Recent loss of indigenous cover in New Zealand

Susan Walker[1*], Robbie Price[2], Daniel Rutledge[2], R.T. Theo Stephens[3] and William G. Lee[1]
[1]Landcare Research, Private Bag 1930, Dunedin
[2]Landcare Research, Private Bag 3127, Hamilton
[3]Department of Conservation, Private Bag 1930, Dunedin, New Zealand
*Author for correspondence (E-mail: walkers@landcareresearch.co.nz)

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Abstract: Recently developed national spatial databases enable improved estimates of how much of the full range of New Zealand's terrestrial biodiversity pattern remains, its rates of change, and how much is legally protected. Analysis using a classification of land environments derived from soil and climate data layers (LENZ) as a surrogate for biodiversity pattern, and spatial databases of land cover and legal protection, shows extreme (>70%) loss of indigenous cover in 57% of land environments, and poor protection (<20% land area protected) in more than two thirds. Loss of indigenous cover has continued, with 49% of environments having lost indigenous cover from 1996/97 to 2001/02, and the highest rates occuring where indigenous cover was already most depleted. The Resource Management Act (1991) (an Act of Parliament bringing together laws governing land, air and water resources and concentrating on the environmental effects of human activities) and associated provisions have not halted these losses on private land. Monitoring progress towards halting biodiversity decline in New Zealand will depend on maintenance and updating of these national databases, and development of measures of processes that sustain indigenous species assemblages and ecosystem functions.

Keywords: loss of indigenous habitat; legal protection; rate of habitat loss; New Zealand

Introduction

In order to meet international goals for the persistence of indigenous biodiversity, it is necessary to protect both biodiversity *pattern* (the full diversity of genes, species, communities, habitats and ecosystems, and landscapes) and the ecological and evolutionary *processes* that sustain this pattern (Margules & Pressey 2000; Moritz 2002). The goal of the New Zealand Biodiversity Strategy (DOC & MfE 2000) is consistent with this principle. The phrases "a full range" and "all species and subspecies" refer to biodiversity pattern, while the maintenance or restoration of a "healthy functioning state" implies the protection of essential biodiversity processes. The Strategy also identifies two key threats to indigenous species on land in New Zealand as 'insufficient and fragmented habitat'(i.e. loss of biodiversity *pattern*) and 'introduced invasive species which damage their habitat and important ecosystem processes', i.e. loss of biodiversity *processes*.

Internationally, more progress has been made towards the objective measurement and description of biodiversity pattern than of biodiversity processes; this reflects the challenge of determining and measuring the key processes that sustain species assemblages and ecosystem functions across spatial scales. In New Zealand, progress towards measures of both pattern and processes has been slow. However, national spatial databases of legal protection, land cover and abiotic drivers of terrestrial biodiversity have been recently developed; these allow us to better estimate how much of the full range of New Zealand's terrestrial biodiversity pattern remains, and how much is included within legally protected areas. Here we summarise the distribution of past and recent indigenous habitat loss, and legal protection for natural heritage, across land environments.

Methods

Our analyses combined three national spatial datasets, which we converted to 25 m GIS raster files. A combinatorial analysis of these datasets was run in GIS using the ArcSampling program developed by Landcare Research. This program created output tables for importing into a Microsoft Access database for final tabulation.

We used Land Environments of New Zealand (LENZ) as a surrogate for the potential full range of terrestrial ecosystems and their associated biodiversity. LENZ is a classification of New Zealand's abiotic

terrestrial environmental pattern based on 15 environmental climate and landform variables likely to influence species distributions (Leathwick *et al*. 2003).

We used the second Land Cover Database (LCDB2, based on 2001/02 imagery; Terralink 2004) to estimate remaining indigenous cover, and hence the change in indigenous cover from pre-settlement times to the present day, by land environment. For this, we assigned the 43 LCDB cover classes to either an indigenous (22 classes), or a non-indigenous (21 classes) category (Appendix 1). A few pixels identified as bare soil or inundated areas in LCDB2 had been classified within an exotic cover class in LCDB1. These pixels were assigned to the non-indigenous LCDB2 cover category (Walker *et al*. 2005). To identify recent changes in indigenous cover, we compared LCDB2 with the first LCDB (LCDB1; based on 1996/97 imagery, updated 2004 version with land classes consistent with LCDB2; Terralink 2004).

To define legally protected lands we used a spatial database of private and public land managed for conservation (Protected Areas of New Zealand; PANZ) updated to May 2005. The database is an updated version of the legally protected areas database used for analyses by Walker et al. (2005), and includes all public conservation lands and covenants administered for the purposes of natural heritage protection by DOC, QEII Open Space and Nga Whenua Rahui covenants, and Territorial Local Authority Regional Parks. Methods used to compile this database are described by Rutledge *et al*. (2004).

To summarise results, we grouped the 500 Level IV land environments into six categories, following a combinatorial analysis of the three datasets. Five categories of 'threatened environments' were defined on the basis of past habitat loss and current legal protection. Because loss of biodiversity accelerates as habitat loss advances (based on the shape of the generalised species-area relationship; Rosenweig 1995) the first three categories are environments where habitat loss has been greatest (i.e. those in which 0–10%, 10–20% and 20–30% indigenous cover remains nationally; Table 1; Fig 1A). Two further threat categories (critically underprotected and underprotected) include environments with more than 30% of their land area remaining in indigenous cover, but <10%, and 10–20% of their land area legally protected, respectively. These categories apply because indigenous habitats that are not legally protected are more likely to be cleared, and less likely to receive conservation

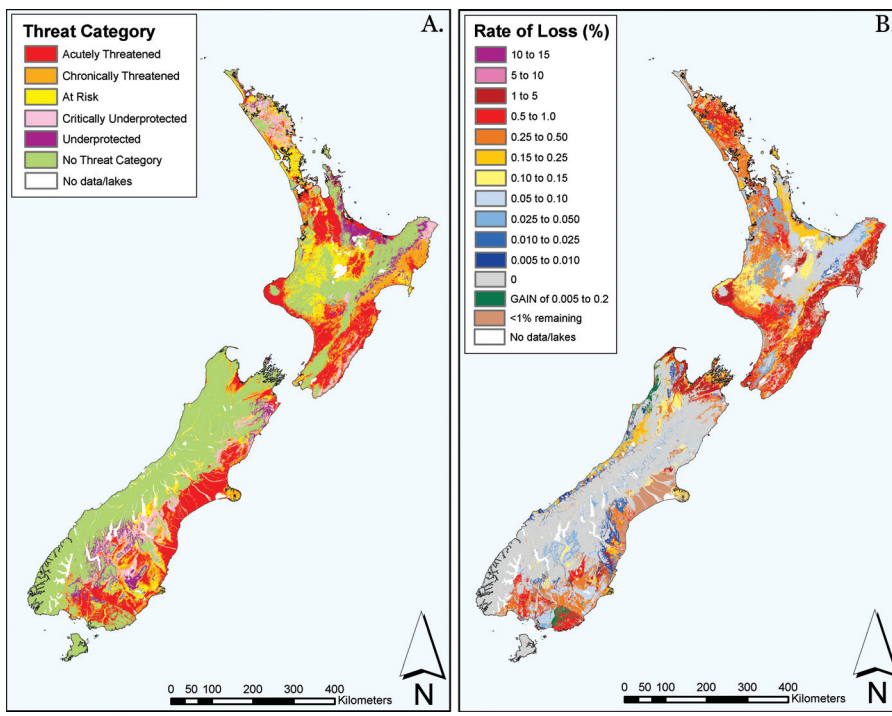

Figure 1. A. Environment threat categories based on % loss and % protection in May 2005 (Table 1) and B. rate of recent loss (% loss of indigenous cover in the five year period 1996/97 to 2001/02), across New Zealand's 500 Level IV land environments.

Table 1. LENZ environments threat categories, and defining criteria (Walker *et al*. 2005).

Category	Criterion
Acutely Threatened[1]	<10% indigenous cover remaining
Chronically Threatened[1]	10–20% indigenous cover remaining
At Risk[1]	20–30% indigenous cover remaining
Critically Underprotected	>30% indigenous cover remaining <10% legally protected
Underprotected	>30% indigenous cover remaining 10–20% legally protected
No Threat Category	>30% indigenous cover remaining >20% legally protected

[1]In order of decreasing risk to remaining biodiversity cf the national system for classifying species according to threat of extinction (Molloy *et al*. 2002).

management inputs to mitigate threats (e.g. from pests and weeds). Together, the five categories of threatened environments are therefore likely to contain some of New Zealand's most severely reduced and poorly protected ecosystems, habitats and species. Environments with >20% of their area legally protected and >30% indigenous cover remaining were assigned to a sixth category.

Results

Indigenous cover remaining in 2001/02

LCDB2 data indicate that about one half of New Zealand's land area (12 632 214 ha, or 49%) remained under some form of indigenous cover in the summer of 2001/02 (Table 2). The loss of terrestrial indigenous cover since human settlement has been uneven across environments. The 284 environments retaining less than 30% indigenous cover comprise 57% of all 500 Level IV environments, and cover 42% of New

Table 2. Categories of New Zealand's land environments in 2001/02: a. number and % of environments, b. area and % of New Zealand, c. area of remaining indigenous cover and % of New Zealand, d. area remaining indigenous cover not legally protected, % of New Zealand, % of NZ indigenous cover, and % of indigenous cover that is not legally protected in threat category, and e. number of environments and % of environments in threat category with net loss of indigenous cover between 1996/97 and 2001/02.

	Land Environment category						
	Total (all 500 environments)	Acutely Threatened	Chronically Threatened	At Risk	Critically Under-protected	Under-protected	No threat category
a. Environments (LENZ Level IV)							
No.	500	158	74	52	33	23	160
% Environments.	100.0	31.6	14.8	10.4	6.6	4.6	32.0
b. Full extent of environments							
Area (ha)	26 000 680	5 888 292	2 323 074	2 788 941	1 771 686	1 511 697	11 716 990
% NZ	100.0	22.7	8.9	10.7	6.8	5.8	45.1
c. Indigenous cover (I) remaining in environments							
Area (ha)	12 632 214	220 862	344 889	674 218	754 428	809 686	9 828 132
% NZ	48.6	0.8	1.3	2.6	2.9	3.1	37.8
% remaining in indigenous cover	"	3.8	14.8	24.2	42.6	53.6	83.9
d. Indigenous cover not protected (INP) in environments							
Area	4 795 569	184 916	289 103	468 250	673 178	571 598	2 608 525
% NZ	18.4	0.7	1.1	1.8	2.6	2.2	10.0
% NZ remaining I	38.0	1.5	2.3	3.7	5.3	4.5	20.6
% indigenous cover not protected	38.0	83.7	83.8	69.5	89.2	70.6	26.5
e. Environments (LENZ Level IV) with net loss of indigenous cover between 1996/97 and 2001/02							
No.	245	76	48	26	12	15	66
% of environments in Threat Category	49.0	48.1	64.9	50.0	36.4	65.2	42.5

Zealand's land area, mainly in the coastal, lowland and montane (or cool temperate; Wardle 1991 p. 78) zones (Fig 1A). In contrast, high proportions of indigenous cover remain in the subalpine and alpine zones. Almost one third (158, or 32%) of Level IV land environments retain less than 10% of their indigenous cover; these are categorised as acutely threatened environments and cover 23% of New Zealand's total land area. The average percentage of indigenous cover that remains in acutely threatened environments is 3.8% (Table 2).

Current protection

Just under one third (8 096 063 ha, or 31.1%) of New Zealand's land area had some legal protection recorded in the protected area database compiled in May 2005. However, protection exceeded 20% of the environment land area in just 162 (32.4%) of the 500 Level IV environments. Of the 12 632 214 ha of indigenous cover remaining in the summer of 2001/02, 4 795 569 ha (38%) was not identified as legally protected in the May 2005 protection database (Tables 2 and 3).

Threatened environments

In two thirds (67%) of land environments, indigenous cover had been reduced to less than 30% of its original extent (i.e. prior to human settlement) by summer 2001/02, and/or less than 20% of the land area was legally protected (and hence likely to be receiving some level of management input to sustain biodiversity; Table 2) in May 2005. In the five threatened environment categories, high percentages (69.5–89.2%) of the area of remaining indigenous cover were not legally protected (Table 2).

In environments with <30% indigenous cover remaining, unprotected indigenous cover was largely classified as Manuka and/or Kanuka, Indigenous Forest and Broadleaved Indigenous Hardwoods (Table 3). Extensive areas (690 774 ha) in these environments were classified as Low Producing Grassland, which we classify as non-indigenous, but which hold some indigenous ecosystems, habitats and species. In the Critically Underprotected and Underprotected environments, the most extensive indigenous cover classes were Tall Tussock Grassland (mainly in the inland eastern South Island high country), Manuka and/or Kanuka, and Indigenous Forest (largely in eastern regions of the North Island) (Table 3).

Recent indigenous cover loss

The area of non-indigenous cover in LCDB1 reclassified as indigenous cover in LCDB2 (the total gain) was only 346 ha (Table 4). The total area that changed from indigenous to non-indigenous land cover types between 1996/97 and 2001/02 (17 550 ha) was

Table 3. Indigenous cover not legally protected remaining in New Zealand 2001/02 (by LCDB2 class and class combinations).

Cover class	Area in cover class and threat category (ha)						
	Total (all 500 environments)	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Under-protected	No threat category
Indigenous cover not legally protected							
Broadleaved Indigenous Hardwoods	348 763	31 424	49 024	52 320	37 213	32 553	146 230
Depleted Grassland	226 184	3602	22 188	26 633	116 647	10 901	46 213
Fernland	43 806	1016	1738	1925	14 588	4446	20 093
Grey Scrub	63 427	3675	8176	8528	19 961	5196	17 891
Indigenous Forest	1 360 167	46 877	52 862	166 978	97 940	104 754	890 757
Manuka and/or Kanuka	835 034	49 229	102 928	132 803	143 871	85 021	321 183
Matagouri	26 494	3628	3177	6893	7820	818	4157
Tall-Tussock Grassland	1 344 396	5228	23 122	38 477	204 206	295 919	777 444
Alpine[1]	140 473	13	106	262	5086	12 214	122 793
Rock[2]	313 367	15 464	12 906	20 002	17 277	13 509	234 209
Wetland/Water[3]	93 458	24 760	12 876	13 429	8569	6268	27 556
Total	4 795 569	184 916	289 103	468 250	673 178	571 598	2 608 525
Low producing grassland not legally protected							
Low producing grassland	1 511 719	146 104	238 944	305 726	403 595	99 706	317 643

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

therefore very similar to the net loss of indigenous cover over that time (17 204 ha).

The biggest changes from indigenous to non-indigenous cover types nationally were in Broadleaved Indigenous Hardwoods (6745 ha), Manuka and/or Kanuka (5609 ha), Tall-Tussock Grassland (2482 ha) and Indigenous Forest (2232 ha) (Table 4). Comparison of cover classes shows that planting of exotic forestry trees (represented by the Afforestation and Other Exotic Forest cover classes) into areas of indigenous vegetation accounted for most of these changes (c. 11 557 ha or 65%). Harvesting or felling of 1982 ha of indigenous forest (Forest – Harvested LCDB2 class) accounted for 11% of the changes, conversion of indigenous vegetation to high-producing grassland (i.e. pasture) or cropland for 6%, and conversion of indigenous vegetation to low-producing grassland for 16% of the changes (Table 5).

Of the low-producing grassland class in 1996/97, 29 338 ha changed to another non-indigenous class (Table 4), most of this through conversion to exotic forestry. The area of low-producing grassland affected by these changes is 1.67 times greater than the total national decrease in indigenous cover classes. Since many areas of low-producing grassland contain mixtures of indigenous and exotic species, significant loss of indigenous biodiversity has likely occurred.

There was a net loss of indigenous cover in almost half (245, or 49%) of Level IV land environments between 1996/97 and 2001/02 (Table 2; Fig 2A). Indigenous cover increased in just four (0.8%) environments, and these increases were relatively small (1 - 35 ha). Approximately 55% of the net loss of indigenous cover (9484 ha) was in threatened environments (Table 4). The largest net loss was in Chronically Threatened environments (2529 ha), but losses in At Risk (2207 ha) and Critically Underprotected (2406 ha) environments were almost as large. Most of the indigenous cover lost in the five-year period was on land not legally protected in May 2005 (94% of the total loss). In threatened environments, about 98% of indigenous cover lost was on land not defined as legally protected in May 2005.

The area of indigenous cover recently lost was not related to the percentage of indigenous cover remaining in that environment in 1996/97 (Fig. 2A). However, rates of recent loss of indigenous cover (area lost, expressed as % of LCDB1 indigenous cover) were highest in environments where indigenous cover was already much reduced (Fig. 2B). Fig. 1B illustrates the geographic distribution of the rate of indigenous cover loss by land environment.

Table 4. Change and loss of indigenous cover (ha; 1996/97 to 2001/02) by environment threat category.

	Area in cover class and threat category (ha)						
	Total	Acutely Threatened	Chronically Threatened	At Risk	Critically Underprotected	Under-protected	No threat category
Change from indigenous cover to non-indigenous cover							
Broadleaved Indigenous Hardwoods	6745	552	635	1303	598	114	3543
Fernland	90	0	0	25	2	0	63
Grey Scrub	46	7	2	0	1	1	35
Indigenous Forest	2232	145	249	313	534	214	778
Manuka and or Kanuka	5609	371	1154	551	798	157	2577
Matagouri	6	6	0	0	0	0	0
Tall Tussock Grassland	2482	47	462	7	478	675	813
Rock	234	1	0	53	2	53	125
Water/Wetland	105	17	35	28	0	0	24
Total	17 550	1147	2537	2281	2412	1214	7958
Change from non-indigenous cover to indigenous cover							
All non-indigenous cover classes	346	20	8	74	6	0	238
Net loss of indigenous cover							
Net loss of indigenous cover	17 204	1127	2529	2207	2406	1214	7720
Net loss of indigenous cover not protected (% of net loss of indigenous cover)	16 153 (93.9)	1114 (98.8)	2495 (98.7)	2187 (99.1)	2359 (98.0)	1094 (90.1)	6904 (89.4)
Change from low-producing grassland to other non-indigenous cover							
Low-producing grassland	29 338	3157	9135	6840	1287	3510	5409

Table 5. Changes from indigenous to non-indigenous cover types (ha; 1996/97 to 2001/02).

	Non-indigenous cover type 2001/02										
	Built-up Area	Surface Mine	Short-Rotation Cropland	High-Producing Exotic Grassland	Low-Producing Grassland	Gorse and/or Broom	Afforestation (not imaged)	Afforestation (imaged, post LCDB1)	Forest – Harvested	Other Exotic Forest	Total
Indigenous cover type 1996/97											
Coastal Sand and Gravel	0	0	0	0	32	0	0	22	0	1	55
River and Lakeshore Gravel and Rock	0	0	0	0	0	3	0	0	0	0	3
Landslide	0	0	0	0	172	6	0	0	0	0	178
Tall-Tussock Grassland	0	0	0	0	0	0	54	1196	0	1236	2486
Herbaceous Freshwater Vegetation	0	2	0	55	0	0	38	6	0	0	101
Herbaceous Saline Vegetation	0	0	0	86	0	0	0	0	0	0	86
Fernland	0	0	0	0	0	0	0	90	0	0	90
Manuka and/or Kanuka	0	8	0	565	2052	0	797	2148	3	42	5615
Matagouri	0	0	0	0	0	0	6	0	0	0	6
Broadleaved Indigenous Hardwoods	2	1	3	361	490	227	1802	3815	46	0	6748
Subalpine Shrubland	0	0	0	0	0	0	0	46	0	0	46
Indigenous Forest	3	4	0	0	34	0	0	259	1934	0	2233
Total change	5	16	3	1067	2779	236	2697	7582	1982	1278	17 646
% of 17 646 ha	0.0	0.1	0.0	6.0	15.7	1.3	15.3	43.0	11.2	7.2	
Total in threatened environments	5	3	3	801	1765	222	1079	2947	1368	1238	9431
% of 9 431 ha	<0.0	0.1	<0.0	5.6	15.8	1.3	15.4	43.2	11.3	7.3	

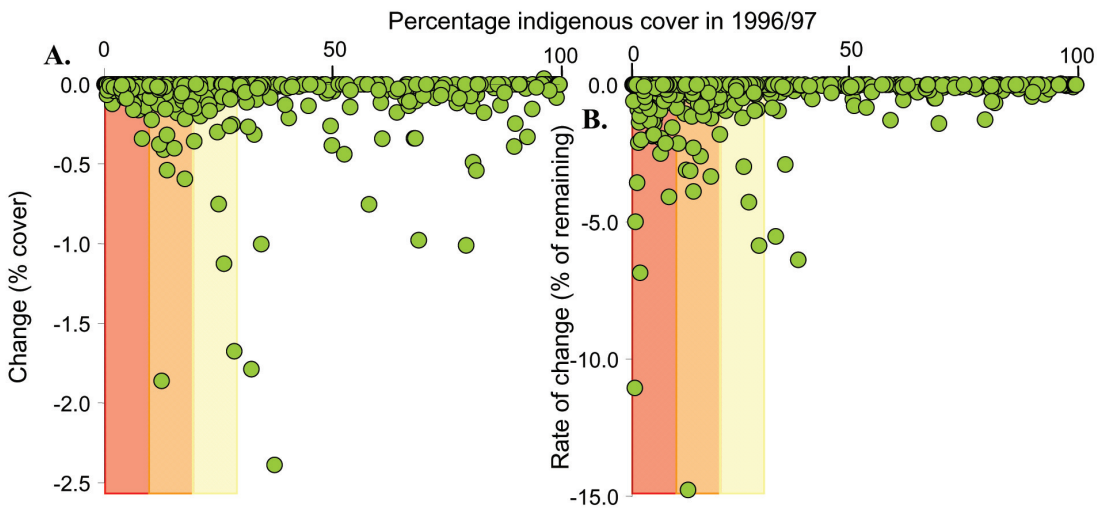

Figure 2. Change from 1996/97 to 2001/02 in New Zealand's Level IV land environments (represented by green circles). **A.** Change in indigenous cover (% of whole environment). **B.** Rate of change in indigenous cover (% of remaining indigenous cover in 1996/97). Red, orange and yellow shading dentoe Acutely Threatened, Chronically Threatened, and At Risk environments, respectively.

Discussion

Historic and recent loss of indigenous cover

Because of their accessibility and value for agriculture and settlement, New Zealand's coastal, lowland, and montane environments have been substantially modified, resulting in considerable loss of the indigenous biodiversity of these zones, and poor protection of what now remains. The much-reduced areas of indigenous cover remaining in these threatened environments support a disproportionately large percentage of New Zealand's most seriously threatened species (e.g. plants; de Lange *et al*. 2004), habitats and ecosystems. Although remaining indigenous ecosystems in these environments are typically highly modified, their protection is needed to halt the decline of New Zealand's indigenous biodiversity.

Clearance of indigenous cover and associated loss of indigenous biodiversity continues throughout New Zealand, including in environments with the least remaining indigenous cover. Ongoing depletion of indigenous cover in threatened environments will exacerbate the loss of biodiversity, extinguishing local genotypes, species, and assemblages that have developed in response to distinctive environmental conditions.

In New Zealand, clearance of indigenous cover was historically concentrated on land of highest value for agriculture. However, these data indicate that recent clearance extended to more marginal land, notably for exotic forestry. Despite biodiversity certification processes adopted by sectors of the forestry industry, LCDB data from 1996/97 to 2001/02 show that plantation forestry remained one of the major causes of indigenous cover loss in New Zealand.

Overall, the data suggest that public awareness and education, voluntary protection, Resource Management Act (1991) provisions, and formal legal protection of remaining indigenous biodiversity have not halted the removal and/or displacement of vulnerable indigenous biodiversity in much reduced and poorly protected ecosystems and habitats. This may arise from a continuing perception that only pristine ecosystems are important or significant for biodiversity (e.g. Norton & Roper-Lindsay 2005). This fails to recognise that a high proportion of New Zealand's most threatened species survive only in depleted and highly modified ecosystems in threatened environments; therefore, protection of highly modified habitats is essential to prevent the extinction of many species.

The need for more sophisticated assessment of biodiversity status and loss

This analysis of indigenous land cover change was possible because of recent investment by Government agencies in key national spatial databases. New Zealand's ability to assess and report on its performance regarding loss and protection of indigenous biodiversity will in future depend upon continued, multi-agency support for these key national databases.

LCDB1 and LCDB2 data represent the first nationally comprehensive vegetation monitoring undertaken in New Zealand. However, they provide only a coarse assessment of changes in indigenous habitats and ecosystems, due to the broad qualitative nature of LCDB cover classes, the reliance on subjective manual distinction of spectral signatures, and resolution issues associated with the 1 ha minimum mapping unit used (Thompson *et al*. 2003). Incremental losses of habitat (e.g. forest edge dieback) and gradual trends (e.g. succession or habitat deterioration) are not detected, and mapping and classification errors in the databases remain unidentified but are likely to be large in relation to detected change. Grassland types and losses appear to be particularly poorly depicted. For example, LCDB1 vs LCDB2 comparison indicates that no conversion from tall tussock grassland to pasture occurred anywhere in New Zealand from 1996/97 to 2001/02. This is not credible, given the recent national trends in pasture development and intensification (Parliamentary Commissioner for the Environment 2004), and our LCDB comparison may therefore considerably underestimate the true loss of indigenous habitats and ecosystems.

LENZ provides a first national classification of the abiotic component of ecosystems, based on explicit climate and soils data layers, but it does not distinguish very small-scale ecosystems which may support disproportionally high levels of indigenous biodiversity, including distinctive biogeographic and genetic components. Further, we do not yet understand how species richness and turnover varies across environments and biotic groups; therefore, by default, we treat LENZ environments as equal in biodiversity contribution. We know this is unrealistic.

Finally, our legal protection data are binary, and provide no indication of the extent to which biodiversity is maintained. Intensive 'mainland island' protection controls nearly all pests and weeds, but this is limited to very small areas (e.g. about 1.1% of the land administered by DOC). Direct clearance of indigenous cover is limited in other areas under legal protection, and some conservation inputs (e.g. stock fencing, pest and weed control) are applied, but we cannot assess the degree to which these inputs maintain biodiversity.

The challenge of quantifying the state of New Zealand's biodiversity

Effective policy and planning for biodiversity conservation in New Zealand depends on the

development of national, multiscale, biodiversity assessment systems. These require spatially explicit abiotic and biotic national data layers, and innovative methods for integration and reporting.

LENZ is a major step forward in depicting the abiotic components of terrestrial ecosystems, but its underlying climate and soil data layers must be maintained, updated and supplemented by the relevant agencies, leading to improved versions. Freshwater and marine environment classifications will be released shortly, and will require similar upkeep. Biotic inventory and monitoring in New Zealand is largely uncoordinated and underdeveloped. The land cover data layers (LCDB1, LCDB2) used in this study provide a rudimentary basis for regular assessments of changes in indigenous cover on land, while the legally protected areas database (PANZ) provides elementary information on its legal protection. As shown here, when integrated with LENZ environments, these surrogate databases can provide national indices of representativeness (i.e. the continuing existence of natural habitats and their legal protection across land environments). These indices can be tracked over time to indicate progress towards conservation goals provided that date-stamped updates are funded by the relevant national agencies.

In summary, this analysis represents some progress towards the objective measurement and description of biodiversity pattern in New Zealand, and can provide improved guidance on priorities for protection (e.g. through district plans' constraints on clearance, or other legal protection mechanisms). However, the component national datasets still have limited thematic resolution, and there is currently no provision for maintaining and updating the national environment and land cover datasets.

A far greater challenge lies in developing measurements of, and systems for, reporting changes in the key processes (e.g adaptation, reproduction, dispersal) that sustain indigenous species, their assemblages, and ecosystem functions. This is particularly important in New Zealand due to the high vulnerability of the biota to invasive species (Atkinson & Cameron 1993). Coordinated national assessment of pressures on biodiversity and their impacts on biodiversity processes are needed to supplement measures of pattern before it is possible to assess how much of the full range of indigenous biodiversity persists, how rapidly it is being lost, and how adequately resources allocated to different biodiversity conservation activities protect it. We recognise the importance of these issues, and the need for other, complementary, biodiversity assessment tools to enable more effective and systematic biodiversity conservation in New Zealand.

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Editorial Board member: Chris Lusk