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The Threatened Environment Classification for New Zealand 2012: a guide for users

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Summary

This document provides guidance for users of the Threatened Environment Classification, which was developed by Landcare Research to help identify places in New Zealand in which the terrestrial indigenous ecosystem, habitat, and community types are both much reduced and poorly protected nationally. The classification has been updated to 2012, incorporating recent national spatial databases of land cover and protected areas.

Part One of this guide introduces the Threatened Environment Classification. Part Two presents more detailed and technical material as background to its appropriate use and applications. Part Three describes different ways to access the Threatened Environment Classification, and provides a glossary of terms and a guide to links, materials and supplementary information that users may find helpful.

The Threatened Environment Classification 2012 combines data from three national databases – the Land Environments New Zealand (LENZ), the Land Cover Database (LCDBv4.0, based on 2012 satellite imagery), and a 2012 update of the national protected areas network – into a simple six-category GIS tool. 'Threatened environments' (categories 1–5) are those environments in which much (>70%) of the original indigenous cover has been cleared and/or low proportions (<20%) of land is legally protected for natural heritage. Category 6 includes environments in which indigenous cover has been less reduced (>30% of indigenous cover remains) and more than 20% of the land area is protected for the primary purpose of maintaining its natural heritage.

The Threatened Environment Classification is most appropriately used to provide information on the loss and protection context of indigenous biodiversity components identified on the ground. In conjunction with site surveys, it can help to identify places that are priorities for formal protection against clearance and/or incompatible land uses, and for ecological restoration of lost species, linkages, and buffers. Inappropriate use may result if the principles and limitations of the underlying data are misunderstood.

The 2012 update of the Threatened Environment Classification is freely available for use by the public and organisations, and can be readily accessed online.

Background

The indigenous ecosystems, habitats and communities of many of New Zealand's mainland coastal, lowland and montane environments have been substantially reduced in area and altered by human impacts. Areas of habitat for indigenous species that remain in these environments today are often highly modified and degraded from their original states. Relatively few areas are securely protected against development and clearance by either private or public mechanisms, and they are therefore vulnerable to ongoing loss and degradation. In this guide, we refer to environments where indigenous cover has been much reduced, and/or where there is little legal protection for natural heritage, as 'threatened environments'.

Despite their often poor condition and high degree of modification, remaining areas of habitat in threatened environments are generally important for maintaining the full range of biodiversity that remains in New Zealand. This is because they support components of New Zealand's indigenous biodiversity that are either absent, or seldom occur, in more remote and

well-protected forested and alpine environments. Threatened environments are the only places where a high proportion of New Zealand's most threatened ecosystems, habitats, communities and species are to be found. Furthermore, populations of relatively common species in threatened environments may represent ecotypes (populations with adaptations to particular environmental conditions) that are now uncommon across the country.

The importance of habitats in threatened environments was recognised in the New Zealand Biodiversity Strategy (DOC & MfE 2000), in which the first priority action for biodiversity on land is to formally protect *'…those habitats and ecosystems important for indigenous biodiversity that are not represented within the existing protected area network or that are at significant risk of irreversible loss or decline…'*. The Threatened Environment Classification was developed to provide a context that can assist users to identify these places. The first version of the Classification was released in 2006 (Walker et al. 2005, 2006). It was made freely available and has been used by a variety of New Zealand organisations and individuals to provide information on the loss and protection context of indigenous terrestrial biodiversity components identified on the ground.

A series of workshops was held around the country in 2007 to transfer the Classification to local, regional and central government agency users, and a supporting user guide was produced (Walker et al. 2007). Also in 2007, indigenous vegetation in first two categories of the Threatened Environment Classification was identified as a non-statutory national priority for biodiversity protection on private land (MfE 2007), which is *"[t]o protect indigenous vegetation associated with land environments, (defined by Land Environments of New Zealand at Level IV), that have 20 percent or less remaining in indigenous cover."* The MfE (2007) national priorities have been incorporated into a variety of environmental policies and plans across New Zealand.

In 2014, a major update of the Threatened Environment Classification ('Threatened Environment Classification 2012') was made possible by updates of the national land cover and natural heritage protection databases that inform it. The update is described in a journal paper (Cieraad et al. 2015).

This document introduces the 'Threatened Environment Classification 2012' and provides a user guide. Terms used in this guide are defined in the 21.

1 Part One: Introduction

1.1 What is the Threatened Environment Classification?

The Threatened Environment Classification is a source of broad, national-scale background information about land in New Zealand. Specifically, the Classification indicates:

- how much native (indigenous) cover remains within land environments
- how much land is legally protected (for the purpose of protecting natural heritage), and
- how past loss of indigenous cover and natural heritage protection are distributed across New Zealand's landscape.

The Classification combines this information into a simple and practical GIS tool with just six categories of land environments. 'Threatened environments' (categories 1–5) are those in which much (more than 70%) of the former indigenous cover has been cleared and/or only a small proportion (less than 20%) of land is legally protected for natural heritage purposes (Table 1). The sixth category includes environments in which indigenous cover has been less reduced (more than 30% remains) and relatively greater proportion of the land area (more than 20%) is protected for the purpose of maintaining its natural heritage.

Table 1 The six threat categories

Category	Category name and criteria
1	<10% indigenous cover left
2	10–20% indigenous cover left
3	20–30% indigenous cover left
4	>30% left and <10% protected
5	>30% left and 10–20% protected
6	>30% left and >20% protected

This guide refers to the categories in Table 1 as 'threat categories'. The first five categories are likely to contain some of the most severely reduced and poorly protected of New Zealand's ecosystems and habitats, and are collectively referred to as 'threatened environments'.

Criteria for each category (e.g. <10% indigenous cover left) are now used as descriptive names. We no longer use names mirroring classes in the former New Zealand Threat Classification System (e.g. 'Acutely Threatened'), which appeared in early versions of the Classification (e.g. Walker et al. 2005, 2006; tables 1 & 2 and fig. 1 of Walker et al. 2007).

The Threatened Environment Classification is most appropriately used to provide information on the loss and protection context of indigenous biodiversity components that are identified

on the ground. In conjunction with site surveys, it can help to identify places that are priorities for formal protection against clearance and/or incompatible land uses, and for ecological restoration of lost species, linkages and buffers. It can also be used as a framework for biodiversity planning, implementation and reporting.

Problems may arise if the Threatened Environment Classification is used inappropriately because the principles or limitations of the underlying data are poorly understood. These principles, the limitations of the underlying datasets, and their implications for appropriate use are described in Part 0 of this guide.

1.2 Data combination and use in the Threatened Environment Classification

The Threatened Environment Classification 2012 is a combination of three national databases:

- the Land Environments of New Zealand (LENZ; Leathwick et al. 2003). The Classification uses Level IV of LENZ, which defines 500 environment units across New Zealand's three main islands
- cover classes of the fourth land cover database (LCDBv4.0) assigned to either an 'indigenous' or an 'exotic' category, and
- the protected areas network, identifying areas legally protected for the purpose of natural heritage protection.

The Land Environments of New Zealand are used to represent New Zealand's terrestrial biodiversity pattern. Land environments are classified at four different national scales: Level I (20 land environments, A to T); Level II (100 land environments, A1 to T1); Level III (200 land environments, A1.1 to T1.1); and Level IV (500 land environments, A1.1a to T1.1a), in a nested hierarchy. Level IV is used for the Threatened Environment Classification because it best reflects the environmental differences that drive biodiversity patterns as well as patterns of past and present land clearance in the landscape (Walker et al. 2005). Rivers, lakes, and marine ecosystems (i.e. non-terrestrial ecosystems) are not displayed or incorporated into the Threatened Environment Classification.

In the Threatened Environment Classification, the total area of 'indigenous' cover classes within a land environment is used as a surrogate for the area on which components of New Zealand's indigenous biodiversity still remain. These biodiversity components are assumed to include indigenous ecosystems, habitats, and communities, and the indigenous species, subspecies, varieties, and genetic diversity they support. The percentage of a land environment that no longer supports indigenous cover is used to indicate the relative magnitude of clearance and loss of terrestrial biodiversity components within that environment the past.

The percentage of the land environment covered by legal protection for the purpose of natural heritage protection is used in the Threatened Environment Classification as a surrogate for the relative vulnerability of the remaining components of indigenous biodiversity to pressures such as land clearance and incompatible land uses.

1.3 Mapped examples

The six-category Threatened Environment Classification greatly reduces the complexity of the 500 Level IV units of LENZ, while also adding utility by providing relevant information about the status and protection of indigenous biodiversity within each environment 'from North Cape to the Bluff'.

Figure 1 illustrates how the three different layers of information (Level IV land environments, and land cover and protected area percentages) are combined in the Threatened Environment Classification.

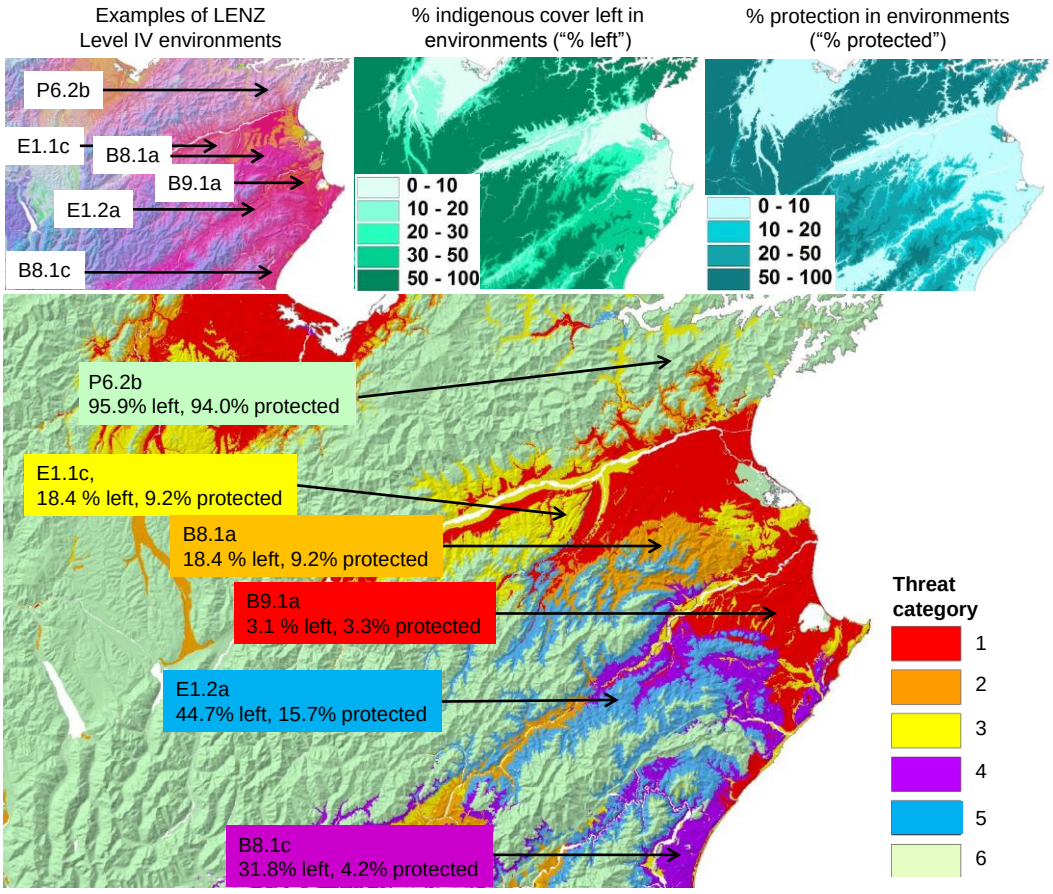

Figure 1 Threatened Environment Classification 2012 for Marlborough. This example shows the underlying data layers (insets) and the classification that results from their combination (main map). Six of the many land environments are highlighted as examples. Users can create their own maps of threatened environments at http://ourenvironment.scinfo.org.nz/ (as explained in Part Three).

When loaded into a GIS or viewed as a map, this information can be absorbed at a glance. Figure 1 shows that the coastal plains of the Wairau and Awatere rivers have been cleared of most of their former indigenous cover (land environment B9.1a, threat category 1 in red, <10% indigenous cover remaining). Any remaining indigenous patches among the agriculture, exotic forestry, and settlement land uses that now prevail represent some of the last components of indigenous biodiversity present on this land environment.

Figure 1 also shows that much clearance and conversion of indigenous vegetation has also occurred on valley floors and gently rolling country, and the foothills of ranges adjoining the Wairau Valley (Categories 2 and 3, in orange and yellow, less than 20 and 30% indigenous cover remaining, respectively).

South of the Wairau Valley, foothill environments of the Awatere, Flaxmore, and Clarence valleys retain somewhat more (>30%) indigenous cover than those in the Wairau, but legal protection for natural heritage in these environments is limited (Categories 4 and 5, in purple and blue).

In contrast, environment P6.2b north of Blenheim in (Category 6, in light green) largely falls within the legally protected Mount Richmond Forest Park. Most of this rugged hill country environment remains under indigenous cover and is protected.

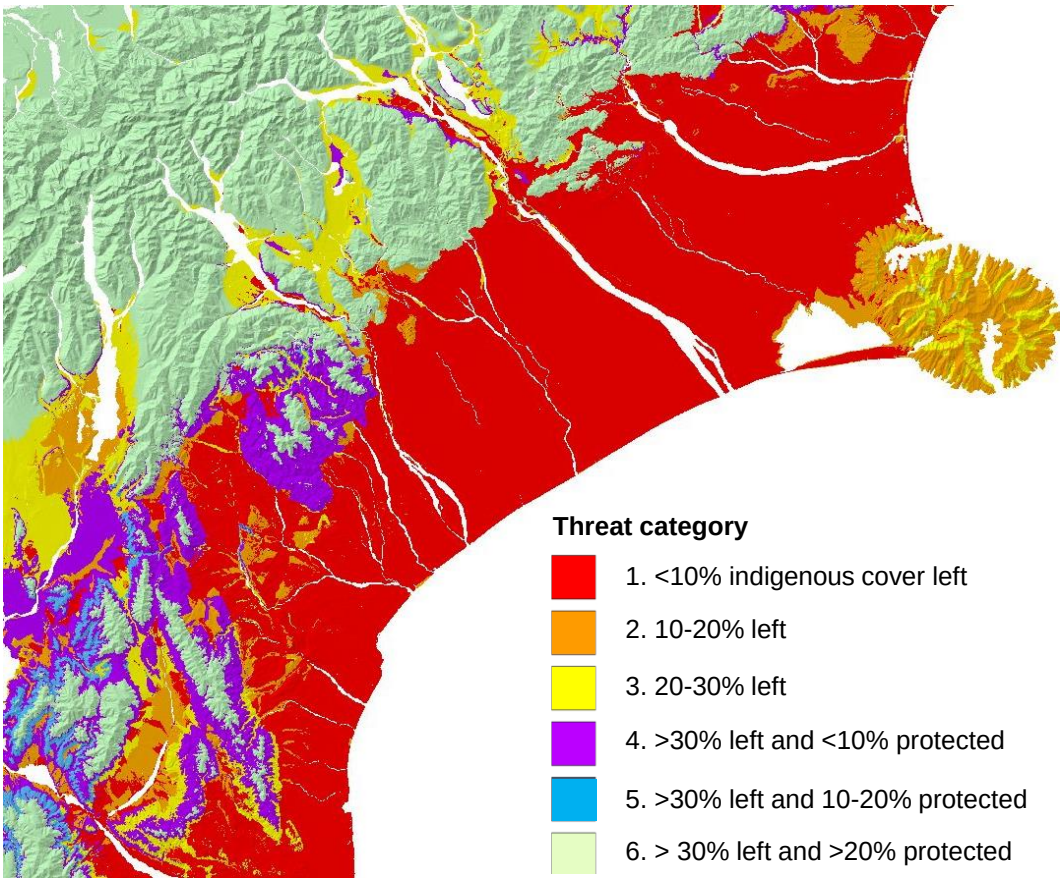

Figure 2 Threatened Environment Classification 2012 showing the pattern in Canterbury.

Our second example (Fig. 2) shows the loss and protection contexts of some Canterbury environments at a glance:

- The red colour indicates that flat, lowland environments (such as those on the Plains and coast of Canterbury) retain less than 10% of their land area under some form of indigenous cover (Category 1).

- The more accessible environments on Banks Peninsula are coloured orange because they have retained somewhat more (between 10 and 20%, Category 2) indigenous cover than the Plains.
- The yellow colour indicates two very different types of Category 3 environments (the fluvial valley floors of rivers draining east from the Southern Alps, and the volcanic ridges of Banks Peninsula) retain somewhere between 20% and 30% of their area under some form of indigenous cover..
- Environments of lower hillslopes of eastern mountain ranges (in purple) retain somewhat more than 30% of their land area under indigenous cover, but natural habitats are formally protected over less than 10% of their land area.
- The indigenous cover of cooler, steeper, and wetter environments of the ranges west of the Plains (in green) has been less reduced and better protected in the past.

1.4 Versions of the Threatened Environment Classification

The first Threatened Environment Classification was released in 2006, which reflected the national land cover database derived from satellite imagery captured in 2001/02, and protected areas in 2004. A revision of the classification has been made possible by the release of the updated national land cover database 'LCDBv4.0'derived from satellite imagery captured in 2011/12. An updated national spatial database of protected areas in 2012 was assembled concurrent with the most recent satellite imagery. The combination of these databases with New Zealand's land environments constitutes the "Threatened Environment Classification 2012".

2 Part Two: Principles, data, and limitations

This part of the guide describes the policy motivation and the conservation and ecological principles behind the Threatened Environment Classification. It then describes how the available data sources are used in the Classification, as well as their limitations. Some inappropriate ways to use the Classification are also listed.

2.1 Strategic, conservation and ecological principles

Representation across environmental space

The motivation for developing the Threatened Environment Classification was to help identify '*…those habitats and ecosystems important for indigenous biodiversity that are not represented within the existing protected area network or that are at significant risk of irreversible loss or decline…*' and thereby give effect to the first priority action for biodiversity on land in the New Zealand Biodiversity Strategy (DOC & MfE 2000).

The Classification uses two assumptions: 1) that the physical ('abiotic') environment is a major driver of both biological diversity and the human impacts of habitat clearance and modification upon it; and 2) retaining potential for indigenous species to persist across a full range of environmental conditions is required to maintain biological diversity.

The Classification also follows the basic conservation principle that the highest priorities for protection are components of biodiversity that are both most 'irreplaceable' (rare or much reduced) *and* most vulnerable to future loss (Margules & Pressey 2000). Some types of natural habitats and ecosystems, and the species and genetic types they contain, are both rarer and less likely to persist than others, because they compete with incompatible human uses of the same portion of 'environmental space'. In New Zealand, many irreplaceable and vulnerable biodiversity components are found where land clearance has largely eliminated indigenous ecosystems and species habitats in the past, and where it is now progressing into more marginal environments (e.g. Weeks et al. 2012). New Zealand's steepest, coldest, and wettest environments still experience relatively little direct habitat loss.

Figure 3 illustrates the concepts of geographic and environmental space, and the highly skewed pattern of indigenous habitat loss and protection across both types of space in New Zealand. To create the Figure, we 'sampled' eight variables (slope, elevation, and six measures of climate) across New Zealand at the intercepts of a 10-km grid. We then plotted all pairs of variables against one another, distinguishing the Threatened Environment Classification category at each point by colour.

The non-random patterns of colour in the scatterplots illustrate how much the threatened environments are clustered in New Zealand's environmental space, as well as in geographic space (the two-dimensions shown by a map). In particular, the scatterplots show that high rates of habitat loss and/or low rates of legal protection for natural heritage are features of all of New Zealand's environments that are flat (low **slope** in Fig. 3), low (low **elevation** in Fig. 3) and dry (high deficit and vpdef in Fig. 3), and those that also have highly seasonally variable rainfall (high **rnvar** in Fig. 3).

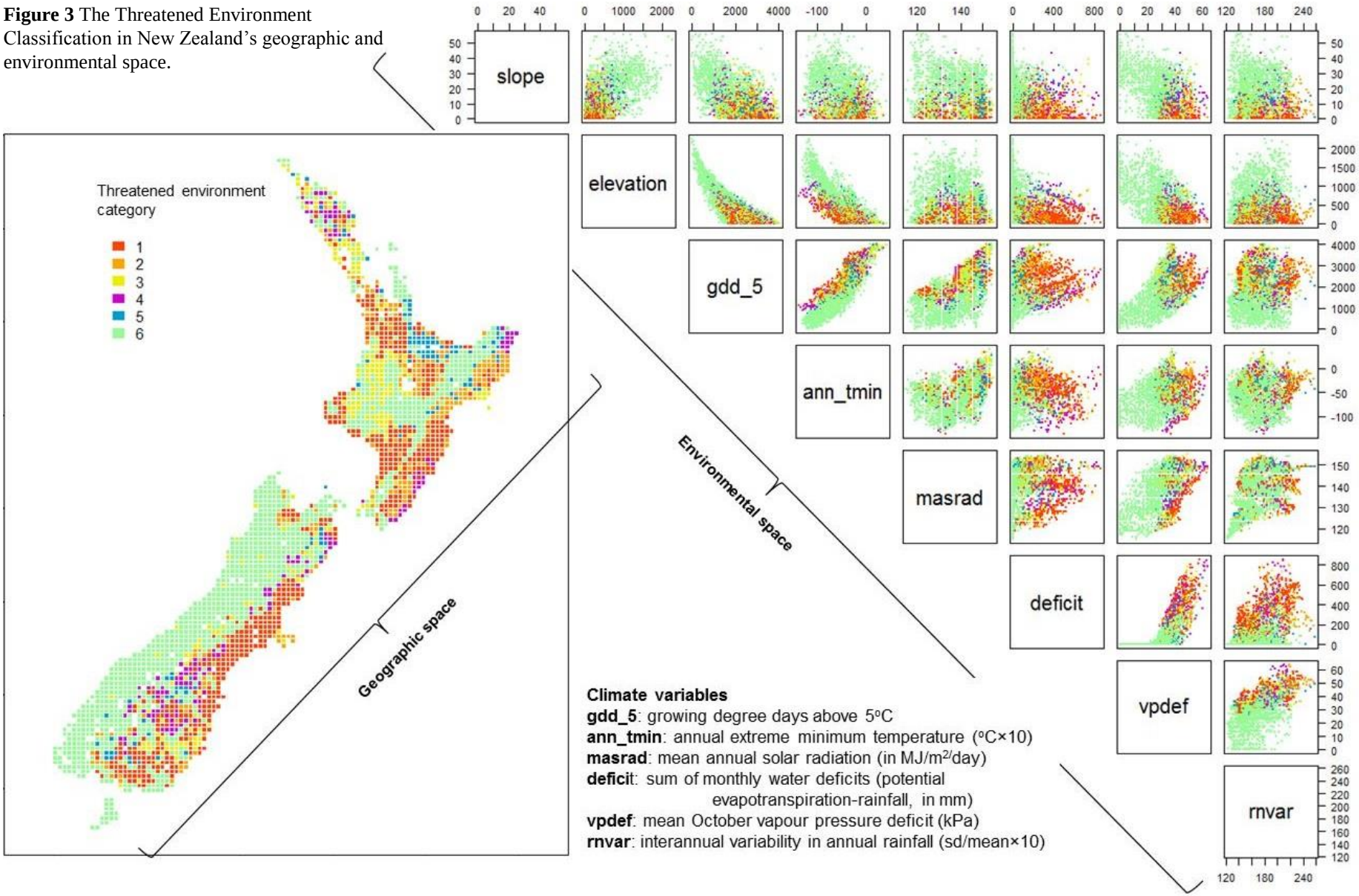

Figure 3 The Threatened Environment Classification in New Zealand's geographic and environmental space.

These environmental features (the combination of flatness, lowness and dryness with rainfall variability) are represented only in threatened environments. Likewise, components of New Zealand's biological diversity that are specialised for, and adapted to, dry and seasonal conditions are only to be found in much reduced and poorly protected environments.

Figure 3 shows that there are no less-reduced and better-protected environments (Category 6, represented by pale green) that have a combination of low slope (low **slope** in the top row in Fig. 3), low elevation (low **elevation** values in the second row), high soil and vapour pressure deficits (values towards the right in the **deficit** and **vpd** columns, respectively), and high interannual rainfall variability (values towards the right in the **rnvar** column). Conversely, there are no threatened environments that are steep, high, cold, and wet, and that have reliable annual rainfall.

Accelerating loss and degradation with increasing habitat loss

Through its focus on environments in which indigenous cover has been most reduced, the Threatened Environment Classification recognises that loss and degradation of biodiversity components accelerate as habitat loss advances. Species are lost, the physical and biological condition of habitats is modified, and there is a breakdown in connectivity among remaining patches which is needed for resilience and persistence. All happen at an increasing pace.

It has long been known that there is a non-linear relationship between an area of habitat and the number of species found within it (called the species-area relationship or SAR). A 'power curve' form of the SAR is very common ($S = cA^z$, where S is number of species, A is area, c is a constant and z is the exponent that determines the shape of the curve). The amount of curvature varies with evolutionary context (islands often have flatter curves – higher z-values – than continents; Rosenzweig 1995; Triantis et al. 2008) and with the type of biota (e.g. animals, plants, and microorganisms). However, the overall non-linear form of the curve is remarkably constant across ecological studies. Monks et al. (2010) fitted and validated a species-area relationship for the number of plants in habitat fragments across South Island New Zealand, which showed the classical power-curve shape and had a z-value of 0.377.

When habitat is lost, species are also lost at increasing rates. Theoretically, these rates of species loss are *not* expected to mirror the SAR for the same habitat, but rather to follow another relationship called the endemics-area relationship or EAR (He 2012; Tanentzap et al. 2012). However, like SARs, EARs are usually strongly non-linear and broadly approximate power curves, with each increment of further loss tending to result in a greater magnitude of eventual loss of remaining species (Figure 4).

An important feature of the theoretical endemics- area relationship is that it predicts the extinction of species (or conversely the proportion of species remaining) only at the instant that habitat loss occurs (He 2012; Tanentzap et al. 2012; Pimm & Brooks 2013). It does not account for any later extinction (also known as extinction debt) that may be caused by habitat removal but follow. Extinction debt (a term coined by Tilman et al. 1994) arises because habitat fragmentation and the loss of some but not all individuals within a population can commit species to extinction before all individuals in a population have died. These additional extinctions are expected to be realised over time, and therefore EARs only predict the minimum number of extinctions that will occur (Tanentzap et al. 2012). Near-term

extinctions arising from extinction debt can be larger, sometimes much larger, than the instantaneous extinction rates predicted by EARs (Kuussaari et al. 2009; He 2012).

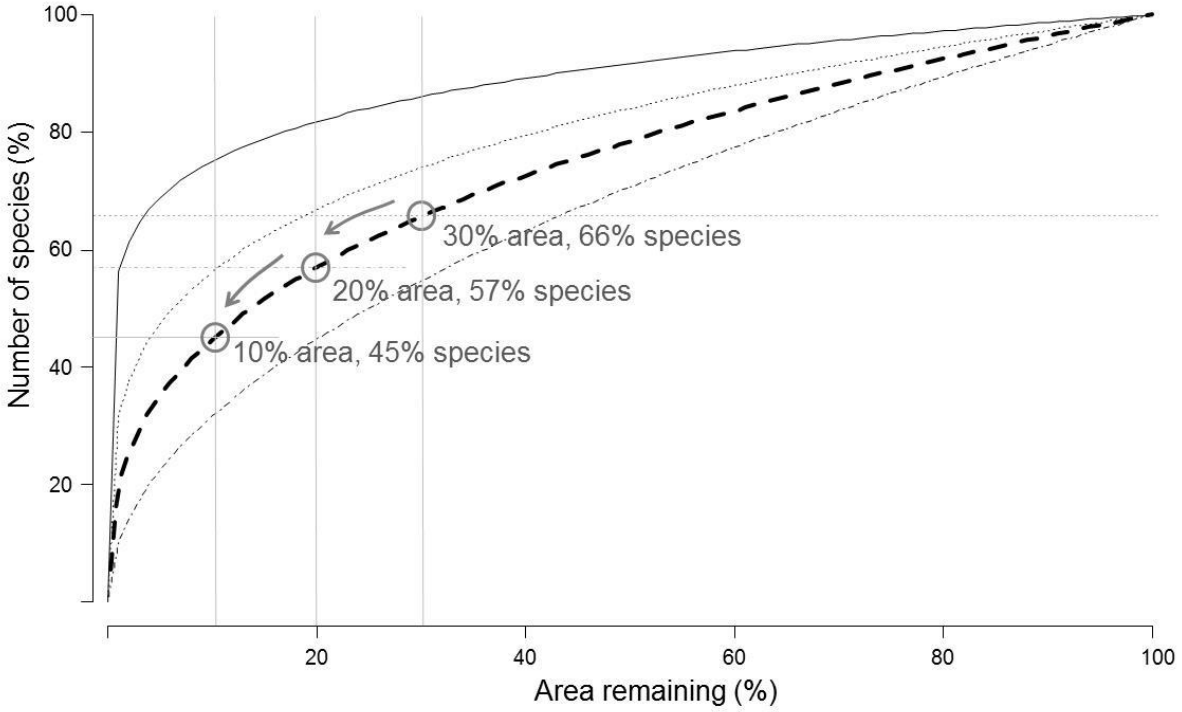

Figure 4 Four hypothetical endemics-area relationships (EARs) approximating power curves. The curves estimate the percentage of original species that will remain the instant after the removal of a given percentage of habitat area. The horizontal grey lines indicate the proportion of species predicted to remain the instant after 70% and 80% of the habitat is removed, leaving 30 and 20% of area remaining (grey vertical lines), assuming the EAR indicated by the bold dashed line. EARs do not account for or anticipate extinction debt (that is, further loss of species committed to extinction by the removal of habitat, but not lost immediately).

By reducing the size of remaining species populations, habitat loss increases their susceptibility to future extinction because small populations are more likely to suffer demographic fluctuations and genetic drift, and are more vulnerable to chance environmental events (Lande 1988, 1993). Communities in small, isolated fragments also receive fewer immigrant species to balance these elevated extinction rates, as predicted by island biogeography theory (MacArthur & Wilson 1967).

Ecosystems and habitats also become more fragmented as loss advances, and this alters their physical and biological characteristics (Fahrig 2002; Fraser et al. 2014). For example, habitat patches develop longer edges relative to their total area resulting in smaller buffered core areas. These changes are also non-linear and accelerating (Fahrig 2002). Conditions within fragments are also changed by flows of nutrients and incursions of diseases, competitors and predators from the matrix in which fragments are embedded (e.g. Gibson et al. 2013; Fraser et al. 2014). These changes may affect ecological processes such as germination or birth rates, survival, and growth, and flow through to changes in the composition and dominance of resident species.

Progressive removal of indigenous habitat also increases distances between habitat patches, and isolation increases rapidly once the percentage of habitat remaining drops below about 25 to 30% of the landscape (Andrén 1994; Collingham & Huntley 2000). Isolation reduces the movement of individuals and genetic material between patches needed to maintain species populations and their viability (Hanski 1998). This further compromises the persistence of remaining species and the ecological functioning in the remaining communities (Fraser et al. 2013).

Implications

To retain completely healthy functioning habitat and community states and their full species diversity, it is necessary to halt habitat loss before accelerating degradation processes begin. Nevertheless, international experience suggests protecting and maintaining modified patches of indigenous habitats in extensively cleared land environments is extremely important for maintaining biological diversity (e.g. Turner et al. 1996; Bodin et al. 2006; Saura et al. 2014).

This is also likely to be the case in New Zealand.

First, many of New Zealand's most threatened ecosystems, habitats, communities, and species are now found only in threatened environments. Remaining patches of indigenous vegetation in extensively cleared land environments are modified, but represent the few last remaining examples of habitat types, communities, and species indigenous to New Zealand's flat, low, dry environments.

Second, the environmental space that has become much reduced and is now poorly protected in New Zealand is strongly differentiated from the space that is less reduced and better protected. Populations of common species in threatened environments are therefore likely to represent genetically distinct geographic varieties or races that are adapted to specific environmental conditions (known as 'ecotypes') and are now uncommon across the country. In New Zealand, it is in threatened environments that species populations are most likely to have adaptations to the drier and more-variable climatic conditions expected under future climate change across many parts of the country.

Finally, maintaining modified habitat patches in extensively cleared land environments is important because the loss and degradation of biodiversity components is expected to accelerate as habitat loss advances. Small additional losses of habitat area are predicted to lead to increasingly large additional effects on the persistence and viability of biota in other remaining patches once habitat loss becomes advanced.

2.2 Use of data in the Threatened Environment Classification

Representing a 'full range' of terrestrial habitats and ecosystems

The LENZ classification (Leathwick et al. 2003) describes the diversity of New Zealand's terrestrial environments, based on physical (abiotic) information only (climate, soil, and landform). Parcels of land within the same LENZ environment share similar environmental conditions. Variation in most of the underlying environmental factors is continuous, and, like any classification, the LENZ units simply provide a way of imposing a convenient structure

of classes upon it. Many of the changes that distinguish environments will be gradual and therefore not able to be seen on the ground.

LENZ is used in the Threatened Environment Classification as a surrogate for the potential 'full range' of terrestrial ecosystems and species habitats once found across New Zealand. Because abiotic factors are major drivers of the patterns of most living organisms, we assume that different land environments potentially supported assemblages of ecosystems, habitats and species in the past which differed somewhat from those in other environments. Just as in LENZ, the units of the Threatened Environment Classification are simply used as one of many possible alternative categorisations of continuous variation in potential biological character across New Zealand.

An additional convenient feature of LENZ for our purpose is that the abiotic factors are good predictors of the patterns of human land use (Leathwick et al. 2003), and therefore of the risk to indigenous biodiversity components from land conversion.

As described above, the Threatened Environment Classification uses LENZ level IV environments (500 nationally) because they best reflect the scale of environmental differences that drive biodiversity patterns, as well as patterns of past and present land clearance in the landscape (Walker et al. 2005).

Representing risk to remaining ecosystems, habitats and communities

The Threatened Environment Classification uses past habitat loss and poor legal protection within New Zealand's land environments to indicate where ecosystems, habitats and communities that are at risk are likely to be found.

Past habitat loss

The level of past habitat loss in a land environment is used as the primary indicator of risk. Past habitat loss is indicated by the percentage of the total area of a land environment which, according to the Land Cover Database, remains under an 'indigenous' land cover class.

The Classification groups environments into uses four cover-loss categories (>30% indigenous cover left, 20–30% cover left, 10–20% cover left, and <10% cover left). These thresholds were chosen to be easy to remember, and follow logically from the pattern of accelerating risk to biodiversity components as habitat loss advances. Biodiversity components become more irreplaceable and vulnerable to further loss as habitat loss increases, so there is no 'safe' level of loss.

The Threatened Environment Classification applies thresholds to individual land environments (LENZ Level IV units). The use of higher loss-thresholds might be warranted if habitat loss occurred at random across environmental space, so that similar environments sharing biodiversity components had different amounts of loss. In this situation, reservoirs of similar biological communities and species in similar nearby environments might dampen losses of species and connectivity. However, loss in New Zealand has been far from random. As Figures 1, 2 and 3 indicate, similar and adjacent environments have generally undergone losses of similar magnitudes.

Protection from loss

Our secondary indicator of risk is how well the ecosystems, habitats, and biodiversity associated with an environment are protected from further loss. For this, the Classification uses the percent area of land within a land environment (which may or may not be indigenous cover) that is formally protected. The Classification regards land to be formally protected if it has legal designation that provides for the conservation of its natural heritage (including biodiversity) such as a covenant on the title of private land, reserve, or conservation area.

We assume that in areas where more than 30% of the land still remains under some form of indigenous cover, biodiversity components are more at risk of loss and decline if little of the environment has formal protection for natural heritage purposes. This is because protected ecosystems, habitats, and communities are less likely to be cleared for commercial land uses (Walker et al. 2006; Weeks et al. 2012). Furthermore, their greater long-term security makes it more likely they will receive investment in conservation management (e.g. fencing, pest and/or weed control). Land environments that have more than 30% of their land area under indigenous cover are assigned to threat category 4 if they have <10% of their land area protected, and to category 5 if they have 10–20% protected.

2.3 The data sources and their limitations

The Threatened Environment Classification provides national-scale information on habitat loss and protection in a way that is consistent across New Zealand, because it treats all areas (or land environments, as they are called) on the same basis. It is based on data rather than opinion, and is repeatable, because the national datasets that inform it are available, and the results can be reproduced.

However, users should be aware that estimates of remaining cover and protection within environments from existing national databases are unlikely to be precise. Therefore there is some uncertainty in the assignment of environments to threat categories within the Classification. This section describes and explains some of the most important features, limitations, and implications of the underlying data that must be recognised and taken into account when using the Threatened Environment Classification.

The Land Environments of New Zealand (LENZ) is a classification of present environments (climate, soils, and landform). It is not a classification of ecosystems, vegetation communities, or a combination of vegetation and landform like other classifications that have been used in ecology in New Zealand (such as land systems). Instead, LENZ is built on physical factors only. Many of these cannot be seen by an observer, and change continuously along gradients (such as temperature, rainfall, and solar radiation). Others can be seen (slope) and a few may have sharp boundaries that can be seen (for example, some soil factors, often observed in their effects on vegetation). Because boundaries between environments generally divide gradual, continuous climatic gradients, it is no more realistic to expect LENZ boundaries to be seen on the ground than to expect a landscape of 20-m steps based on contour lines. Rather, habitats and ecosystems in one environment are likely to grade continuously into those of adjacent environments.

Land environments are not uniform entities, and even at the finest level of LENZ (Level IV) a land environment will be capable of supporting a variety of different natural communities

and ecosystems. Indigenous cover and protection statistics for a land environment are an average taken across the different native habitats and ecosystems contained within it.

The diversity of living ecosystems and habitats remaining within environments today is a product of large-scale and local variations in the environment and the influence of recent and more ancient historical events. Because LENZ takes account of history only indirectly (e.g. through soil and landform characteristics) distinctive biogeographic types may not be discriminated. For example, in the Waikato Region, LENZ does not distinguish volcanic cones of different geological ages that support different and distinctive communities. It is therefore possible that certain biodiversity components in that Region are more or less threatened than indicated by the Classification.

Not all environmental factors that influence biodiversity pattern were included in the creation of LENZ and the resolution of the underlying variables is limited. For these reasons, LENZ generally fails to distinguish ecosystems and habitat types arising from local-scale or extreme environmental conditions. Poorly discriminated habitats include many 'naturally uncommon ecosystems' (Williams et al. 2007) such as limestone outcrops (karst), saline habitats, and geothermal areas. Others are coastal habitats influenced by wind and salt spray, and various freshwater, wetland and floodplain ecosystem types. These ecosystem types are important components of the 'full range' of New Zealand's biodiversity and often support distinctive and diverse biota. If they have been more or less affected by land development than have adjacent ecosystems, they will not share the loss and protection status of the wider environment.

Sources of information other than the Threatened Environment Classification are required about the context and status of freshwater and wetland ecosystems, and those defined by local-scale and extreme conditions. For example, the Freshwater Ecosystems of New Zealand (FENZ) national geo-database contains information on the natural diversity of New Zealand's river, lake, and wetland ecosystems and the pressures on them. A list of types of naturally uncommon terrestrial ecosystems has been compiled and classified according to threat status (Williams et al. 2007; Holdaway et al. 2012).

The Land Cover Database (LCDB) maps a set of classes of vegetation cover based on satellite imagery. The Threatened Environment Classification 2012 uses LCDB v. 4.0 which classifies satellite imagery taken in 2011/12.

The Classification takes LCDB cover classes 'at face value'. However, each of the LCDB cover classes is broad and thematic. Each contains a variety of vegetation that is incompletely known and defined. We also know there are misclassifications and errors in the database (but not their full magnitude or locations). LCDB inaccuracies arise from errors either in (1) placement of boundaries between two classes (positional or geometric accuracy) or (2) assignment of cover class to a polygon (thematic accuracy). Some cover classes are more susceptible to one type of accuracy problem than others. Irregular boundaries or gradual transitions are less likely to be accurately placed than sharp boundaries that often define exotic forest stands or cropping fields. Grassland classes are more prone to thematic inaccuracy because they have indistinct or variable spectral signatures in satellite imagery.

Thematic accuracy is limited by the qualitative nature of LCDB classes and therefore lack of quantitative definition of cover class composition on the ground. Absence of quantitative

class description means that definition of errors around the classes and their boundaries may not be possible in some cases.

Our most important caveat is therefore that LCDB cover classes cannot, and should not, be relied on to assess whether the land cover supports indigenous species on the ground at local and property scales. Field inspection will be needed.

For the purpose of indexing past loss of indigenous habitats in the Threatened Environment Classification, cover classes are divided into either indigenous or exotic categories (Appendix 1). This 'binary split' is based on a subjective assessment by ecologists of whether the vegetation in a cover class is 'mainly' indigenous or mainly exotic across all of New Zealand. A number of LCDB classes are 'mixed': they support mixtures and intergrades of indigenous and exotic species and plant communities, so our binary split is an oversimplification (e.g. see Cieraad 2008, Brockerhoff et al. 2008, and Walker et al. 2008). Ideally we would be able to assign a percentage loss to mixed classes. However, data are not available to quantify more accurately the degree of habitat loss experienced in mixed cover classes across the country, and it is not wholly clear how a percentage loss should be assessed. For example, the vegetation cover in the 'depleted grassland' class (assigned to indigenous in the Classification) is often dominated by the exotic hawkweed *Hieracium pilosella*, but indigenous species frequently dominate in number.

The consequence of the binary split is relatively large uncertainties in the threat category assignments of environments that are largely covered by mixed LCDB classes. For example, 'low producing grassland' and 'mixed exotic shrubland' are assigned to the exotic category but often support native short tussocks and shrubs in places. Therefore the Classification may overestimate past loss in some environments where these mixed cover classes are extensive. Conversely, a single LCDB cover class is provided for wetlands (Herbaceous Freshwater Vegetation), which is assigned to 'indigenous'. Hence, our calculations assume that all wetlands still support native cover, which is unlikely. Some environments that support extensive wetlands that have been substantially modified by adjoining land use (e.g. environment L3.1a on the Southland Plains) will incorrectly be assigned to less-threatened categories.

The *Protected Areas* dataset used for our analysis is incomplete and has limitations. Some errors will tend to increase and others will tend to decrease estimates of biodiversity that is actually protected in threatened environments. For example, we made considerable effort to identify and exclude Crown land managed by DOC for purposes other than conservation (e.g. buildings, gravel reserves, racecourses, cemeteries, marginal strips), but may not have been able to identify all of them (Walker et al. 2005).

On the other hand, there are likely to be additional protected areas that do not appear in any of the spatial databases that were sourced and collated. For example, the data layers available to us did not include council-protected areas in many districts, and certain types of privately protected land (including biodiversity sanctuaries such as the ecological island at Mt Maungatautari in the Waikato, and small-scale private conservation covenants). Furthermore, our dataset likely excludes some areas where biodiversity is protected but the legal designation does not reveal this (e.g. some recreation reserves, marginal strips, crown-administered riverbeds). Such omission errors will lead to underestimates of area of indigenous cover protected in some districts.

We attempted to minimise unintended omission errors in the databases provided to us by overlaying past and present protected areas in GIS and making enquiries about any sizeable polygons that were previously included and not present in the more recent data. We found three parts of the Catlins Conservation Park in the Southland Conservancy had been excluded from the DOC GIS layer of public conservation land used in the analyses (version July 2012, downloaded from Koordinates.com). Our enquiries suggest these omissions are erroneous, but they were not rectified for the release of the Threatened Environment Classification 2012. Other exclusions may or may not be justified. For example, the protected areas used in the former Threatened Environment Classification included some sizeable scenic reserves that no longer appear in the public conservation land data (e.g. the 4390-ha Lake Okataina Scenic Reserve, Bay of Plenty, and the 3260-ha Pukeamaru Scenic Reserve and 1900-ha Raukumara Conservation Area on the East Coast).

The protection dataset supplied by DOC for earlier versions of the protected area database included some areas that were legally protected by organisations other than DOC, Nga Whenua Rahui, QEII, and councils. However, these privately owned areas are not included in versions of the public conservation land database now made available through Koordinates.com, although many apparently remain protected. The largest of these areas is Hinewai Reserve on Banks Peninsula, which remains owned and managed for conservation by the Maurice White Trust. We did not include these privately owned protected areas in the current analysis because of the difficulty of (1) tracing the multiple private and community organisations that legally protect land, (2) establishing whether or not these areas remain legally protected for biodiversity conservation purposes, and (3) sourcing up-to-date spatial data depicting boundaries for these areas.

There may also be errors in the boundaries of land parcels in the GIS data with which we were supplied. This source of error could either inflate or decrease the areas estimated to be protected in some districts.

A final important caveat is that the protected areas data used in the Classification provide information only on whether an area or site has legal protection for the purpose of retaining natural heritage or not. On the ground, the degree to which this protection provides for the persistence of biodiversity is not a binary state but a continuum. The type and strength of protection provided by the legislation and subsidiary agreements (e.g. covenant conditions, grazing leases, extraction licences) varies widely. A range of extractive and habitat-destroying activities is permitted and carried out in many areas of public and private land that are deemed to be protected. Furthermore, even under the same legal mechanism (e.g. National Park designation or private covenant agreement), there can be quite different management actions with potentially very different outcomes for the persistence of the biodiversity components nominally protected (e.g. merely legal protection against clearance but no management actions, legal protection with fencing against stock, fencing with predator and feral herbivore control).

2.4 What the Threatened Environment Classification is not

The Threatened Environment Classification is part of a biodiversity protection toolkit that can complement survey and other information. Below we describe things that the Classification is not, and why.

Not a substitute for field survey

The Threatened Environment Classification provides a context for the assessment of the importance of remaining indigenous vegetation, communities and species for the maintenance of the full range of New Zealand's indigenous biodiversity. It does not provide information on whether indigenous biodiversity components are still actually present at any particular site. Either local and regional ecological survey information or *de novo* site inspection will be needed to establish whether indigenous species and/or communities are present.

Not for locating planning boundaries

Boundaries between land environments, and therefore between categories of the Threatened Environment Classification are inappropriate for use as planning boundaries. Because of the way LENZ is built, neither it nor the Classification takes account of landscape context (e.g. connectivity of natural communities) and it will usually cut across continuous gradients. However, LENZ and the classification *can* be used to identify gradients of environment, past habitat loss and protection for inclusion within planning units.

Not for locating threatened species

There is a strong correlation between the Threatened Environment Classification categories and the locations of threatened and at-risk plant species on pastoral leases in the inland South Island high country (Walker et al. 2008b, 2012). However, it cannot be assumed that this relationship will hold for species in all parts of New Zealand or for biotic groups other than plants. For example, we would not expect the more threatened environments to still support species that are now considered threatened but are also highly sensitive to alterations of their primary habitat. Species and groups that have trouble persisting in small populations (e.g. after the population has been reduced by combinations of habitat loss, predation, browsing, and/or grazing) are now likely to be confined mainly to less reduced and better protected environments.

Not appropriate for prioritising pest and weed control

It makes sense to invest in pest, weed, and fire control to maintain and restore remnants of much reduced habitats that are poorly protected elsewhere. Fragmented remnants close to towns, cities and roads are particularly vulnerable to weeds and fire. However, to maintain the sensitive biodiversity and ecosystem components and functions now lost from more modified landscapes, it is also important to maintain native habitats in places that have been safest from human land-use pressures, and investment in pest and weed control may be

urgently needed here too. Strategies and plans for these threats will require additional information and tools.

Not a substitute for other frameworks

LENZ and the Threatened Environment Classification do not replace the widely used biogeographic planning framework of ecological regions and districts (ERs and EDs). Rather, they are able to complement these and indeed other planning units (e.g. council regions and districts, catchments, sets of properties) by adding environmental data, identifying areas of potentially similar ecological character and gradients between environments, and providing national statistics on past loss of indigenous cover and legal protection within and across them.

Not a statement about how much is enough

The Threatened Environment Classification directs users to places that are likely to be most imminently threatened as a consequence of past land uses and by some current and future land uses, and are therefore priorities for additional protection and restoration. The Threatened Environment Classification does not define all that is important for the maintenance and persistence of indigenous biodiversity into the future, or how much is needed to achieve this. There is no implication (and no ecological rationale for assuming) that 30% of environments under some form of indigenous cover, and 20% of their land area under formal protection, are sufficient to maintain the full range of indigenous biodiversity, and/or to halt its decline.

3 Part Three: access, glossary and links

3.1 Access to the Threatened Environment Classification

The Threatened Environment Classification is free, and can be accessed in several ways. The easiest way to explore the Threatened Environment Classification 2012 is to view it in Landcare Research's free interactive online GIS portal classification "Our Environment" http://ourenvironment.scinfo.org.nz.

Here you can also look at many other national spatial data, and make your own maps of regions of interest.

On http://lris.scinfo.org.nz/ you can download the classification as a GIS layer (see below). Alternatively, you can download the classification table as an Excel file on http://www.landcareresearch.co.nz/resources/maps-satellites/threatened-environment-classification/downloads .

Quick guide to showing the classification and making a pdf map in Our Environment

- Go to: http://ourenvironment.scinfo.org.nz
- Click: "Create a map",
    - You will now see several topics which you can select to depict on your map
- Scroll down towards the bottom of the page; under "About Ecosystems and habitats" tick "Which areas of indigenous vegetation are under threat?"
- Scroll back up to the top of the page, and click the large button ("Click topics and then click here")
- Accept the conditions of use to view the map
- You will now see the Threatened Environment Classification depicted on the map of New Zealand, as shown in the numbered Figure 5, below.
    - The meta-data **(5)** and legend **(8)** are available on the right of the screen.
    - If you do not see the layer on the map of New Zealand, you need to tick the box "Threatened Environment Classification" in the "Layers" box on the left of the screen **(6)**.

You can **zoom in and select the area of interest** using your mouse wheel or the zoom scroller or zoom box that you can find in the top left of the map window **(1)**.

A **better-looking map** can be created by adding Hill-shade: click "Colour Terrain Map" and then slide the Layer Transparency slider (number **(7)** in the figure below) in the bottom left of the map window (for example to 30%).

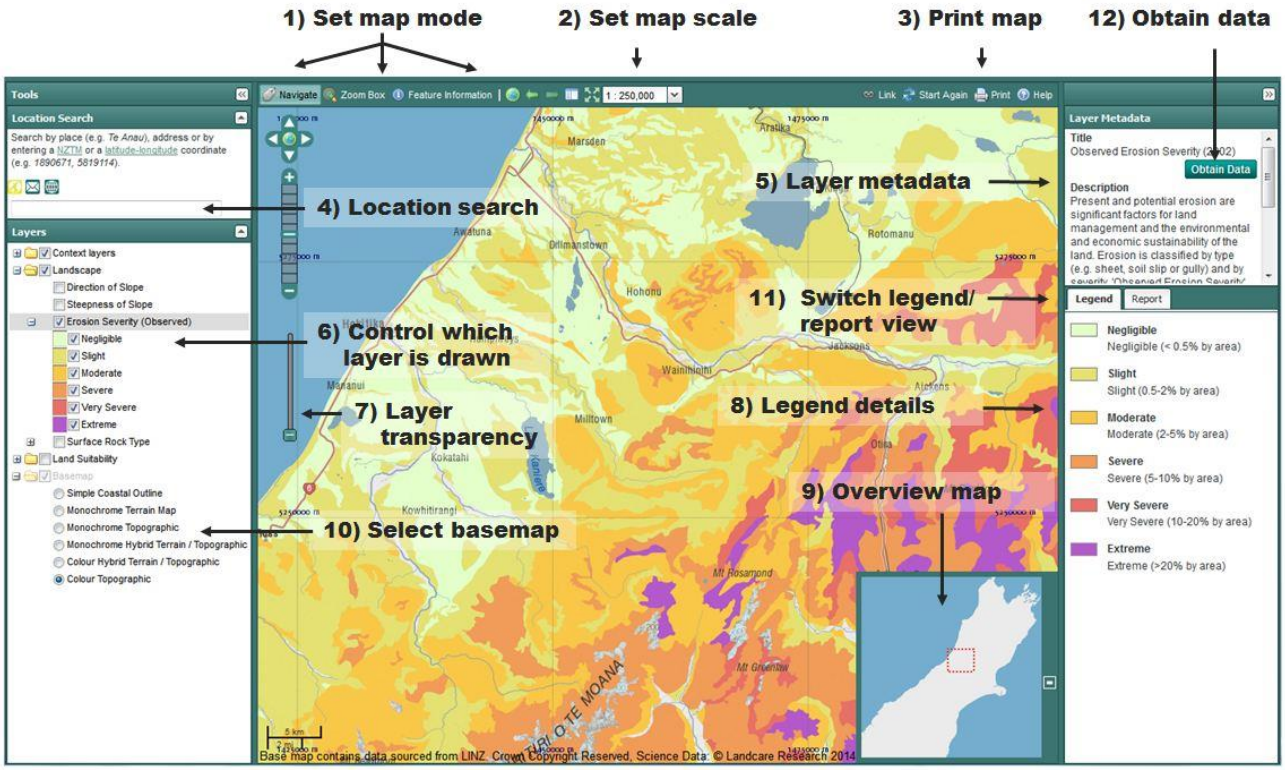

Figure 5 Annotated screenshot of a map in Our Environment.

To **create a printable PDF map**, use the Print facility **(3)**.

- Click on the Print icon to open the print window. The extent of your map is shown by the orange box. Click on the box and drag it around to change the geographic location of your map.
- Changing the scale or paper size will affect the amount of detail or the size of the geographic area that will appear on the map.
- You can enter a title for the map.
- When you are satisfied with the result, request the PDF file by clicking on "Create PDF and download" button. Depending on how your computer is set up, you will either be able to view the PDF file directly or save it onto your computer.

Note that the time it takes to create the PDF file will vary depending on the complexity, size, and scale of the map. You may have to wait a couple of minutes for the file to be created and downloaded.

Clicking on the "**obtain data**" button **(11)** takes you to the Threatened Environment Classification website (http://www.landcareresearch.co.nz/resources/maps-

satellites/threatened-environment-classification), where you can find more information and links to downloadable data.

More information on how to make the most of the capabilities of the interactive online GIS portal Our Environment is provided at http://ourenvironment.scinfo.org.nz/ourenvironment#getting_started

Downloading the Threatened Environment Classification as a GIS layer

Visit the Land Resource Information Systems (LRIS) portal http://lris.scinfo.org.nz/

Type "Threatened Environment" in the search box, or navigate to the layer by selecting in the left side bar: Category: Biota >Ecology>Ecosystem type>Terrestrial Ecosystem.

You can add the layer to your basket for download by clicking the "+" button. While everyone can search and view data, you need to be a registered user to download data. Public users of the LRIS Portal will have to register to establish a user id (a valid email address) and password. It is free, and you will not receive any spam messages.

See https://lris.scinfo.org.nz/p/getting_started/ for more details.

Access to underlying data

You can download the Threatened Environment Classification table as an Excel file on http://www.landcareresearch.co.nz/resources/maps-satellites/threatened-environment-classification/downloads. This table shows for each of the 500 LENZ level IV environments the percent of land area that remains under indigenous cover in 2002, 2008 and 2012 (using satellite imagery of the corresponding timestamps as classified in LCDBv4.0), and the percent of land area protected for natural heritage protection in 2004 and 2012 (using PAN-NZT1 and PAN-NZT2.1). It also provides the threat categories for 2012.

GIS users can use this table to upload the classification into GIS by joining it to the LENZ (level IV) layer (legend files are also available for download here). The Land Environments of New Zealand (LENZ) and the land cover database (LCDBv4.0) are available for download from http://lris.scinfo.org.nz/. The protected areas network database is not publicly available due to copyright and privacy issues.

3.2 Glossary: terms used in this guide

Biodiversity (biological diversity): Biodiversity is a contraction of biological diversity, which is the variety of life on earth. It refers to the variety of all biological life (plants, animals, fungi and microorganisms), the genes they contain, and the habitats and ecosystems on land and in water where they live.

Ecosystem: An interacting system of living creatures and non-living parts (including sunlight, air, water, and nutrients). Ecosystems can be small or large, short-lived, or long-lived.

Habitat: The place or type of place in which a living thing naturally occurs, and which provides it with the characteristics and resources it requires.

Indigenous species: A plant or animal species that occurs naturally in New Zealand. A synonym is 'native species'.

Indigenous (or native) *cover*: A community containing naturally occurring species that are indigenous to New Zealand. The term includes both vegetated surfaces ('indigenous vegetation') and surfaces that support little or sparse vegetation, or indeed no vegetation (e.g. scree). Vegetation that has regenerated with human help following disturbance is included, but the term does not include plantations or vegetation established for commercial or aesthetic purposes.

Land environment: A unit of the Land Environments of New Zealand (LENZ) classification (Leathwick et al. 2003), indicating an area of land with similar physical (abiotic) environmental characteristics variables such as climate, landform and soil.

Species: A group of organisms capable of interbreeding freely with each other but not with members of other species.

Taxon (pl. taxa): A named biological classification unit assigned to individuals or sets of species, for example species, subspecies, genus, or order.

Threatened species: A species that is vulnerable, endangered, or presumed extinct.

3.3 Links

Threatened Environment Classification

The Threatened Environment Classification and associated information (including this user guide) and downloads are accessible from http://www.landcareresearch.co.nz/resources/maps-satellites/threatened-environment-classification.

The paper associated with the release of Threatened Environment Classification 2012 is available at:

Cieraad E, Walker S, Price R, Barringer J 2015. An updated assessment of indigenous cover remaining and legal protection in New Zealand's land environments. New Zealand Journal of Ecology 39(2): 309–315.

Data layers

LENZ

http://www.landcareresearch.co.nz/resources/maps-satellites/lenz

LENZ technical guide: https://www.landcareresearch.co.nz/__data/assets/pdf_file/0020/21773/LENZ_Technical_Guide.pdf

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

LCDB

https://lris.scinfo.org.nz/layer/412-lcdb-v40-land-cover-database-version-40/

PAN-NZ

http://www.landcareresearch.co.nz/resources/maps-satellites/pannz

Policy documents

Department of Conservation (DOC) and Ministry for the Environment (MfE) 2000. The New Zealand biodiversity strategy. Wellington, DOC and MfE. 144 p. http://www.biodiversity.govt.nz/picture/doing/nzbs/contents.html

Statement of National Priorities for Protecting Rare and Threatened Biodiversity on Private Land: http://www.biodiversity.govt.nz/land/guidance/index.html

Naturally uncommon ecosystems

Williams PA, Wiser S, Clarkson B, Stanley MC 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31: 119–128.

Holdaway RJ, Wiser SK, Williams PA 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26: 619–629. http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems

Freshwater ecosystems

The Department of Conservation website for the Freshwater Ecosystems of New Zealand (FENZ) geo-database http://www.doc.govt.nz/conservation/land-and-freshwater/freshwater/freshwater-ecosystems-of-new-zealand/ states that it 'provides an independent, national representation of the biodiversity values and pressures on New Zealand's rivers, lakes and wetlands.'… 'FENZ consists of a large set of spatial data layers and supporting information on New Zealand's rivers, lakes and wetlands. It contains data gathered from a wide variety of sources. It can be used to objectively map and quantify various aspects of New Zealand's freshwater, providing:

- Comprehensive descriptions of the physical environment and biological character.
- Classifications that group together rivers and streams, lakes and wetlands having similar ecological character.
- Estimates of human pressures and impacts on biodiversity status.
- Rankings of biodiversity value that indicate a minimum set of sites that would provide representative protection of a full range of freshwater ecosystems while taking account of both human pressures and connectivity.'

The site also states that 'FENZ requires specialist GIS knowledge for its technical operation and biodiversity knowledge for understanding the content. Because of FENZ's complexity, DOC is providing advice, briefings and training (where possible) to ensure users understand its strengths, limitations and appropriate applications.' Potential users are referred to fenz@doc.govt.nz.

Threatened species

The most up-to-date lists of threatened species can be found at: http://www.doc.govt.nz/publications/science-and-technical/products/series/new-zealand-threat-classification-series/

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Appendix 1 – Assignment of land cover classes

Table A1 Thirty-three land cover classes (LCDBv4.0) and their classification as either Indigenous or Exotic for the Threatened Environment Classification

Class No.	LCDBv4.0 Class name	Assignment
1	Built-up Area (settlement)	Exotic
2	Urban Parkland / Open Space	Exotic
5	Transport Infrastructure	Exotic
6	Surface Mines and Dumps	Exotic
10	Coastal Sand and Gravel	Indigenous
12	Landslide	Indigenous
14	Permanent Snow and Ice	Indigenous
15	Alpine Grass / Herbfield	Indigenous
16	Gravel and Rock	Indigenous
20	Lake and Pond	Indigenous
21	River	Indigenous
22	Estuarine Open Water	Indigenous
30	Short-rotation Cropland	Exotic
33	Orchard Vineyard and Other Perennial Crops	Exotic
40	High Producing Exotic Grassland	Exotic
41	Low Producing Grassland	Exotic
43	Tall-Tussock Grassland	Indigenous
44	Depleted Grassland	Indigenous
45	Herbaceous Freshwater Vegetation	Indigenous
46	Herbaceous Saline Vegetation	Indigenous
47	Flaxland	Indigenous
50	Fernland	Indigenous
51	Gorse and/or Broom	Exotic
52	Mānuka and/or Kānuka	Indigenous
54	Broadleaved Indigenous Hardwoods	Indigenous
55	Sub-Alpine Shrubland	Indigenous
56	Mixed Exotic Shrubland	Exotic
58	Matagouri or Grey Scrub	Indigenous
64	Forest – Harvested	Exotic
68	Deciduous Hardwoods	Exotic
69	Indigenous Forest	Indigenous
70	Mangrove	Indigenous
71	Exotic Forest	Exotic