, while environments at higher elevations retain relatively high proportions of indigenous vegetation cover.

Within most land environments that are extensive within the high country (notably including modified, vulnerable and poorly protected lowland environments such as those within Level I environment N) the data show that reviewable pastoral leases retain higher proportions of indigenous vegetation cover than does freehold land. Therefore, it appears that indigenous biodiversity has been retained on pastoral leases to a greater extent than on land under freehold tenure. This may be due to effective restrictions on certain farming uses that disturb soil or vegetation under the Land Act (1948) and the subsequent CPLA (1998).

6.2 Representation of high country in protected areas

The full variety of biodiversity in the high country is poorly represented in protected areas. Firstly, a lower percentage of land is protected in the high country than is the average for New Zealand, and secondly, land is protected mainly at high elevation, while there is a deficiency of protected areas within environments at low elevations.

6.3 Effectiveness of protection for biodiversity in the high country

The goal of a network of protected areas is to separate elements of biodiversity from the processes that threaten their persistence in the wild (Margules & Pressey 2000). The extent to which this is achieved depends on how well reserves fulfil two objectives: the degree to which they represent the full variety of biodiversity and their ability to ensure

its persistence (by maintaining natural processes and viable populations, and by excluding threats).

The two measures we use in this report to assess effectiveness of biodiversity protection in the high country (representativeness and vulnerability) underpin these two objectives. The measures indicate that, relative to realistic targets, the present network of protected areas in the high country (1) inadequately represents the full variety of biodiversity, and (2) provides poorly for the persistence of that full range of biodiversity, since it largely excludes those environments that are most at risk of imminent biodiversity loss.

Remaining indigenous vegetation in high country environments where protection targets are unmet will be significant for biodiversity protection, on the basis of the principal significance criterion of representativeness. Lowland environments predominate among these poorly protected high country environments. Land environments with average elevation greater than 1100 m will not be significant for biodiversity protection on the basis of the representative criterion.

The high average vulnerability of high country environments (poor provision for the persistence of the full range of biodiversity) signals an urgent need for more effective biodiversity protection in the high country overall. However, the degree of vulnerability of biodiversity is also uneven across high country environments. Vulnerability is particularly high in low elevation environments, where there has been most clearance of indigenous vegetation in the past, and there are few protected areas. These are also those environments currently most at risk of further modification by invading weeds and pests and a range of different human land uses (e.g. urbanisation and intensive agricultural development). Therefore, biodiversity protection is needed most urgently, and low-elevation environments are ranked most highly, according to this significance criterion.

Our test of the operational applicability of these measures indicates that the tenure review process has increased representativeness and made some progress towards protection targets in the least vulnerable environments. However, our calculations suggest this progress will have come at the cost of an increase in the average susceptibility of high country environments to biodiversity loss, and an increase in the average vulnerability of biodiversity. This is because additional protection has been achieved mainly in better protected environments, while indigenous vegetation in less well protected environments has been freeholded, increasing the likelihood of land use intensification and consequent biodiversity loss. As a result of this bias, it appears that biodiversity loss is now more assured and imminent overall, and requirements for biodiversity protection have become more serious and urgent. This indicates net lost ground for biodiversity conservation, and is contrary to Government objective (g) for the high country.

The process we demonstrate to assess progress in biodiversity protection is conservative rather than precautionary, i.e. weighted it in favour of showing favourable (i.e. positive) change in biodiversity protection effectiveness. This is because our index of susceptibility to biodiversity loss is conservative, as explained in Methods (Section II 5.1 Effectiveness of protection: *Vulnerability measure and components*). Moreover, the

protocol takes no account of susceptibility to biodiversity loss accruing from intensive development of indigenous vegetation occurring in the high country outside reviewable pastoral leases (this would only be possible if more adequate and regularly updated land cover data become available). We do, however, make the precautionary assumption that indigenous vegetation freeholded from pastoral leases will undergo intensification and eventual conversion to exotic cover. This may not always be the case completely, but the assumption is consistent with the difference in indigenous vegetation percentages on pastoral leases and freehold land in the same environments across the high country (Section I Results Table 10) and reflects removal of the protective constraints of the Land Act and the subsequent CPLA.

Constraints, biases and methodological issues
Section II of this report provides a whole of high country framework for setting biodiversity protection targets, and assessing (1) effectiveness of biodiversity protection, (2) significance of biodiversity for protection, and (3) progress towards the Government's biodiversity objective (g). However, the resolution at which the framework may be applied is limited by the accuracy and resolution of the underlying digital data. In particular, the vegetation data are outdated (e.g. it is likely that some areas mapped as indigenous vegetation have been cleared). Operational application of the framework will therefore require field survey and assessment, and rigorous and systematic updating of vegetation cover data as this becomes available. However, the limitations of the underlying data do not detract from the value of a whole of high country framework for guiding property-level protection decisions to efficiently achieve Government objectives.

6.4 Requirements for protection for biodiversity in the high country

In order to meet Government objective (g) for the high country there will need to be progress in both improved representativeness and decreased vulnerability. This means priority will need to be given to protecting less well represented, more modified and more threatened lowland and montane ecosystems that contain the majority of Acutely and Chronically threatened species. High country outcomes consistent with the New Zealand biodiversity strategy will result from implementing protection for the most vulnerable and imminently threatened biodiversity, primarily in lowland environments that are also most suitable for alternative economic uses. This requirement and its associated challenges are not unique to New Zealand. Identical requirements have been recognised and similar challenges are being faced by a range of international initiatives that seek to halt the decline in indigenous biodiversity through improving the representativeness of reserve networks (e.g. Heijnis et al. 1999; Heydenrych et al. 1999; Margules & Pressey 2000; Pressey & Taffs 2001b; Gaston et al. 2002; Gelderblom et al. 2003; Rouget 2003).

In some high country environments, there are a variety of different places (spatial options) where targets consistent the Government's high country objective (g) can be achieved. However, in other cases, all the remaining area in indigenous vegetation on pastoral leases will be required to meet these targets. In the international literature, such areas are termed 'irreplaceable', or 'required' (e.g. Pressey et al. 1994; Pressey 1999b; Ferrier et al. 2000; Pressey & Taffs 2001a; Noss et al. 2002). Irreplaceability is a

consequence of retreating options for biodiversity protection, and signals that the loss of biological features associated with an irreplaceable area has reached an advanced stage.

Irreplaceable areas of remaining indigenous vegetation in low-elevation environments are typically small (see Results Section 4.3 Biodiversity protection targets), and it is therefore unlikely that the protection of such limited areas will amount to a significant setback for traditional productive use in the high country. However, many of these areas of indigenous vegetation are small and fragmented, and the reserving of many small, dislocated patches will not necessarily serve to increase the effectiveness of biodiversity protection. Therefore, spatial requirements for the persistence of fragmented lowland ecosystems will need to be carefully considered and provided for in reserve design. Connectivity and other spatial considerations of reserve design (e.g. metapopulation dynamics, source–sink population structures, successional pathways, spatial requirements of particular species, effects of habitat modification, and evolutionary processes; Margules & Pressey 2000) are not considered in this report, but will be covered in a second report (Walker et al. in prep.). Planning for effective biodiversity protection in the high country will require a comprehensive range of targets to be set: these will include targets for the protection of biodiversity processes (e.g. spatial requirements; Pressey et al. 2003) as well as targets for the protection of pattern, which are the focus of this report. A full range of targets may be incorporated into a systematic conservation and land use planning framework.

6.5 Competing and conflicting objectives

This report focuses on just one Government objective for the high country: objective (g): 'conservation outcomes for the high country are consistent with the New Zealand Biodiversity Strategy'. Government has a further nine objectives for the high country (Appendix 1), and these are not all complementary.

The places that are highly significant for the biodiversity objective (g) will usually fail to overlap with those that are significant for the creation of high country parks in objective (h) (Progressively establish a network of high country parks and reserves). As described above, areas of indigenous vegetation required to meet objective (g) are often in disturbed, modified, economically productive landscapes, while those required to meet the criteria for inclusion in high country parks under Government objective (h) (listed in Cabinet Policy Committee Report Back on Government Objectives for the High Country, paragraph 50) will typically have scenery and wilderness and be more remote, rugged, and residual from intensive uses.

In other words, the creation of high country parks (within objective h) will tend to preserve scenic and recreational values and affect biodiversity that is already comparatively safe. Unless parks (and reserves) are designed to include full elevation sequences and more modified lowland vegetation, they will do little to improve the conservation status of the most threatened ecosystems, habitats and species, which are addressed by objective (g).

These two objectives will tend to compete for the resources allocated to conserving significant inherent values. Our results suggest that progress towards protection targets has been achieved mainly in the least vulnerable high country environments to date, which suggests that this competition is usually won by objective (h).

Government objective (b) (free land capable of economic use from economic constraints) has been in conflict with objective (g), because it requires the same places for different, incompatible purposes. The results of this conflict are indicated by rising vulnerability in poorly protected lowland and montane environments as a result of the tenure review process.

The challenge is to find a solution that contributes optimally to all 10 Government objectives. The problem of optimising land tenure decisions to meet competing and conflicting objectives is not unique to the high country or to New Zealand (Bingham et al. 1995; Faith & Walker 1996b; Faith et al. 1996; 2001; 2003; Lunney et al. 1997; Metrick & Weitzman 1998; Pressey 1998; Rosing et al. 2003). In the last 20 years, spatially explicit, systematic techniques for conservation and land use planning have been developed overseas to enable agencies and planners to optimise contributions of land tenure change towards different and competing objectives with maximum efficiency (e.g. Wu & Boggess 1999; Ferrier et al. 2000; Cork et al. 2001; Rodrigues & Gaston 2002; Cowling et al. 2003b)

Tenure review under the Crown Pastoral Lands Act 1998 (CPLA) is the predominant method by which Government may achieve its objectives in the South Island high country. It would be appropriate to apply systematic techniques for conservation and land use planning in the tenure review process in order to enable optimal achievement of the Government's high country objectives.

6.6 Systematic conservation planning

The effectiveness of systematic conservation planning comes from its efficiency in using limited resources to achieve conservation goals, its defensibility and flexibility in the face of competing land uses, and its accountability in allowing decisions to be critically reviewed (e.g. Pressey et al. 1995; Guikema & Milke 1999; Pressey & Cowling 2001; Possingham 2001; Faith et al. 2003). It has been widely applied to reserve selection internationally, notably in Oceania (Chown et al. 2001), South Africa (e.g. Cowling & Pressey 2003), Australia (e.g. Richards et al. 1990; Pressey et al. 1995; Pressey 1998; Cork et al. 2001; Pressey & Taffs 2001a; 2001b—including projects in response to reviews of Crown forestry and pastoral leasehold lands), Papua New Guinea (e.g. Nix et al. 2000; Faith et al. 2001), and the USA (e.g. Noss et al. 2002). Systematic planning is at a very early stage of application in New Zealand (e.g. Stephens et al. 2002).

This report introduces techniques of systematic planning to the tenure review process and demonstrates their operational application to the biodiversity objective (g) for the high country. We demonstrate the use of LENZ (Land Environments of New Zealand) as a landscape context for systematic planning, as suggested by Leathwick et al. (2003c).

Ideally, a full modern systematic conservation and land use planning framework should be customised for tenure review. This would be designed to address all 10 objectives for the high country and enable optimal contributions to each.

7. Conclusions

Two measures (representativeness and vulnerability) can be used to determine effectiveness and significance for biodiversity protection, and can be applied to assess progress towards biodiversity outcomes in relation to realistic targets.

Lowland and montane environments of the high country are poorly represented in protected areas and their remaining biodiversity is particularly vulnerable and of high significance for biodiversity protection.

Analyses of the best available land tenure and vegetation datasets for the high country indicate that both representativeness and vulnerability are increasing, i.e. increased representativeness through protection of the least vulnerable environments is being offset by increased susceptibility to loss and vulnerability in more vulnerable lowland and lower montane environments. This indicates net negative progress in the effectiveness of protection for the full range of biodiversity. Tenure review may therefore be working against Government objective (g).

Progress on Government objective (g) will require protection of indigenous biodiversity in lowland and montane environments where there is potential for alternative productive land uses. Unless parks and reserves are designed to incorporate elevation sequences and include more modified vegetation, progress on Government objective (h) will contribute little to progress on Government objective (g). This is because the objectives will tend to involve protection of land in different places.

8. Recommendations

We recommend the definition of clear biodiversity protection targets to direct conservation effort, and to provide a context for assessing the effectiveness of biodiversity protection.

Two measures — representativeness and vulnerability— are required to assess the effectiveness of protection for biodiversity against these targets, to determine the significance of remaining indigenous vegetation for biodiversity protection, and to measure progress towards Government objective (g) for the high country.

We recommend that a full systematic conservation and land use planning framework is customised for the tenure review process. This will require that targets and appropriate measures of progress be defined for each of the 10 Government objectives. Issues of ownership, accountability, and resources for appropriate spatial data standards will need to be addressed to enable consistent assessment of protection effectiveness, significance, and progress towards objectives.

9. Acknowledgments

The authors thank Jake Overton and Matt McGlone for useful comments on the draft report. We particularly thank Deb Zanders, James Barringer and Daniel Rutledge for their willing assistance with data assembly, and Christine Bezar and Beverly Elliott for editorial input. We thank Grant Hunter for overseeing and guiding the work, and many colleagues, particularly John Leathwick, Geoff Rogers, Theo Stephens, Jake Overton, Matt McGlone and Deb Wilson for intellectual input and the development of the ideas behind this work.

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11. Appendices

11.1 Tenure review objectives

Objective derived from the CPLA	Explanation
a. Promote the management of the Crown's high country land in a way that is ecologically sustainable [CPLA S.24(a)(i)]	The term 'ecologically sustainable' is used rather than the Resource Management Act's 'sustainable management' because, as the Select Committee at the time noted, the CPLA's focus is not on the protection of social and economic issues in relation to people and communities, which is the context of the RMA. The Select Committee also specifically retained the Commissioner's 'discretionary consent' power because it believed that the RMA did not adequately protect the Crown's interest as owner of pastoral land.
b. Enable reviewable land capable of economic use to be freed from current management constraints [CPLA S.24(a)(ii)]	Pastoral leases may only be used for pastoral farming. Economic benefits may accrue to both local communities and individual farmers when land is freed from the constraints of pastoral tenure.
c. Protect SIVs on reviewable land by the creation of protective measures [CPLA S.24(b)(i)]; or preferably by the restoration of the land concerned to full Crown ownership and control [CPLA S.24(b)(ii)]	A variety of protective measures such as covenants or easements over freeholded land are currently available. The preferred means of protection of SIVs is restoration to full Crown ownership and control. To achieve this the Crown purchases the lessee's interest.
d. Secure public access to and enjoyment of high country land [CPLA S.24(c)(i); Part IVA Conservation Act 1987]	This objective is related to the Government's aim of providing for ready and free public access, and recognises the special status of these lands as Crown owned.
e. Take into account the principles of the Treaty of Waitangi [CPLA S.25(1)(b)]	South Island iwi have cultural and economic interests in the high country that the Crown is required to respect.
f. Take into account any particular purpose for which the Crown uses, or intends to use, the land [CPLA S.25(1)(c)]	This provides a link with other Crown high country land use policies (e.g. minerals, as noted by the Select Committee) and with the complementary objectives outlined below.
New complementary objectives	
g. Ensure that conservation outcomes for the high country are consistent with the New Zealand Biodiversity Strategy (NZBS)	While the NZBS has already been confirmed as Government policy, it will be made specific to the high country in this context. This objective is related to the 'Protection of SIVs' objective above as biodiversity values are a subset of SIVs. This means that the Government should give priority to protecting biodiversity values that are indicated by the NZBS. The NZBS promotes the protection of biodiversity

	through objectives and priority actions. One such priority action is to add to public conservation land habitats and ecosystems important for indigenous biodiversity.
h. Progressively establish a network of high country parks and reserves	A high country network of parks and reserves is part of the Labour Party's 2002 election policy. A key objective for the next 5 years for DOC is to 'improve protection of important high country environments and progressively establish, extend and link a network of high country parks and reserves'.
i. Foster sustainability of communities, infrastructure and economic growth and the contribution of the high country to the economy of New Zealand	Land use changes in the high country have potential impacts on the infrastructure (e.g. schools, businesses), society and economics of rural communities. Productive and conservation uses of the high country land use can also contribute to the New Zealand economy.
j. Obtain a fair financial return to the Crown on its high country land assets	The Crown normally expects a return on assets that are being used for commercial purposes to be at market rates.

11.2 Land Environments of New Zealand (LENZ)

Land Environments of New Zealand (LENZ) is an objective numerical classification based on clearly stated assumptions and concepts, is proven to be a good predictor of key biological features, and is easily used at a range of scales. Land environments are areas that are similar in the environmental factors that are important for plant growth. Not all areas within a land environment are contiguous (e.g. valley floors in adjacent valleys may be part of one land environment, while hillslopes in adjacent valleys may be part of a second land environment). Each land environment would be expected to have supported similar potential natural vegetation and contained a similar suite of ecosystems and biodiversity in the absence of human disturbance.

In general, similar environments tend to support similar groups of plants and animals in the absence of human disturbance. Species distributions are not random. They are sorted in relation to the environment and history. This means that similar environments with similar histories tend to support similar groups of plants and animals in the absence of human disturbance. Land Environments of New Zealand (Leathwick et al. 2003a, b) identifies climatic and landform factors likely to influence the distribution of plant and animal species, and uses these factors to define a landscape classification that groups together sites that have similar environmental character. The climate, soil, and geological factors used to construct the classification have been selected for their importance in influencing plant growth. Such a classification can then be used to indicate sites likely to have similar potential ecosystem character – not necessarily the same in all respects but broadly similar groups of species and comparable biological interactions and processes. One major advantage of this approach, as opposed to directly mapping land cover for

example, is its ability to predict the potential character of sites where natural ecosystems have been profoundly modified (e.g. by land clearance or fire) or replaced by introduced plants and animals (e.g. pests and weeds).

Land Environments of New Zealand (LENZ) is created using an automatic numerical classification process. First, 15 data layers that describe aspects of climate and landform known to influence the distributions of biota (plants and animals) are assembled in the form of regular grids covering the area to be classified. Climate estimates are derived from mathematical surfaces fitted to long-run average climate data. The process starts with a digital elevation model, which is a grid of elevations covering the area to be classified. This is coupled with the climate surface to provide estimates for all points on the grid. In some cases, climate variables such as solar radiation, temperature, and rainfall are combined to provide estimates of factors more relevant to biota, such as soil water deficit. Landform data are taken mostly from the New Zealand Land Resource Inventory (a GIS database describing land attributes for the entire country) while slope is estimated from the digital elevation model. Once assembled, the data layers are combined and exported to a numerical classification programme. Here the data are analysed and sites having similar environments are grouped together to form 'land environments'. Classification results are then taken back into the GIS so that the geographic distribution of each of the resulting groups (land environments) can be mapped.

Climate factors included in the LENZ classification are mean annual solar radiation, minimum winter solar radiation, mean annual temperature, mean minimum temperature of the coldest month, annual soil water deficit, average monthly ratio of rainfall to potential evaporation and vapour pressure deficit (dryness of the air). These factors were estimated nationally on a 100-m grid, using thin-plate-spline spatial interpolation of data from irregularly distributed New Zealand meteorological stations (Leathwick & Stephens 1998).

Categorical soil variables included in LENZ are based on the New Zealand Land Resource Inventory (NZLRI) and are drainage, age since major reset of soil formation (estimated in three classes, i.e. younger than 2000 years, 2000 years to post-glacial, and pre-glacial), total phosphorous, calcium, induration, particle size and chemical limitations to plant growth (e.g. salinity).

Land environments are classified at four different national scales: Levels I (20 land environments nationally), II (100 land environments nationally), III (200 land environments nationally) and IV (500 land environments nationally). Each level is nested within each higher level.

11.3 Land Environments that occur in the high country (LENZ Level I)

B Central Dry Lowlands
Environment B consists of dry hill country and older alluvial surfaces in central New Zealand, mostly at low elevations. It is most extensive in the east, extending from

Gisborne and Hawke's Bay in the north, to Marlborough and North Canterbury in the south, with smaller patches in Tasman Bay and on rolling hill country immediately inland from Wanganui. The climate of Environment B is dry and mild with high solar radiation, reflecting its protection from prevailing winds by mountain ranges to the west. Annual water deficits are moderate on average, but may be severe in years with below average rainfall. Vapour pressure deficits are high. The terrain is generally flat to moderately sloping, with soils of low to moderate natural fertility formed on loess, alluvium, greywacke, sandstone, mudstone or limestone.

E Central Dry Foothills

Environment E consists of dry foothills and basin floors at mid-elevations in the eastern parts of both main islands, with the largest areas occurring in the South Island. It is most extensive in inland parts of Canterbury and Marlborough, with smaller areas in Tasman Bay. In the North Island it occurs only in inland Hawke's Bay. Environment E has a cool climate with high annual solar radiation and low average annual water deficit, but high October vapour pressure deficits. The latter reflects its protection from prevailing westerly winds by mountain ranges — the Southern Alps, Kaikoura Ranges and the mountains of north-west Nelson in the South Island, and the Tongariro volcanoes and Kaimanawa and Kaweka ranges in the North Island. Slopes are generally rolling to moderate. Sedimentary rocks are the predominant soil parent material, with greywacke the most widespread, followed by schist and softer Tertiary rocks. Gravels and/or loess from greywacke are widespread in Canterbury and Nelson, and andesitic tephra occurs in Hawke's Bay. Soils are generally well drained and have moderate natural fertility.

F Central Hill Country and Volcanic Plateau

Environment F extends across large areas of low to mid-elevation hill country in central New Zealand. The majority occurs in the central North Island, extending along the western flanks of the Raukumara Range in the north-east, to Taranaki in the west, and to Wellington and Wairarapa in the south. In the South Island, it occurs on the northern coastal hills of north-west Nelson, in the Marlborough Sounds, around Kaikoura and on Banks Peninsula. The climate of Environment F is mild, with high levels of annual solar radiation and moderate winter solar radiation. Although it has a low monthly water balance ratio, the even spread of rainfall throughout the year means that rainfall deficits are slight on average, but with droughts in years with below average rainfall, particularly in the east. A diverse range of soil parent materials include older Mesozoic greywacke and granite, younger Tertiary sandstones and mudstones, and a range of volcanic tephra. Loess dominates on Banks Peninsula, but with some protruding basaltic rock. Soils are generally well drained, and many are of low natural fertility. More fertile soils occur on andesitic tephra and some of the more easily weathered Tertiary rocks.

I Central Poorly Drained Recent Soils

Environment I consists of scattered pockets of poorly drained recent soils that occur mostly on coastal plains and river valleys in eastern New Zealand, from Gisborne to mid-Canterbury. Major concentrations occur on the floodplain of the Waipaoa River near Gisborne, on the alluvial plains of Hawke's Bay, and along the lower Manawatu and Ruamahanga rivers. Smaller areas occur in Nelson, Marlborough, particularly around the

mouth of the Wairau River, and on the Canterbury Plains, mostly around Lake Ellesmere. The climate of Environment I is typified by warm temperatures, high annual solar radiation, moderate annual water deficits and high vapour pressure deficits. The terrain is generally flat and soils are very poorly to imperfectly drained. Recent alluvium from a variety of sources is the dominant soil parent material, some of it also containing loess. Soil fertility is moderate, with some saline soils, particularly on coastal mudflats.

J Central Well Drained Recent Soils
Environment J consists of areas of well-drained recent soils, mostly on floodplains and lower terraces along major lowland rivers in the southern North Island and the northern and eastern South Island. It is most extensive in southern Hawke's Bay, Manawatu and Wairarapa in the North Island, and Nelson, Marlborough and Canterbury in the South Island. Environment J is characterised by a mild, dry climate, with high solar radiation. Moderate annual water deficits and high vapour pressure deficits reflect its lack of exposure to prevailing westerly winds. Alluvium is the dominant soil parent material, but in contrast to Environment I, this is coarser textured with a predominance of gravels and sands, and contains less finer material such as loess. Soils are mostly well drained and of moderately high natural fertility.

K Central Upland Recent Soils
Environment K comprises areas of recent soils at moderate to high elevation in cool, mostly inland parts of both main islands. Most of Environment K occurs on floodplains along major river valleys in inland parts of the eastern South Island. In the North Island, it is restricted to high-elevation sites on the ringplain surrounding the Tongariro volcanoes. The climate of Environment K is cool but with high solar radiation. Although annual water deficits are low on average, more-eastern sites in the South Island receive substantially less rainfall than those exposed to the west or located close to the Southern Alps. Vapour pressure deficits are moderate. Alluvium, mostly from greywacke but some from schist, is the main soil parent material, with varying mixes of gravel and finer material. Andesitic tephra is the dominant parent material around the Tongariro volcanoes. Slopes are generally gentle, and most soils are well drained. Natural soil fertility is moderately high.

L Southern Lowlands
Environment L consists of extensive areas of alluvial and loess soils of varying age in the lowlands of Southland, with smaller areas in South Canterbury, coastal Otago and on Stewart Island. Environment L has a cool climate with low solar radiation. There is a strong gradient in annual rainfall deficits, which, while low overall, vary from very low in the south and south-west, to moderate in the north-east. Landforms are generally flat to gently sloping, with a range of soil parent materials including extensive areas of fine-textured alluvium from schist and greywacke, loess, peat and dune sands. Soils vary widely in their drainage — some are of moderately high natural fertility.

M Western South Island Recent Soils
Environment M consists of recent alluvial terraces along major rivers on the west coast of the South Island, occurring from Buller to southern Fiordland. The climate is mild with

low solar radiation, minimal water deficit and high monthly water balance ratio. Vapour pressure deficits are low, reflecting the high exposure to moist westerly winds. Landforms are generally gently sloping alluvial terraces formed from younger sands and gravels derived from schist, greywacke, granite or Tertiary rocks. Soils vary from very poorly to well drained and natural fertility is moderate.

N Eastern South Island plains

Environment N encompasses the extensive plains and inland basin floors of Canterbury, Otago and Southland. In Canterbury, this includes both the plains and the floor of the Waitaki Basin. In Otago, N extends from coastal areas north of Dunedin west to the Upper Taieri Plains and inland to the foot of the Southern Alps. A small area also occurs on the Waimea Plains in inland Southland. Environment N has a cool climate with moderate solar radiation, and moderate water and vapour pressure deficits. The terrain is generally flat to very gently sloping. Soils are mostly formed on alluvial sands and gravels derived from greywacke and schist, some of which are overlain with loess. They are generally moderately drained and of moderate natural fertility.

P Central Mountains

Environment P is one of the most extensive and widely occurring Level I land environments, including the mountains of central and southern North Island, Taranaki and northern and eastern parts of the South Island. In the western South Island, Environment P extends from the Abel Tasman National Park through the Tasman Mountains south to the Paparoa and Victoria ranges, with scattered occurrences in southern Westland. In the east it includes higher elevation parts of the Marlborough Sounds, extensive areas in the Richmond Range, and high-elevation sites from the Kaikoura Ranges south along the mountains eastward of the Main Divide to around Lake Ohau in the Upper Waitaki Basin. Further south from here it is largely restricted to middle elevations. The climate of Environment P reflects both its high elevation and, in the south, its partial sheltering from prevailing westerly winds by the Southern Alps. Temperatures are cold, with high annual and moderate winter solar radiation. Rainfall deficits are only slight, the average monthly water balance ratio is moderate and vapour pressure deficits are low. Landforms in Environment P mostly consist of mountains and steep, lower-elevation hills. Greywacke is by far the predominant soil parent material, along with granite, schist, Tertiary mudstones and sandstones and gravels. Soils are mostly well drained and of low natural fertility.

Q Southeastern Hill Country and Mountains

Q is the dominant environment of the mountains and hill country of the southeastern South Island, extending from the Rangitata River in South Canterbury through Otago to the Catlins in eastern Southland and westwards to the eastern fringes of Fiordland. The climate of Environment Q is cool, with low annual and winter solar radiation, reflecting its southern latitude. The climate is also strongly influenced by the sheltering effects of the Southern Alps, particularly to the north, resulting in low water deficits and moderate vapour pressure deficits — drier conditions than occur in most of New Zealand's other mountain environments. Landforms consist mainly of rolling to steep hills and mountains, but extensive areas of rolling downlands occur in the south. Parent materials

are mainly schist, greywacke and Tertiary rocks, extensive areas of which are loess-mantled. Substantial areas of alluvium from these rocks occur in the south, while other locally important parent materials include older basaltic and andesitic rocks and glacial till. The soils are generally moderately well drained, and are the most fertile of any mountain environment.

R Southern Alps
Environment R extends along the main divide of the South Island from the Spencer Mountains of inland Nelson south along the Southern Alps to the Fiordland Mountains. It also includes small areas on the crests of ranges both to the east and west of the Main Divide, including the tops of the Takitimu Mountains, Ben Ohau Range, and Richardson Mountains in the east, and the Paparoa and Victoria ranges to the west. The climate of Environment R is cold, with lower temperatures than in any of the other Level I land environments except Environment T, reflecting its average elevation of nearly 1100 m. This high elevation, coupled with its exposure to rain-bearing westerly winds, results in low solar radiation, very low water and vapour pressure deficits, and very high monthly water balance ratios. Average slopes are steeper in Environment R than in any other Level I land environment, with mountain landforms predominating. Dominant soil parent materials in Environment R are granite, greywacke and schist, with smaller areas of older volcanic rocks and gneiss. Soils vary in character depending on the parent material, but are generally very thin (skeletal) and sometimes peaty.

S Ultramafic Soils
Environment S, with its highly distinctive ultramafic rocks, occurs in several locations scattered through the western South Island, mainly in Nelson, Marlborough, South Westland and inland Southland. The most extensive area in the north occurs in the Red Hills at the western end of the Richmond Range. Smaller patches occur on D'Urville Island, on Dun Mountain east of Nelson City, and in the upper Takaka catchment. In the south, Environment S occurs on the Olivine Range in South Westland, in coastal parts of northern Fiordland, in the Humboldt Mountains, and in several locations from the Livingstone Mountains to West Dome near Mossburn. The only other area of ultramafic rocks in New Zealand occurs near North Cape, and is included in Environment A1. The defining feature of Environment S is its ultramafic parent material, i.e. igneous rock, generally coarse grained, low in silica, and with unusually high concentrations of iron and magnesium minerals. Soils formed on these rocks are generally of very low fertility with concentrations of minerals such as magnesium and nickel that are toxic to plants. They also tend to be shallow and have low amounts of clay-size particles and organic matter, resulting in low water- and nutrient-holding capacity. The climate of Environment S is cold, with high monthly water balance ratios and only slight water deficits, reflecting its mean elevation of around 900 m. Solar radiation is moderate, and vapour pressure deficits are low. Landforms are generally steep and mountainous. Soils are well drained but very infertile.

T Permanent Snow and Ice
Environment T consists of the ice caps and permanent snowfields of the Southern Alps. Although it has the highest mean elevation (1800 m) of any Level I land environment, it

includes features such as the Franz Josef and Fox Glaciers that extend to lower elevations. The climate is typified by very cold temperatures, very high precipitation, much of it as snow, very low vapour pressure deficits, and low levels of annual and winter solar radiation, particularly in the south. Slopes vary from undulating to very steep. No subdivision of Environment T has been made beyond Level I.

Indigenous cover

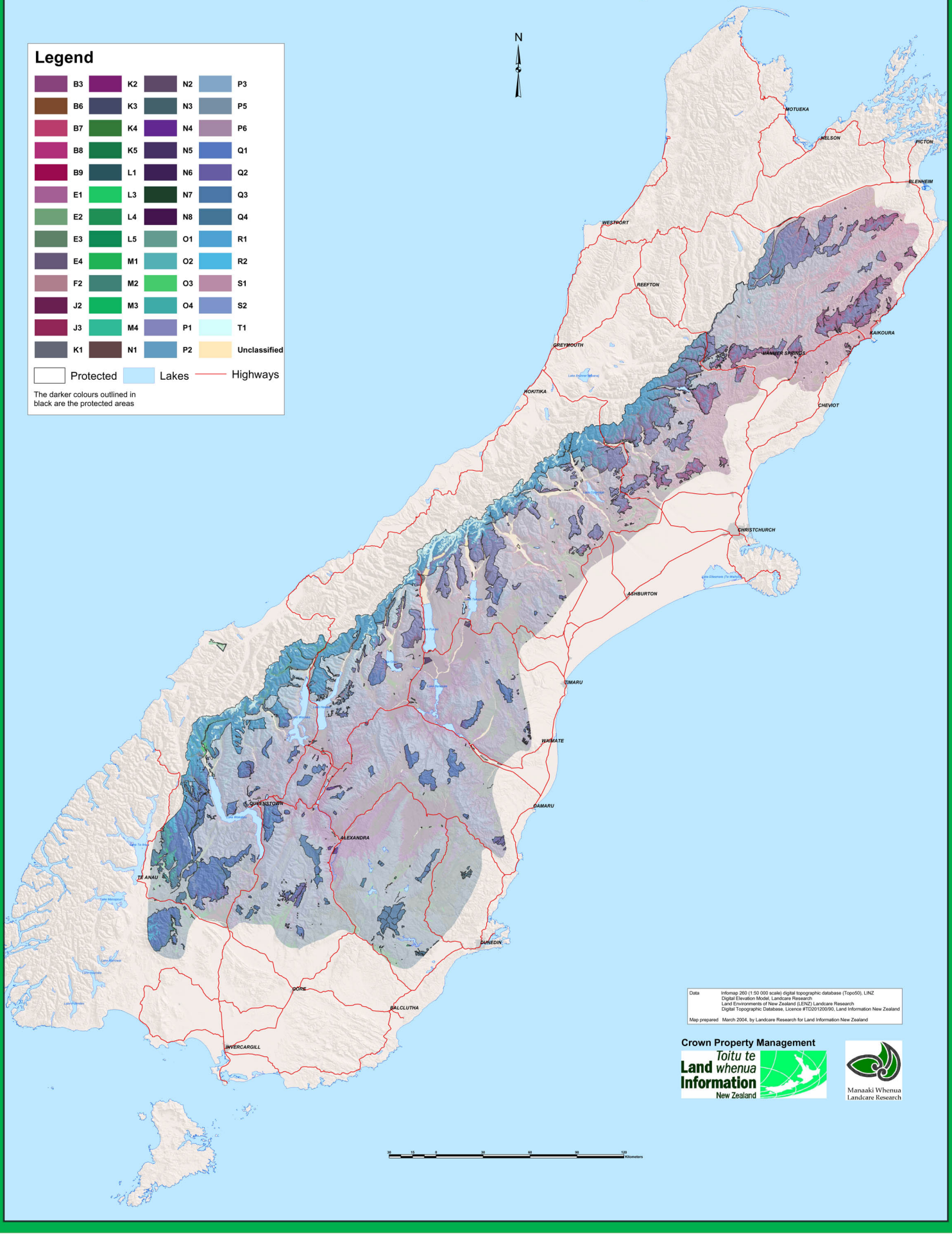
The following cover categories from the interim vegetation cover map (Newsome et al. 2003) are defined as predominantly indigenous for our purposes:

Beech Forest
Indigenous Forest (undefined)
Indigenous Scrub
Perennial ice and snow
Podocarp-Broadleaved Forest
Podocarp-Broadleaved-Beech Forest
Short Tussock Grassland
Tall Tussock Grassland
Tussock Grassland (undefined)
Tussock-Herbfield
Wetlands

Water Bodies and Bare Ground are not categorised.
The remaining seven categories of Newsome et al. (2003) are categorised as predominantly exotic vegetation cover.

MAP 1 DOC Protected Land

Level II Land Environments of South Island High Country



Data Infomap 260 (1:50 000 scale) digital topographic database (Topo50), LINZ
Digital Elevation Model, Landcare Research
Land Environments of New Zealand (LENZ) Landcare Research
Digital Topographic Database, Licence #TD201200/90, Land Information New Zealand

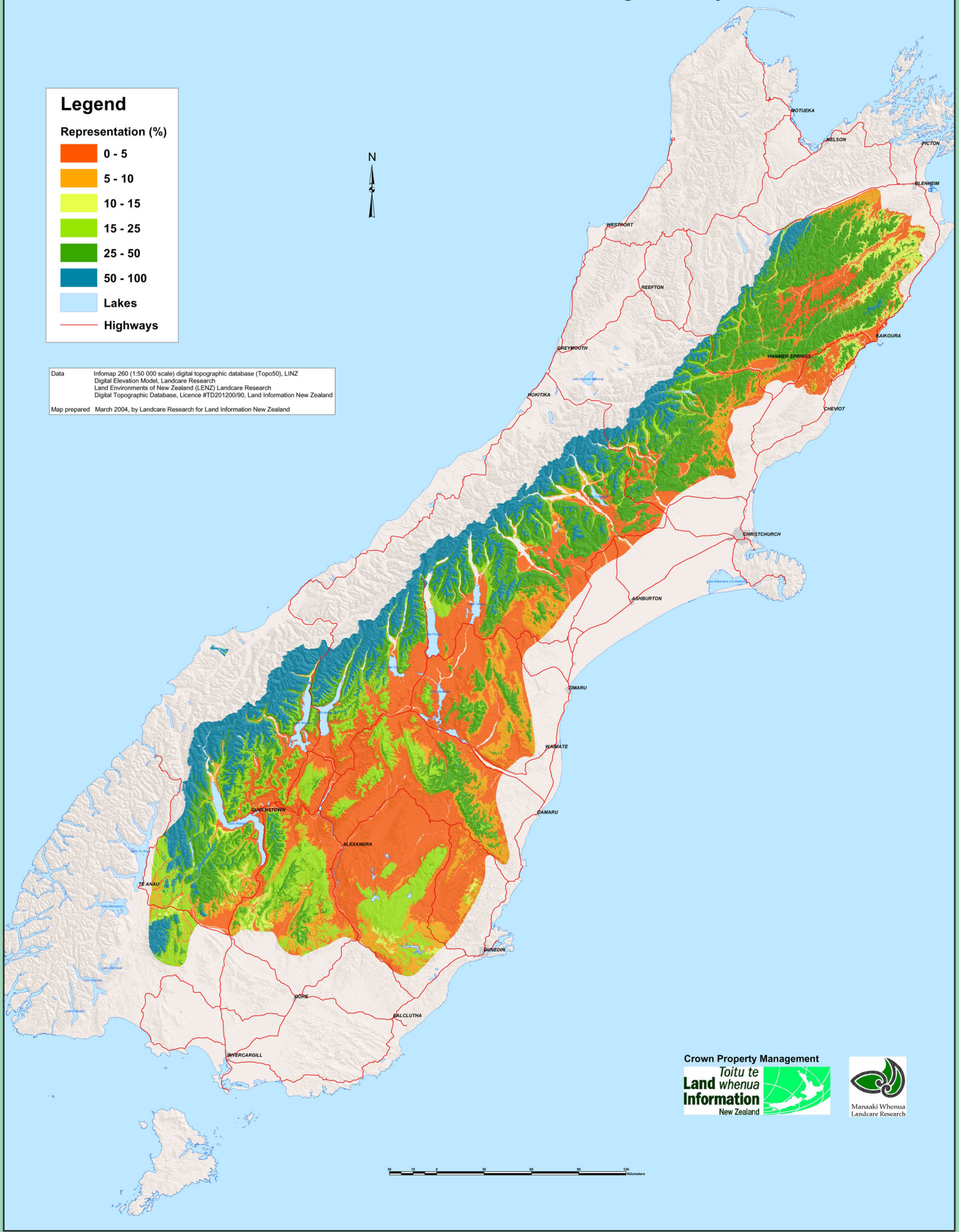
Map prepared March 2004, by Landcare Research for Land Information New Zealand

Crown Property Management

Toitu te Land whenua Information New Zealand

Manaaki Whenua Landcare Research

Map 2 Percentage of Land Environments Represented in New Zealand Protected Areas (LENZ Level IV):
Land Environments of the South Island High Country



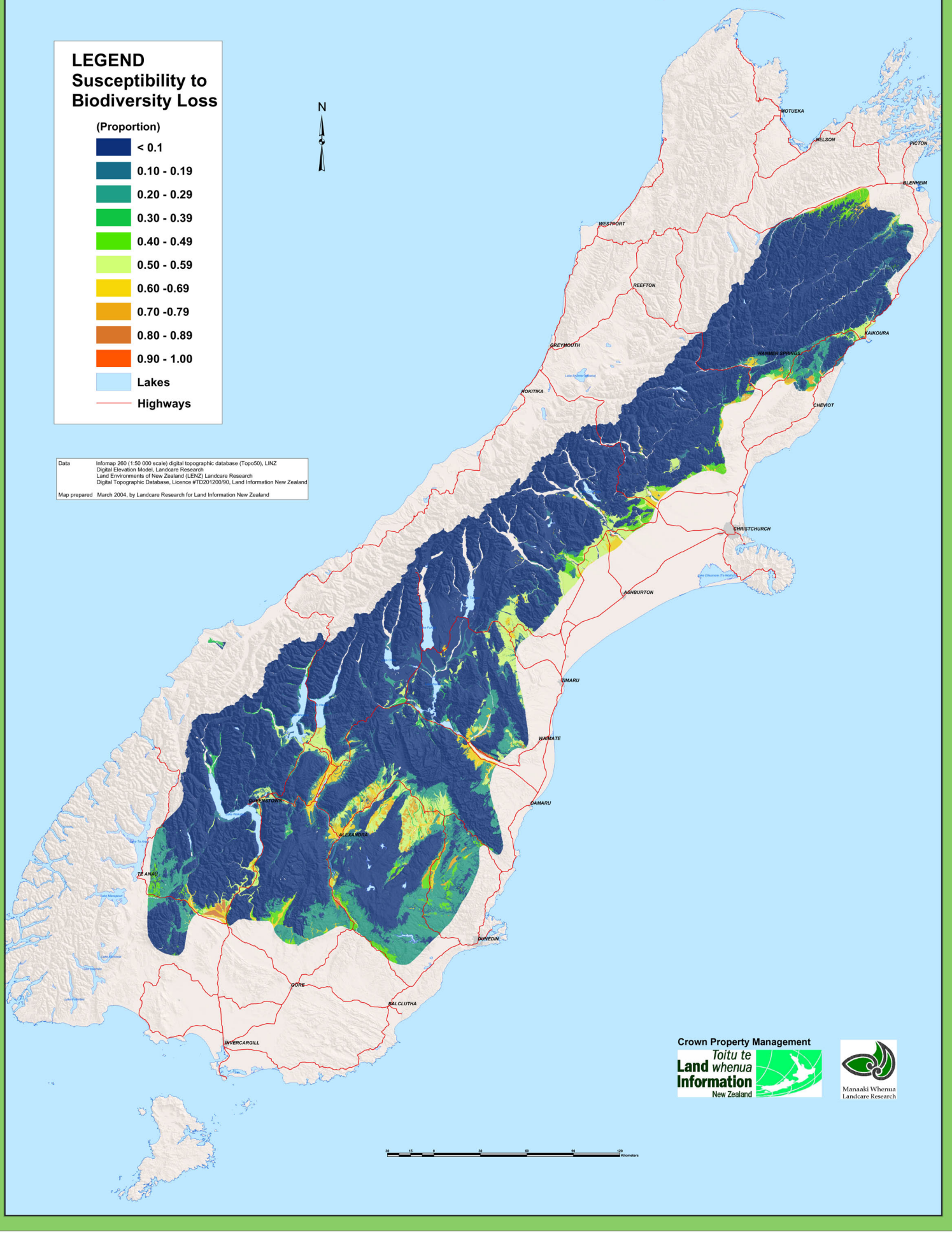
Crown Property Management

Toitu te Land whenua Information New Zealand

Manaaki Whenua Landcare Research

Map 3 Susceptibility to Biodiversity Loss

Level IV Land Environments of the South Island High Country



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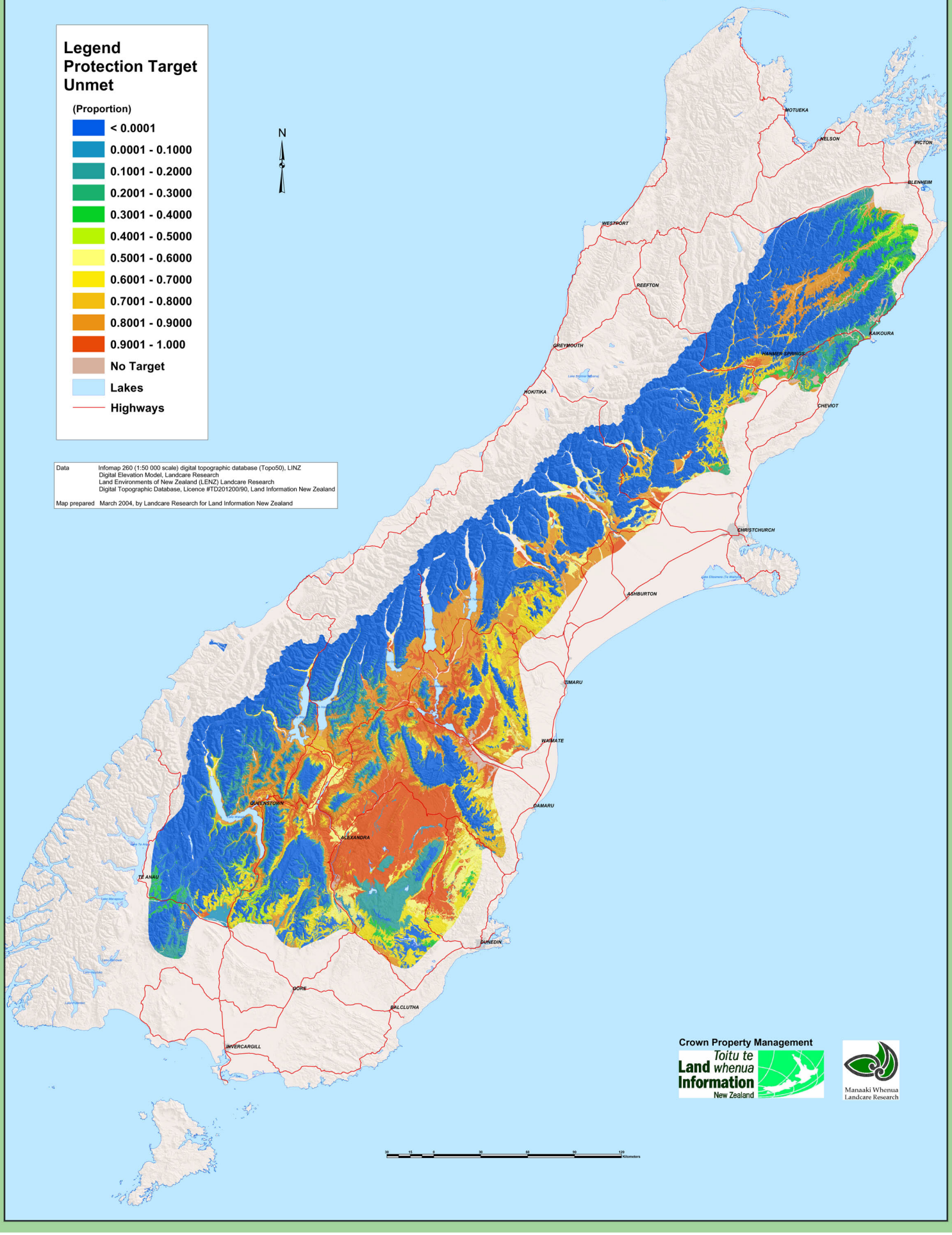
Manaaki Whenua Landcare Research

Map 4 Proportion of Protection Targets Unmet
Level IV Land Environments of the South Island High Country



Map 5 Vulnerability of Biodiversity
Level IV Land Environments of South Island High Country