

NEW ZEALAND'S NATURALLY UNCOMMON ECOSYSTEMS

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ABSTRACT: We provide an overview of naturally uncommon ecosystems in New Zealand. Terrestrial ecosystems that were rare before humans colonised New Zealand often have highly specialised and diverse assemblages of flora and fauna, characterised by endemic and rare species. A national-scale typology provides a list of 72 naturally uncommon ecosystems distributed across the country. These may be small (e.g. 100 m² to a few hundreds of hectares) but geographically widespread, or larger (e.g. 10 000s of hectares) but geographically restricted. Many of these ecosystems occur in azonal environments that lack trees, despite often lying below the regional treeline. Naturally uncommon ecosystems have been highlighted as priorities for protection of rare and threatened native biodiversity on private land and are recognised as such by government departments and territorial authorities. To support this, policymakers must be able to identify instances of naturally uncommon ecosystems, to know where they occur, and to know how threatened they are. Approaches have been developed to map the distribution of each ecosystem based on combinations of modelling from existing spatial layers, interpretation of remotely sensed images, literature, and local knowledge. Web-based factsheets have been prepared for all 72 ecosystems to allow them to be readily identified in the field. Criteria for the IUCN's draft Ecosystem Red List have been applied to New Zealand's naturally uncommon ecosystems and have resulted in 18 being ranked as critically endangered, 17 as endangered, and 10 as vulnerable. Further information is provided for the 18 critically endangered ecosystems.

Key words: biodiversity threats, coastal, conservation policy, ecosystem classification, ecosystem maps, endangered species, endemic species, geothermal, protection status, rarity, threat status, web-based factsheets.

A TYPOLOGY TO DESCRIBE AND DEFINE NATURALLY UNCOMMON ECOSYSTEMS

Most attempts to classify New Zealand landscapes and vegetation types have understandably started with the dominant, common, widespread units. Such typologies have been applied to a range of conservation and management issues, including conservation planning for reserves (e.g. McEwen 1987), identifying environments that have little remaining indigenous vegetation (Walker et al. 2006) and nationwide estimates of above-ground carbon storage (Hall et al. 2001). Some of the better-known typologies depicting vegetation or land cover include the Forest Class Maps (NZ Forest Service Mapping Series 6), published between 1970 and 1993, which provided national coverage for forest classes in New Zealand; the Vegetative Cover Map of Newsome (1987), compiled for publication at the coarse scale of 1:1 000 000, which provided national coverage for all vegetation communities; the ECOSAT Woody Vegetation Layer, which derived a national woody vegetation layer with indigenous forest classes based on canopy reflectance; and the Land Cover Database (LCDB2; Thompson et al. 2004), which provided estimates of the aerial extent of 33 classes of land cover or land use derived from a classification of Landsat satellite imagery. Land Environments of New Zealand (LENZ; Leathwick et al. 2003) provided a typology based on abiotic criteria, including climate and soil parent material. Although exceedingly useful, these typologies were not intended to provide information on the full range of ecosystems present in New Zealand. A system applying to the full array of ecosystem types evolved during the Protected Natural Areas Programme (PNAP) (Kelly and Park 1986; Myers et al. 1987). The intent was to identify representative examples

of the full range of natural ecosystems within each ecological district (McEwen 1987). However, no synthetic work has been done to enable these regional-scale typologies to be scaled up to provide a national-scale ecosystem classification. What this means is that an independent effort was required to develop a typology that could be applied to identify and manage ecosystems that are either threatened or naturally uncommon.

To address this need, Williams et al. (2007) developed a national-scale typology of naturally uncommon ecosystems. Terrestrial ecosystems that were rare before humans colonised New Zealand often have highly specialised and diverse assemblages of flora and fauna, characterised by endemic and rare species. Many of these are under threat from anthropogenic modification and their biodiversity values are declining (Holdaway et al. 2012). By compiling information from the literature and canvassing New Zealand ecologists and land managers, Williams et al. (2007) provided a list of 72 naturally uncommon ecosystems. Naturally uncommon ecosystems were defined as those having a total extent less than 0.5% (i.e. < 134 000 ha) of New Zealand's total area (268 680 km²). They encompass ecosystems that are small (e.g. 100 m² to a few hundreds of hectares) but geographically widespread (e.g. coastal dune deflation hollows) to those that are larger (e.g. 10 000s of hectares) but geographically restricted (e.g. frost flats on the North Island's Volcanic Plateau). Many of these ecosystems occur in azonal environments that lack trees, despite often lying below the regional treeline.

The first step in defining each type of naturally uncommon ecosystem was to define environmental drivers that distinguish them from the predominant ecosystems of the region and from other naturally uncommon ecosystems (Williams et al. 2007).

TABLE 1 Diagnostic classifiers that combine to distinguish the physical environments of naturally uncommon ecosystem types from each other and more common environments. They comprise six classes of physical factors (soil age, parent material chemistry, particle size, landform, drainage, climate) and one class describing disturbance. Reprinted with permission from Williams et al. (2007).

Soil age ³	Parent material/chemical environment	Particle size (Udden–Wentworth scale)	Landform ²	Drainage	Disturbance regime	Climate
Raw Recent Mature Over-mature	Quartzose rocks Soft quartzitic sediments Quartzite Acidic rocks Mudstone (soft) Sandstone (soft) Mudstone (hard) Sandstone (hard) –greywacke Rhyolite Granite and gneiss Schist Basic rocks Tuffaceous mudstone Tuffaceous sandstone Andesite Diorite Basalt Gabbro Ultrabasic rocks Calcareous rocks Limestone Marble Other parent substrates Alluvium and till Loess Shells Peat Dune sand ⁴ Chemical environment Groundwater salinity Atmospheric salinity Geothermal – acid rain Geothermal – acid soils, toxic elements Enhanced nutrients	Bedrock (in situ) Boulders >256 mm Cobbles 64–256 mm Gravel 2–64 mm Sand 62.5 µm – 2 mm Silt and clay <62.5 µm	Hillslope ⁵ Hillcrest ⁶ Plain Terrace Fan Depression ⁷ *Gorge Doline Tor Cliff Scarp Talus *Moraine Beach ridge Beach Dune (comprised of dune crest and dune slope) *Cave entrance *Subterranean (e.g. caves and cracks) Estuary Lagoon *Dome	Excessive drainage Near permanently saturated (but water table not high) Permanently high water table Regularly high water table Seasonally high water table (periodically dry) Open water	Abiotic Periodic fire (including eruptions) Periodic flooding Biotic Seabirds – guano deposits Seabirds and marine mammals – trampling and grazing Seabirds – burrowing	Coarse-scale ¹ Coastal Inland Alpine Fine-scale >200 frost days p.a. High water balance (high–very high monthly water balance ratio) ⁸ High cloud cover (<1500 sunshine hours and >200 rain days p.a.) Semi-arid (high–very high annual water deficit) ⁸ Extreme wind exposure Late snow lie Geothermal – excessive heat Geothermal – superheated steam

¹ Coastal = coastal (within 1 km of the coast and with altitude <300 m); inland = lowland, montane, subalpine; alpine = lower alpine, upper alpine, nival – of Myers et al. (1987).

² A subset of those listed in Speight (1990); *= not listed in Speight

³ Following Hewitt (1992) and Leathwick et al. (2003)

⁴ Derived from a combination of particle size and landform

⁵ Includes mountain slopes

⁶ Includes ridges and summits

⁷ Includes hollows, basins and swales

⁸ Following Leathwick et al. (2003)

The drivers used included soil parent material/chemistry, parent material particle size, climate, landform, drainage, soil age, and disturbance. Each category uses diagnostic classifiers that define different types of conditions that may apply to each naturally uncommon ecosystem (Table 1); for example, the classifiers for ‘drainage’ include ‘excessive drainage’ and ‘seasonally high water table (periodically dry)’. Unique combinations of these diagnostic classifiers define and name the physical environments of each naturally uncommon ecosystem. No hierarchy of categories is implied; for example, active sand dunes are defined by the combination of diagnostic classifiers indicating *raw* soils comprising *sand* on *dunes* in *coastal* environments. They are distinguished from shingle beaches that are defined as having *raw* or *recent* soils comprising mainly *gravel* and *cobbles* on *beach* landforms in *coastal* environments.

Examples of naturally uncommon ecosystems include shingle beaches, volcanic dunes, gumlands, and granite sand plains (Figure 1A–D). Seventy-five percent of these systems support nationally threatened plant species (e.g. *Phylloglossum drummondii*, copper-bearded orchid (*Calochilus herbaceus*), spiral sun orchid (*Thelymitra matthewsii*), and king fern (*Todea barbara*) on gumlands; see summary in Holdaway et al. 2012) and species with limited distributions (e.g. leafless pōhuehue (*Muehlenbeckia ephedroides*), which is restricted to braided riverbeds, shingle beaches and inland outwash gravels); they may also support specialised life forms (e.g. halophytes in salt pans, tropical taxa in geothermal areas). Furthermore, such ecosystems often provide important refuges for native plants and animals within highly modified landscapes (e.g. Wisser and Buxton 2008).

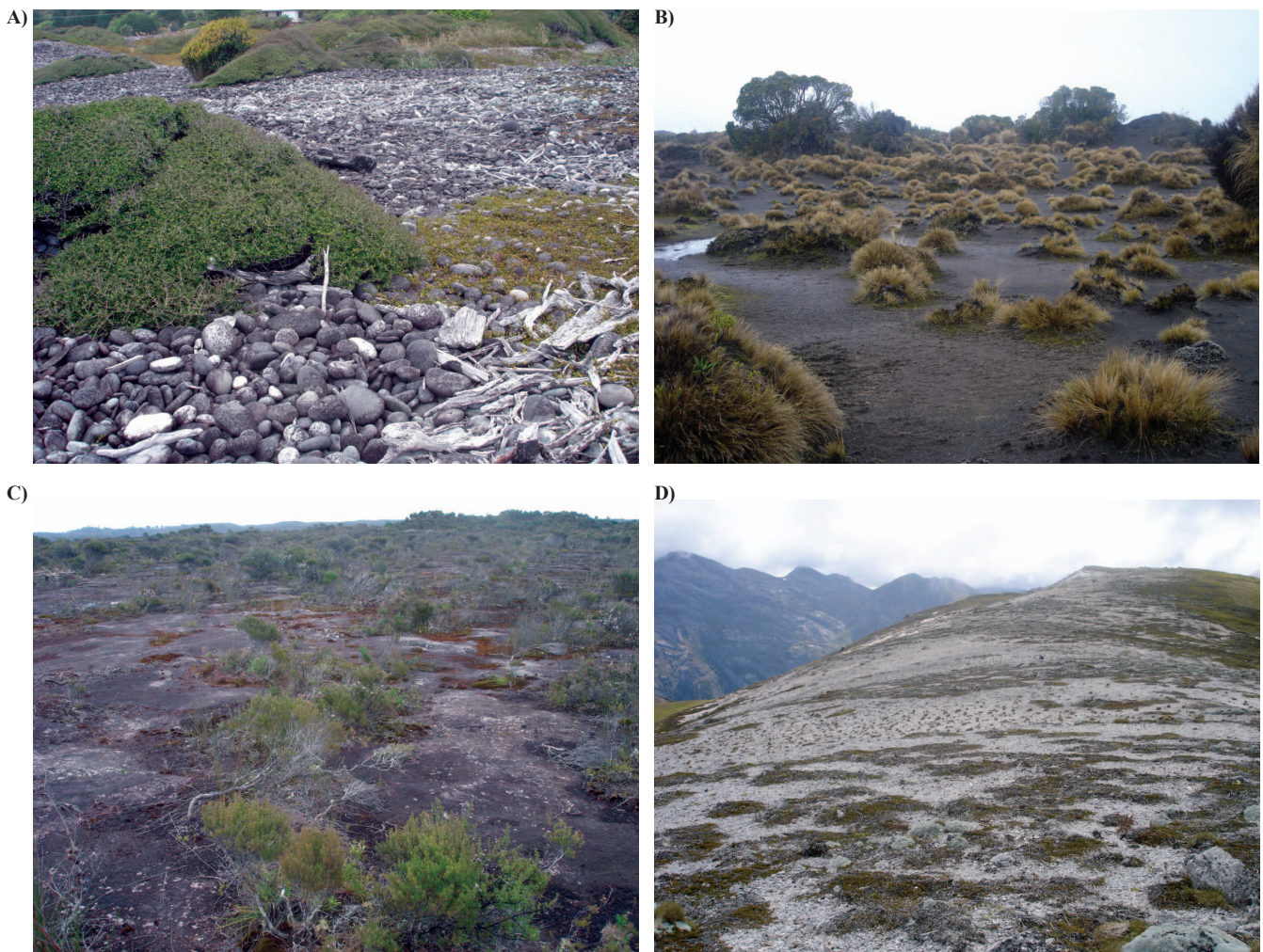


FIGURE 1 A, Shingle beach at Cobden Beach, Westland, with wind-shaped *Coprosma propinqua*. B, Volcanic dunes in the Rangipo Desert, central North Island, with scattered bristle tussock (*Rytidosperma setifolium*) in the foreground and bog pine in the background. C, Gumland (northern heathland) with scattered mānuka and the cemented pan visible at the surface, Lake Ohia, Northland. D, Granite sand plain on the Lookout Range, Northwest Nelson. All photos by Susan Wisser.

PRIORITIES FOR BIODIVERSITY PROTECTION ON PRIVATE LAND

In 2007 the Ministers of Conservation and the Environment issued a joint statement of national priorities for protecting rare and threatened native biodiversity on private land (National Biodiversity Priorities) (<http://www.biodiversity.govt.nz/pdfs/protecting-our-places-brochure.pdf>). Although not statutory, this statement provides guidance to local authorities, communities and private landowners about the types of ecosystems and habitats on private land that, from a national perspective, are most threatened and hence in need of protection. These national priorities are to protect: (1) indigenous vegetation associated with land environments (defined by Land Environments of New Zealand at Level IV) that have 20% or less remaining in indigenous cover; (2) indigenous vegetation associated with sand dunes and wetlands (ecosystem types that have become uncommon due to human activity); (3) indigenous vegetation associated with naturally uncommon terrestrial ecosystem types (based on Williams et al. 2007); and (4) habitats of acutely and chronically threatened indigenous species.

Those basing decision-making on this statement have found priority 3 conceptually easy to understand because of the obvious parallel with rare species and because most people are familiar with at least one kind of naturally uncommon ecosystem.

MEETING INFORMATION NEEDS OF END-USERS: WEB-BASED FACTSHEETS AND MAPS

Broad information needs around naturally uncommon ecosystems include:

- How can we identify specific naturally uncommon ecosystems?
- Where do they occur?
- Which naturally uncommon ecosystems are the most threatened?

Although Williams et al. (2007) provide concise definitions of each naturally uncommon ecosystem these are insufficient to allow examples of such ecosystems to be clearly identified on the ground. To this end, factsheets for each of the 72 ecosystems have been provided on a website. These factsheets provide a detailed definition of the ecosystem, photographs, summaries of notable flora and fauna, current threats, and hyperlinks to key references and useful information resources. They are available at <http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems>. The goal is to provide conservation managers and policymakers with a resource to facilitate their efforts to reverse the decline and degradation of these important elements of New Zealand's natural heritage. An example of a factsheet is provided in Figure 2.

Description – biota and controlling processes, what distinguishes them from other similar ecosystems?

Locations – where do/ might they occur? Are they widespread or geographically restricted?

Threats – weeds and pests, recreational vehicles, mining, fire, urbanisation, agricultural expansion, etc.?

Notable flora and fauna – any rare, restricted or endemic species?

Further reading – research papers, reports, and popular articles

Links – related websites

SEABIRD-BURROWED SOILS

These areas are where soils have been disturbed and enriched by seabirds burrowing for nesting, track formation, and guano excretion. Bird colonies may be in the open with almost no vegetation and only a few nitrophilous plants (e.g. *Diphysa australis*), beneath low-growing scrub (e.g. *Muehlenbeckia complexa*) or tussock grasses, or beneath a low forest where the birds simply drop through the canopy onto the forest floor where the cover of vegetation is proportional to the amount of bird activity.

Where do they occur?
These systems may not have been originally rare, because they would once have been widely distributed on the New Zealand coast, as far inland as the mountains of Te Urewera, and as high as the slopes of the Seaward Kaikoura Range, where they still exist. Now they are largely confined to islands, from the far northern New Zealand to the subantarctic. There are at least 22 in the Auckland Region alone.

Threats
High-fertility sites are invaded by weeds such as barley grass (*Hordeum* spp.) and annual exotic herbs spreading from surrounding areas, including via bird dispersal. These ecosystems are vulnerable to serious depletions of burrowing birds and other native fauna due to predation by rats, cats, and stoats. Sites with sparse and low vegetation cover pose little risk of fire, but forested sites may burn. The seabirds themselves are also at risk from being caught in fishing trawlers and from declining fish stocks on which they feed. Invasive mammals like rats also predate the chicks.


Notable Flora and Fauna
Threatened plants include the nationally critical native hibiscus (*Hibiscus trionum*), coastal peppercress (*Lepidium banksii*), native Hibiscus (*Hibiscus richardsonii*), the nationally vulnerable coastal cress (*Lepidium flexicaule*), *Lepidium naufragorum*, nau (*Lepidium oleraceum*) and New Zealand water cress (*Rorippa divaricata*). Declining species include *Cypripedium insularis*. Rarest species include orache (*Atriplex australasica*), renegades (by *Astragalus brucei*), Williams's broom (*Carmichaelia williamsii*), Chatham Island button daisy (*Lepidochloa featherstonii*) and large-leaved milk tree (*Strobilium banksii*). Naturally uncommon species include Buchanan's orache (*Atriplex buchananii*), sand brome (*Bromus arenarius*), *Senecio carnosus*, *Senecio marotii*, Mokohinau groundsel (*Senecio repangae* subsp. *pohohinuensis*) and *Senecio repangae* subsp. *repangae*. Vagrant species include *Senecio australis* and coloniser species include devil's horsehair (*Achyranthes velutina*) and mawhai (*Sicyos australis*).

Many petrel species create burrows, including the range restricted Pycroft's petrel (*Pterodroma pycrofti*) and Westland black petrel (*Procellaria westlandica*), and gradual decline Cook's petrel (*Pterodroma cookii*), and black petrel (*Procellaria parkinsoni*). Tuatara (*Sphenodon* spp.) are present, sometimes co-habiting with birds, on some islands. There are several forms: nationally endangered Brothers Island tuatara (*S. guntheri*), range restricted Cook Strait tuatara (*S. punctatus* 'Cook Strait') and sparse northern tuatara (*S. punctatus* subsp. *punctatus*).


Other threatened vertebrates associated with seabird burrows include Whitaker's skink (*Oligosoma whitakeri*) and the robust skink (*Oligosoma allenii*).

Further Reading
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Holdaway RN, Hawke DJ, Causier JE, Ogden S 1999. Soil indicators of pre-European seabird breeding in New Zealand at sites identified by predator deposits. *Australian Journal of Soil Research* 37: 103-113.
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Towns DR 1992. *Recovery plan for Whitaker's skink and robust skink*. Threatened Species Recovery Plan Series No. 3. Wellington, Department of Conservation. 45p.
Wardie DA, Bellingham PJ, Fukami T, Mulder CPH 2007. *Promotion of ecosystem carbon sequestration by invasive predators*. *Biology Letters* 3: 479-482.


Links
[New Zealand Birds](#)
Rod Morris Photography. [Brothers Island tuatara \(Sphenodon punctatus\) male sharing burrow with fairy prion chick](#).
Prepared by Matthew DiBona, Peter Williams, Susan Wiser & Michelle Weidner





Middle Island in the Mercury group (Peter Bellingham)



Red-billed gulls and *Lepidium oleraceum*, Tairāea Head



Whitaker's skink

Pycroft's petrel

FIGURE 2 Factsheet for the uncommon ecosystem ‘seabird-burrowed soils’ is one of the 72 factsheets available at <http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems>.

To inform policy and land-use decisions, it is critical that the national extent, geographic distribution, tenure and condition of naturally uncommon ecosystems are known. Lack of knowledge about where these ecosystems occur often leads to their unwitting destruction. Landcare Research and the Department of Conservation have been endeavouring to describe the spatial extent of each by GIS mapping all occurrences of each type of naturally uncommon ecosystem. This has involved searching the literature and databases, poring over spatial information (maps), and contacting experts to build a digital picture of the extent of each ecosystem. Digitisation has been required where maps and location points were not yet in digital format. Some maps could be produced easily using existing data layers. For example, the layer for ‘marine mammal rookeries and haul-outs’ was constructed from locations in the National Aquatic and Biodiversity Information System (<http://www.nabis.govt.nz>) that depicted breeding colonies of New Zealand fur seal (*Arctocephalus forsteri*), New Zealand sea lion (*Phocarctos hookeri*), and southern elephant seal (*Mirounga leonina*). These data were supplemented by ad hoc survey locations catalogued by Department of Conservation staff, as well as locations identified by individual researchers. These were point locations, so polygons were modelled with boundaries 500 m either side of a colony point location and up to 20 m altitude and less than 100 m inland (Figure 3). Other ecosystems, such as braided riverbeds, required syntheses of existing data layers and digitisation. Still others are more difficult to depict readily. For example, ephemeral wetlands may be very small (< 100 m²) and there could be thousands scattered widely across New Zealand. These locations are not captured in any existing spatial data layers and

there is no authoritative list of localities. We are exploring other methodologies to model the probability of where ephemeral wetlands are likely to occur and then to indicate the proportion of the land surface they occupy. Where actual locations are known, these could be digitised and potentially used to drive the model.

WHICH NATURALLY UNCOMMON ECOSYSTEMS ARE THE MOST THREATENED?

Since human settlement of New Zealand, many ecosystems have declined extensively in area and function. Although one-third of New Zealand’s land area is legally protected, the distribution of reserves has a strong bioclimatic bias toward montane and alpine regions, and many of our lowland ecosystems are facing ongoing and increasing threats from agricultural intensification, conversion to plantation forestry, mining, urban development, herbivory by introduced mammals, and invasive non-native species. A potential solution to this decline is management at the ecosystem level. Instead of focusing on individual species, this targets the preservation of ecosystem habitat and ecological integrity, hopefully leading to the protection and long-term integrity of populations of the full suite of species within each ecosystem. However, for these ecosystem-based conservation efforts to be prioritised, the most threatened ecosystem types must be identified.

To inform the setting of conservation priorities and prevent the loss of ecosystems, the International Union for Conservation of Nature (IUCN) recently proposed a quantitative approach to ecosystem-risk assessment (Rodriguez et al. 2011). Building on the success of species Red Lists, the IUCN criteria assess the risk of ecosystem loss based on properties of the ecosystem, including

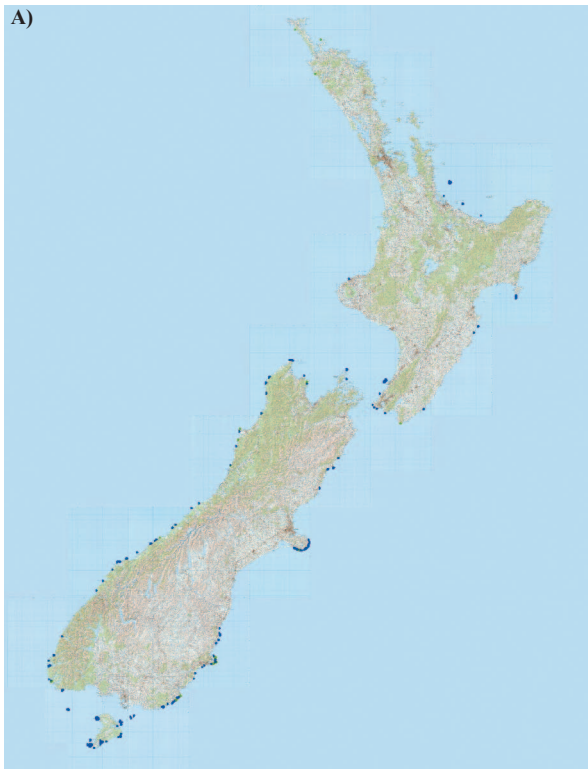


FIGURE 3 GIS map for the marine mammal rookeries and haul-outs. A, New Zealand scale. B, Close-up illustrating different mapping categories.

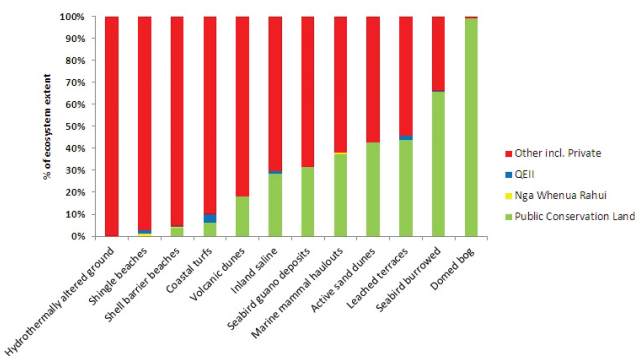


FIGURE 4 Proportion of the total extent of each of 12 mapped endangered (critically endangered, endangered and vulnerable) naturally uncommon ecosystems under different land tenures.

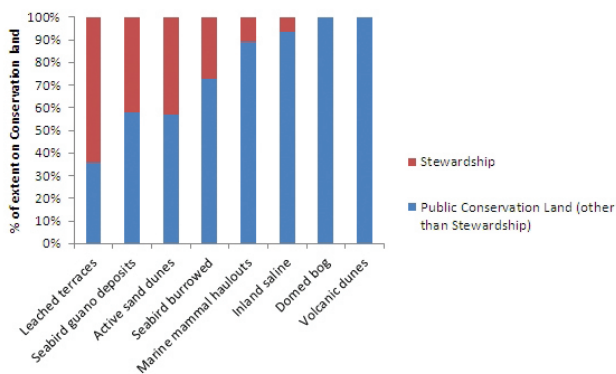


FIGURE 5 Proportion of the total extent on conservation land of each of seven mapped endangered (critically endangered, endangered and vulnerable) naturally uncommon ecosystems on land classed as 'Stewardship' versus other conservation classifications.

the degree to which it is geographically restricted, the presence of serious ongoing threats, and observed declines in geographic extent, ecological function, and ecosystem processes.

Naturally uncommon ecosystems contain 145 (85%) of mainland New Zealand's taxonomically distinct nationally critical, nationally endangered, and nationally vulnerable plant species (de Lange et al. 2009), 66 (46%) of which are confined to naturally uncommon ecosystems. Consequently, naturally uncommon ecosystems have been widely recognised as priority areas for conservation protection. There is, however, a need to identify the most threatened naturally uncommon ecosystem types. We addressed this need by applying the criteria for the draft IUCN Ecosystem Red List to New Zealand's naturally uncommon ecosystems. We used expert opinion to assess changes in ecosystem distribution and function over the past 500 years and

TABLE 2 Status of the 45 threatened naturally uncommon ecosystems in New Zealand. Reprinted from Holdaway et al. (2012)

Critically endangered	Endangered	Vulnerable
Shell barrier beach	Active sand dune	Coastal cliffs on mafic rock
Coastal turf	Dune deflation hollow	Screens of calcareous rock
Old tephra plains	Stony beach ridge	Young tephra plains and hill slopes
Inland sand dunes	Shingle beach	Boulder fields of calcareous rock
Outwash gravels	Stable sand dune	Cliffs, scarps and tors of mafic rocks
Inland saline	Coastal cliffs on calcareous rock	Cliffs, scarps and tors of calcareous rocks
Leached terraces	Ultramafic sea cliffs	Moraine
Fumaroles	Volcanic dunes	Lake margins
Geothermal stream sides	Sandstone erosion pavements	Blanket mire
Geothermal heated ground	Frost hollows	Estuary
Geothermal hydrothermally altered ground	Volcanic boulder fields	
Seabird guano deposits	Sinkholes	
Seabird burrowed soil	Dune slacks	
Marine mammal influenced sites	Domed bog (<i>Sporadanthus</i>)	

the last 50 years. Ecological integrity indicators (e.g. declines in native vegetation cover and increases in abundance of exotic weeds and pests; Lee et al. 2005) were used as a framework to evaluate reduction in ecosystem processes. These ecosystem-level criteria and their associated thresholds are linked to current ecological theory that predicts probability of elimination.

Our results show that since human settlement of New Zealand, many of these ecosystems have declined extensively in area and function and some are now at risk of complete collapse. Eighteen naturally uncommon ecosystems are critically endangered, 17 endangered, and 10 vulnerable (Table 2; Holdaway et al. 2012). Threatened naturally uncommon ecosystems were spread across all higher-level ecosystem classes (including wetlands, inland and alpine, geothermal), and a significant number of ecosystems had multiple criteria conferring their current threat status. Notably, there were more threatened plant species (per unit area) in critically endangered ecosystems than in ecosystems classified as non-threatened.

However, the results in Table 2 should be viewed as first approximations, and the status of individual ecosystems may change as more information is collected. Furthermore, our analysis represents only a subset of New Zealand's potentially threatened ecosystems because it does not encompass ecosystems that used to cover large areas (i.e. were naturally common) but now cover only small areas because of human activities.

Naturally uncommon ecosystems have been included in national-level conservation policy (e.g. Department of Conservation 2012), and our recent application of the IUCN's Ecosystem Red List criteria to these ecosystems now provides a rational basis for identifying the most threatened ecosystems and so informing the setting of conservation priorities.

WHICH NATURALLY UNCOMMON ECOSYSTEMS ARE WELL PROTECTED?

Fifteen of the 72 naturally uncommon ecosystems have maps at a final draft stage; of these, 12 are for endangered ecosystems. This allows the land tenure and protection status of each mapped ecosystem to be examined (Figure 4). Only one ecosystem, domed bogs, has over 80% of its extent protected. Four ecosystems – volcanic dunes, hydrothermally altered ground, shingle beaches and coastal turfs – have particularly poor protection, with less than 20% of their total area formally protected; consequently, they are high priority for future protection efforts.

Seven of the 12 ecosystems have more than 20% of their total extent on land administered by the Department of Conservation. However, four of these – leached terraces, seabird guano deposits, active sand dunes, and seabird burrowed ecosystems – have more than 20% of their area classed as 'Stewardship Land', which is yet to be classified as to its conservation status (Figure 5). These lands are high priority for evaluation.

NATURALLY UNCOMMON ECOSYSTEMS AND CONSERVATION DECISION-MAKING

The efforts described above have improved recognition of these important ecosystems in resource consent decisions, restoration, and conservation priority setting. The 2007 National Biodiversity Priorities statement has influenced protection at a national scale by helping shape the subsequent priorities of the Biodiversity Condition and Advice Funds, Nga Whenua Rahui, the Nature Heritage Fund and the Queen Elizabeth II National Trust (QEII National Trust 2007, 2012). Regional councils and territorial authorities are using the statement to guide how they

set priorities for practical actions and biodiversity responsibilities under the Resource Management Act 1991 (e.g. Taranaki Regional Council 2008; Environment Canterbury 2013). Land Information New Zealand has also included the National Biodiversity Priorities as one of the biodiversity protection options whereby a lessee of Crown Lands can qualify for a reduction in rent (Land Information New Zealand 2007). Naturally uncommon ecosystems are also receiving important recognition in several other processes. They are frequently recognised as significant during the resource consent process (e.g. Golder Associates 2008; Resource and Environment Management Nelson Limited 2010; Board of Inquiry into the New Zealand Transport Agency Waterview Connection Proposal 2011), agribusinesses are recognising them in industry guidelines for sustainable development (e.g. Hill Young Cooper Limited 2007), and they are being recognised in policy decisions and proposals involving biodiversity offsets (e.g. Hawke's Bay Regional Council 2012; Wildland Consultants 2012).

DESCRIPTIONS OF THE NATURALLY UNCOMMON ECOSYSTEMS THAT ARE CRITICALLY ENDANGERED

This section describes the subset of naturally uncommon ecosystems that we have designated as critically endangered (Holdaway et al. 2012). Photos are shown in Figure 6. Factsheets describing all 72 ecosystems, including those that are not critically threatened, are available online (Landcare Research undated). Each description includes a definition, lists alternative names by which the ecosystem may be known, where it is known to occur, threatened and endemic taxa that inhabit the ecosystem, and identified current threats. The species' threat status follows de Lange et al. (2009).

Shell barrier beaches ('Chenier plains')

A shell barrier beach is a prograded coastal plain comprising shell fragments and coarse sand that is moved by longshore drift and carried landwards through wash action to form bars on the foreshore (Woodroffe et al. 1983). There are only about 12 of these shell plains in the world. Shell barrier beaches are often colloquially referred to as 'Chenier plains'. The largest in New Zealand, at Miranda, is the only one in the world still aggrading. The shells are mainly those of little neck clams (*Austrovenus stutchburyi*), but other molluscs may be present. Shell barrier beaches would once have supported small-leaved shrubs such as saltmarsh ribbonwood (*Plagianthus divaricatus*), mingimingi (*Coprosma propinqua*) and mānuka (*Leptospermum scoparium*), but these have mostly disappeared.

Shell barrier beaches are confined to the Auckland Region, primarily to the Hauraki Gulf and the adjoining Waitemata Harbour. Miranda, in the Firth of Thames, Hauraki Gulf, is mostly Crown land managed by the Department of Conservation, although the wider area (also part of the Chenier plain) is privately owned and grazed. Miranda is included in the Firth of Thames Ramsar site, which is designated as an internationally significant wetland under the Convention on Wetlands. Other sites in the Hauraki Gulf include Stillwater (Stillwater shell barrier spits) and Wade Heads (Weiti River). Sites in the Waitemata Harbour include Shoal Bay (Jutland Road shell barrier beach, Eversleigh Road shell barrier beach), Ngataranga Bay (Norwood Road shell barrier spit), Hobson Bay (Hobson Bay shell barrier island and Portland Road) and Pollen Island (Pollen Island shell barrier).

The Firth of Thames is best known as an internationally important feeding ground for up to 25 000 birds at any one time.





FIGURE 6 Critically endangered ecosystems. **A**, Shell barrier beach (Chenier plain) (Janine Faulkner, Te Ara, the Encyclopedia of New Zealand, © Crown Copyright 2005–2011 Ministry for Culture and Heritage, New Zealand). **B**, Coastal turf, Taranaki (Bev Clarkson). **C**, Old tephra plains (frost flat) with monoao shrubland at Rangitaiki Conservation Area, central North Island (Susan Wiser). **D**, Inland sand dunes at the Cromwell Chafer Beetle Reserve with adventive evening primrose (*Oenothera glazioviana*) (Susan Wiser). **E**, Inland outwash gravels in the upper Clutha Valley (Peter Williams). **F**, Inland saline ecosystem, Galloway, Alexandra Basin (Penny Smale). **G**, Strongly leached terraces and plains with bog pine heathland at The Wilderness Scientific Reserve, Southland (Sarah Richardson). **H**, Fumaroles near Lake Rotokawa, north of Taupo, with prostrate kānuka scrub (middle distance) and wilding pines (background) (Bruce Burns). **I**, Geothermal streamside at Spa (Otumuheke) Stream, Taupo, with native ladder fern, *Christella* 'thermal', inkberry (*Dianella nigra*), and adventive blackberry (Bruce Burns). **J**, Geothermally heated ground (dry) with prostrate kānuka scrub at Karapiti/Craters of the Moon, north of Taupo (Susan Wiser). **K**, Hydrothermally altered ground (now cool) at Mokai, north-west of Taupo, with prostrate kānuka persisting (Mark Smale). **L**, Rare native plants on seabird guano deposits, South Brothers Island (Shannel Courtney). **M**, Marine mammal haul-out with a New Zealand fur seal at Turakirae Head, south-east of Wellington (Rowan Buxton).

Most of these are migratory. Three endemic bird species breed at Miranda: the endangered New Zealand dotterel (*Charadrius obscurus*), the endangered black-billed gull (*Larus bulleri*), and the variable oystercatcher (*Haematopus unicolor*). Non-endemic breeding species include the pied stilt (*Himantopus himantopus*), spur-winged plover (*Vanellus miles*), white-faced heron (*Ardea novaehollandiae*), banded rail (*Rallus philippensis*), black-backed gull (*Larus dominicanus*), white-fronted tern (*Sterna striata*), and pūkeko (*Porphyrio porphyrio*). Many bird species that breed in the Northern Hemisphere overwinter here during the southern summer, including the bar-tailed godwit (*Limosa lapponica*) and red knot (*Calidris canutus*), while 40% of the world population of the endemic wrybill (*Anarhynchus frontalis*) overwinters here. Other notable species include the nationally endangered Australasian bittern (*Botaurus poiciloptilis*), as well as grey teal (*Anas gracilis*), New Zealand shoveler (*Anas rhynchotis variegata*), New Zealand kingfisher (*Halcyon sancta vagans*), cattle egret (*Bubulcus ibis*), and royal spoonbill (*Platalea regia*).

Rare and threatened plants include the nationally critical grey saltbush (*Atriplex cinerea*) and the naturally uncommon New Zealand musk (*Mimulus repens*).

Direct human impacts include drainage, pastoral development and stock damage, and shell extraction in some areas. This high level of disturbance and removal of native vegetation has allowed exotic weeds to pose a serious threat. At Miranda, less than 10% of native vegetation remains and most areas are dominated by numerous exotic herbs and graminoids of which saltmarsh sedge

(*Carex divisa*) and saltmarsh rush (*Juncus gerardii*) are prominent. Because exotics are abundant in these ecosystems, they are the first plants to colonise newly formed bare shell banks. Additionally, demand for coastal property poses a threat to shell barrier beaches around Auckland. Indirect threats include water quality deterioration, sediment deposition and nutrient loading. These are caused by river discharges and environmentally unsuitable farming practices in the catchment, for example intensive stocking and a lack of fences.

Coastal turfs

Coastal turfs are communities of tightly interlaced, ground-hugging, short-statured herbs, grasses, and sedges occupying hard-rock landforms on the headlands most exposed to persistent salt-laden onshore winds and occasional high water (Rogers and Wiser 2010). They can overlie a considerable depth of peat. Originally sandwiched between the shoreline and inland coastal scrub and forest, they have expanded inland after the bordering woody communities were cleared.

Coastal turfs occur in eight mainland New Zealand regions along the western and southern coasts of the North and South Island: the North and South Taranaki bights, the eastern Wairarapa coast, the Te Taitapu (Whanganui Inlet) coast of west Nelson, Westland, Fiordland, Southland, Otago, and the Marlborough Sounds. Coastal turfs also occur on New Zealand's inshore and offshore islands, the latter including Stewart Island (Rakiura), the Chatham Islands, and the subantarctic islands. Across the North and South islands, their total extent is probably less than 40 hectares, making them an exceptionally rare ecosystem. Widespread and abundant native plant species in coastal turfs include native celery (*Apium prostratum*), *Centella uniflora*, *Colobanthus muelleri*, *Hydrocotyle novae-zeelandiae* var. *montana*, *Isolepis cernua*, *Leptinella dioica*, *Selliera radicans*, and *Samolus repens*.

Coastal turfs are subject to invasion by exotic species (e.g. mouse-ear chickweed (*Cerastium fontanum*), catsear (*Hypochaeris radicata*), Bucks horn plantain (*Plantago coronopus*), procumbent pearlwort (*Sagina procumbens*), creeping bent grass (*Agrostis stolonifera*), Yorkshire fog (*Holcus lanatus*), and several clovers and trefoils (*Trifolium* and *Lotus* spp.)). Exotic species are most problematic in ecotones with other communities, because exotic species typically do not become dominant in the most saline conditions. Heavy trampling, particularly on wet turfs, can be damaging as can grazing by ungulates (cattle, sheep, and deer) and browsing by hares in some areas. However, in other situations light grazing may be beneficial by helping turfs retain their dominantly herbaceous character. In the past, this character may have been maintained by birds and marine mammals, whose populations are now substantially reduced. Accessible areas are also susceptible to human impacts like vehicle damage, trampling, and subsequent erosion.

Rare plants include the nationally critical *Gentianella scopulorum* and *Crassula peduncularis*; nationally endangered *Myosotis brevis*; nationally vulnerable coastal cress (*Lepidium flexicaule*), *Mazus novaezeelandiae* subsp. *impolitus* f. *impolitus*, *Carmichaelia juncea* and *Crassula manaia*; declining *Myosotis pygmaea* var. *pygmaea*, *Tetrachondra hamiltonii*, *Lepidium tenuicaule*, *Ranunculus recens*, and *Selliera rotundifolia*; naturally uncommon *Mazus arenarius*, *Crassula helmsii*, *Leptinella dispersa* subsp. *dispersa*, *Wahlenbergia congesta* subsp. *congesta*, *Acaena microphylla* var. *pauciglochidiata*, *Anisotome lyallii*, *Euphrasia repens*, *Leptinella calcarea*, *Leptinella traillii*

subsp. *pulchella*, *Myosotis rakiura*, *Poranthera microphylla*, *Puccinellia walkeri* and *Atriplex buchananii*; and relict *Sonchus kirkii*. Rare invertebrates include the pimelea looper moth (*Notoreas perornata*).

Old tephra plains (frost flats)

Old tephra plains form low-lying flats on the North Island's Volcanic Plateau. They were created when vast quantities of pumice produced by the titanic eruptions that shaped the plateau were washed off surrounding hills and filled basins and valleys. These sites are at relatively high elevation (400–800 m a.s.l.), so they collect cold air and suffer from year-round frosts; consequently they are commonly referred to as 'frost flats'. The term 'frost flat' is sometimes also used to describe frosty, often strongly leached alluvial terraces and plains in the South Island (e.g. 'wilderness' ecosystems), but these systems should not be confused with old tephra plains.

The rhyolite pumice comprising old tephra plains is naturally infertile. Fire has also been important in shaping and maintaining the vegetation, which is typically dominated by monoao (*Dracophyllum subulatum*). Other diagnostic species for this ecosystem are coral lichen (*Cladia retipora*), *Cladonia confusa*, *Deyeuxia avenoides*, catsear, silver tussock (*Poa cita*), woolly moss (*Racomitrium lanuginosum*), and *Rytidosperma gracile* (Smale 1990). Some of the best remaining examples are the heathlands at Rangitaiki and Otangimoana conservation areas on the southern Kaingaroa Plateau.

Threatened plants include *Pittosporum turneri*, which occurs in late-successional systems, and *Pimelea tomentosa*; both are classified as nationally vulnerable. Threatened bryophytes include the naturally uncommon *Crosbya nervosa* and the sparse *Pseudocephalozia lepidozooides*. Phylogenetic analysis has placed an undescribed species of the mushroom *Cystoderma* from the Rangitaiki (PDD92285, Col. J.A. Cooper, 18/5/2011) very close to *Cystoderma andinum* described from a páramo alpine tundra ecosystem of Ecuador. Rare invertebrates include the Lepidoptera *Ericodesma aerodana* and the northern pimelea cutworm moth (*Meterana pictula*), which have *Pimelea* species as hosts, and *Meterana grandiosa*, whose larvae feed on small-leaved *Olearia* species (Patrick and Dugdale 2000).

Old tephra plains are vulnerable to invasion by exotic weeds adapted to low soil nutrients, for example gorse (*Ulex europaeus*) and Scotch broom (*Cytisus scoparius*), both of which fix nitrogen; heather (*Calluna vulgaris*); pines (*Pinus* species); and species of pasture grass such as browntop (*Agrostis capillaris*) and herbs such as mouse-ear hawkweed (*Pilosella officinarum*) in nutrient-enriched areas (e.g. around gull colonies; Smale et al. 2011). Adjacent agriculture and plantation forestry can also result in nutrient pulses that increase vulnerability to weed invasion. Rabbits and hares may be locally abundant. Where these plains are accessible, four-wheel drive vehicles can be especially damaging to the low, scattered vegetation.

Strongly leached terraces and plains ('wilderness')

These ecosystems comprise terraces, outwash plains or dry shingle fans of glacial or fluvial-glacial origin. They are colloquially referred to as 'wilderness' and sometimes erroneously referred to as 'frost flats'. Strongly leached terraces and plains have unusually low soil fertility for their elevation, and so have been described as examples of early post-glacial succession arrested because of low fertility (Molloy 1975). They are frequently free-draining and experience cold winters (high incidence of frost) and

hot summers (seasonal drought). Bog pine (*Halocarpus bidwillii*) is a diagnostic species that forms scattered clumps surrounded by a matrix of mat-forming vegetation or moss/lichenfields.

Known sites are restricted to the southern and eastern South Island, in the Mavora, Mackenzie, Molesworth and Puketeraki ecological regions.

Threatened and rare plants include the nationally endangered Armstrong whipcord hebe (*Hebe armstrongii*), declining coral broom (*Carmichaelia crassicaulis*), relict *Coprosma intertexta*, and a naturally uncommon fireweed (*Senecio dunedinensis*). The rare moth *Ericodesma cuneata* (Tortricidae) has been found quite commonly at The Wilderness, Southland; its larvae feed on *Corokia*.

Most examples of this ecosystem have probably been lost to agriculture (high country grazing or arable farming at lower altitudes). Grazing and conversion to pasture are still threats. Weeds include wilding conifers; dryland shrub species like gorse, Scotch broom, blackberry (*Rubus fruticosus*), sweet briar (*Rosa rubiginosa*), and heather; broadleaved herbs such as hawkweeds (*Pilosella* spp.); and introduced grasses. Rabbits and hares are also serious threats to woody regeneration. Nutrient enrichment from adjacent irrigation and effluent may emerge as a threat.

Inland sand dunes

This ecosystem comprises non-volcanic inland dunes formed from river sand. Consequently, these dunes have never been influenced by coastal processes. Included here are only active or semi-active dunes with raw or recent soils with no well-developed soil horizons. Inland sand dunes are sometimes referred to as 'sand hills' and may include sand plains. Except for some planted exotic marram grass (*Ammophila arenaria*), inland dunes support no specialised sand-binders; instead, they are colonised by the same species that colonise riverbed sand, such as scabweeds (*Raoulia* spp.) and silver tussock (Watt 1979).

Inland sand dunes are best developed in the upper Clutha and upper Waitaki basins of Central and North Otago, and also in the Ashburton, Rakaia, Rangitata, and Waimakariri valleys of Canterbury.

Threatened and rare plants include dwarf woodrush (*Luzula celata*), which is in serious decline. The endangered Cromwell chafer beetle (*Prodontria lewisi*) is confined to one site near Cromwell (Watt 1979).

Most inland sand dunes in Otago and Canterbury have been converted to agriculture or forestry; in the early 1900s these 'useless sand wastes' were considered a 'menace' to adjacent fertile lands and were deliberately planted to stabilise them (Cockayne 1911). Dunes at some locations have been destroyed by or are at risk from hydroelectricity development (McMillan 1978). Exotic weeds are a major threat: pines have invaded dunes adjacent to Lake Tekapo, while the Central Otago Cromwell Chafer Beetle Reserve, where rabbit grazing has been severe, is now dominated by sweet vernal (*Anthoxanthum odoratum*), sheep's sorrel (*Rumex acetosella*), and haresfoot trefoil (*Trifolium arvense*) (Ferreira and McKinlay 2000). In addition to the threats to the few remaining existing sites, human modification of the dynamics of braided rivers has also altered the capacity of rivers to supply sand to adjacent land to form new dunes.

Inland outwash gravels

Inland outwash gravels, formed of assorted alluvium mostly from retreating glaciers and more recent river deposits, occur in intermontane basins. Soils are excessively well drained,

creating particularly stressful environments for plants where conditions also include very high or low temperatures and droughts. Inland outwash gravels comprise landforms including terraces, plains, and fans. Terrace risers are often very stony and covered in low matagouri (*Discaria toumatou*) shrubland or mixed 'grey scrub' (Wardle 1991). The broad terrace treads have a high proportion of fine windblown glacial till. They support many small plants including turf coprosma (*Coprosma petriei*), pātōtara (*Leucopogon fraseri*), *Pimelea* spp., *Poa* spp., scabweeds, creeping pōhuehue (*Muehlenbeckia axillaris*), and common mountain daisy (*Celmisia gracilentia*). The distinctive tumbleweed lichen *Chondropsis semiviridis* is also present. They would once have also supported indigenous woodland with bunch grasses (*Festuca*, *Poa*). Exotic herbs and grasses are now abundant.

Inland outwash gravels are best developed in the upper Clutha and upper Waitaki basins of Central and North Otago; they also occur in the Ashburton, Rakaia, Rangitata, and Waimakariri valleys of Canterbury. Smaller areas are found in the foothill valleys of rivers such as the Mataura (Southland) and Pareora (Canterbury).

Threatened and rare plants include the nationally critical button daisy (*Leptinella conjuncta*), *Brachyscome pinnata*, and dwarf musk (*Mazus novaezeelandiae* subsp. *impolitus* f. *hirtus*); nationally endangered Kawarau cress (*Lepidium sisymbrioides*); nationally vulnerable dwarf musk (*Mazus novaezeelandiae* subsp. *impolitus* f. *impolitus*), pygmy forget-me-not (*Myosotis glauca*), and a native broom (*Carmichaelia juncea*); and declining dwarf broom (*Carmichaelia vexillata*), fan-leaved mat daisy (*Raoulia monroi*), leafless pōhuehue, and trailing bindweed (*Convolvulus verecundus*).

Threatened or rare fauna include banded dotterel (*Charadrius bicinctus*), black-fronted tern (*Sterna albostrigata*), green skink (*Oligosoma chloronoton*), jewelled gecko (*Naultinus gemmeus*), spotted skink (*Oligosoma lineoocellatum*), long-toed skink (*Oligosoma longipes*), and robust grasshopper (*Brachaspis robustus*).

Weed invasion is a major threat. The main species are wilding pines, sweet briar, Scotch broom, Russell lupin (*Lupinus polyphyllus*), and stonecrop (*Sedum acre*). Loss or degradation has been caused by viticulture and residential subdivision (Central Otago), irrigation (upper Waitaki), mining (Nevis Valley, Otago), and damage by off-road vehicles. Sites are also susceptible to grazing by stock, rabbits, and hares.

Inland saline (salt pans)

Inland saline ecosystems are areas of soil where, in the absence of leaching, soluble salts have accumulated to such an extent that they are moderately to highly alkaline (pH >7). They are also known as 'salt pans'. The salts are derived from ancient marine or lake sediments or deeply-weathered schist, and they accumulate in low-lying, gently-sloping areas (Rogers et al. 2000). Inland saline ecosystems can often be identified by a grey-white crust on the surface of apparently bare ground. They are characterised by salt-tolerant plants such as native celery (*Apium prostratum* subsp. *prostratum* var. *filiforme*), Buchanan's orache (*Atriplex buchananii*), *Chenopodium ambiguum*, *Lilaeopsis novaezeelandiae*, and *Selliera microphylla*.

Inland saline ecosystems occur in localised areas of Central and North Otago, particularly in the Lower Manuherikia Valley; on the Maniototo Plain; and in the Clutha Valley south-west of Alexandra.

Threatened or rare plants include the nationally critical salt-grass (*Puccinellia rariflorens*), salt-pan cress (*Lepidium kirkii*), and New Zealand mousetail (*Myosurus novae-zelandiae*); the nationally endangered *Myosotis brevis*; the declining Cromwell broom (*Carmichaelia compacta*); and the naturally uncommon Buchanan's orache and blue wheat grass (*Anthosachne apricus*). These ecosystems have a small but distinctive lepidopteran fauna: a species in the genus *Loxostege* (Crambidae); *Paranotoreas fulva* (Geometridae), which is restricted to Central Otago; and two species, *Scythris triatma* (Scythrididae) and *Kiwaia thyraula* (Gelechiidae), that appear to be typical of salt pans in parts of Central Otago.

Most sites have been destroyed by extensive pasture development and irrigation. Weeds are relatively few, but buckshorn plantain and several barley grasses (*Hordeum* spp.) have successfully colonised these habitats. Many sites are grazed by stock, and rabbits damage vegetation through grazing and burrowing.

Geothermal ecosystems

Four types of geothermal ecosystems are critically endangered: fumaroles, geothermal streamsides, heated ground (dry), and hydrothermally altered ground (now cool). These generally face similar threats. Wilding pines (e.g. *Pinus pinaster*, *P. radiata*), blackberry, broom, and buddleia (*Buddleja davidii*) can be problematic in marginal areas where the soils are cool enough for them to establish, although the hottest soils tend to have few naturalised species. Geothermal areas are generally too unstable for urbanisation but they have been used as dumping grounds. In more stable areas, stock may trample vegetation when this is unfenced. Rabbits and hares are present in many geothermal ecosystems. Geothermal fluid extraction for energy can affect surface activity and change soil temperatures with consequent impacts on plant communities; it can also cause subsidence. Naturally occurring eruptions often destroy vegetation. In places where these areas are used for recreational activities like motocross riding, considerable damage can result. There are some impacts from tourism, but these are usually well controlled. Some trampling occurs where people access hot streams for bathing.

Geothermal ecosystems: fumaroles

Fumaroles are vents or openings that issue steam and hydrogen sulphide and other gases, and are usually associated with past or current magmatic activity. Fumaroles may also be referred to as 'volcanic steam vents'. Constant steam allows frost-sensitive species to survive on fumarole margins, including otherwise tropical ferns (listed below; Given 1980). The moss *Campylopus pyriformis* can be important close to fumaroles where soil temperatures are too hot for vascular plants. Low soil pH also limits the species that can survive in these areas.

Fumaroles occur primarily in the Taupo Volcanic Zone on the Volcanic Plateau in the central North Island.

Threatened plants include the nationally vulnerable *Machaerina complanata*; the declining native ladder fern (*Nephrolepis flexuosa*); the taxonomically indeterminate declining *Christella* aff. *dentata* ('thermal'); and the naturally uncommon *Fimbristylis velata*, giant hypolepis (*Hypolepis dicksonioides*), and *Dicranopteris linearis*. Fumaroles harbour two species of macroinvertebrates confined to high-temperature, low-pH waters: the ephydrid fly *Ephydrella thermanum* and the endemic mosquito *Culex rotoruae*.

Geothermal ecosystems: geothermal streamsides

Geothermal streamsides are steam-influenced microhabitats created by hot springs and streams that allow species (particularly those with tropical origins) to exist in areas that would otherwise be too cold. For example, harakeke (*Phormium tenax*) and pūkio (*Carex secta*) grow beside the hot pools in the Copland Valley at 450 metres, a higher altitude than elsewhere in Westland.

Geothermal streamsides are common in the Taupo Volcanic Zone on the North Island Volcanic Plateau, and also occur in association with the Alpine Fault in the South Island as far south as the Copland Valley. Unfortunately many of these streamsides no longer support native vegetation.

Threatened plants include the nationally vulnerable *Machaerina complanata*, the declining *Cyclosorus interruptus* and native ladder fern, and the naturally uncommon giant hypolepis. Indeterminate species include the declining *Christella* aff. *dentata* ('thermal'). These systems contain two species of macroinvertebrates confined to high-temperature, low-pH waters: the ephydrid fly *Ephydrella thermanum* and the endemic mosquito *Culex rotoruae*.

Geothermal ecosystems: heated ground (dry)

Geothermally heated soils result from heat flow through the ground (in contrast to heat losses from water sources or fumaroles, overflow from geysers and springs, or seepages to nearby lakes or rivers). The heat flowing through the heated ground is released at the surface as steam. Karapiti/Craters of the Moon (Given 1980), for example, is a steamfield that includes heated ground as well as fumaroles, but no streams or areas of standing water. Soil temperatures at 15 cm depth in areas supporting plants (including mosses) range from 40° to 85°C. The endemic prostrate kānuka (*Kunzea ericoides* var. *microflora* – a true-breeding form) is the most characteristic species.

Heated ground primarily occurs in the Taupo Volcanic Zone on the Volcanic Plateau in the central North Island.

Threatened and rare plants include the declining native ladder fern; the taxonomically indeterminate and declining *Christella* aff. *dentata* ('thermal'); and the naturally uncommon *Dicranopteris linearis*, *Fimbristylis velata*, giant hypolepis, prostrate kānuka, and red-bearded orchid (*Calochilus robertsonii*).

Geothermal ecosystems: hydrothermally altered ground (now cool)

Hydrothermally altered soils have been changed by geothermal steam and are highly infertile, being strongly acidic with low amounts of organic matter and phosphorus and sometimes high concentrations of metals and trace elements (Given 1980). This ecosystem is dominated by scrub, mostly prostrate kānuka.

Hydrothermally altered ground occurs primarily in the Taupo Volcanic Zone on the Volcanic Plateau in the central North Island.

Threatened and rare plants include the nationally critical flying duck orchid (*Sullivania minor*); the declining native ladder fern; and the naturally uncommon red-bearded orchid, *Fimbristylis velata*, *Dicranopteris linearis*, and prostrate kānuka.

Seabird guano deposits

Nesting sea birds deposit guano (excrement) that can accumulate to form deposits of varying depth. These areas commonly have sparse vegetation because of bird trampling and the toxically high nitrogen status of fresh guano, but vascular plants can occur towards the edges, in sparse colonies, or on shallow deposits

(Gillham 1960). Halophytes such as native ice plant (*Disphyma australe*), native shore groundsel (*Senecio lautus*), and *Einadia trigonos* are the most common plants. Also associated with guano are green algae, like the recently discovered species from the order Prasiolales (*Prasiola novaezelandiae*) (Heesch et al. 2012). Outside the breeding season, when the birds are absent and rain has washed some areas free of guano, there is likely to be a minor invasion of annual exotic weeds that can tolerate the high nutrient status. These communities grade into other coastal communities such as coastal turfs (see above).

The largest guano deposits are found in association with Australasian gannet (*Morus serrator*) colonies that have been occupied for decades. The most extensive of these is on the North Island at Cape Kidnappers, Hawke Bay. They also occur on several offshore islands, such as White Island/Whakaari, and on coastal rock stacks. Guano deposits occur at Kaikoura with a large red-billed gull (*Larus Novaehollandiae* ssp. *scopulinus*) colony, and scattered deposits occur inland associated with black-backed gull colonies, for example on Mt Tarawera (Bay of Plenty) where colonies are densely vegetated by exotic grasses such as sweet vernal and Yorkshire fog. Guano deposits may also be associated with other seabirds such as cormorants and penguins.

Threatened plants include the nationally critical coastal peppergrass (*Lepidium banksii*). Nationally vulnerable species include *Kirkianella novae-zelandiae* f. *glauca*, *Lepidium naufragorum*, nau (*Lepidium oleraceum*), New Zealand water cress (*Rorippa divaricata*), and Chatham Island forget-me-not (*Myosotidium hortensia*). Recovering species include Chatham island sowthistle (*Embergeria grandifolia*). Relict species include Chatham Island button daisy (*Leptinella featherstonii*), Chatham Island groundsel (*Senecio radiolatus* subsp. *radiolatus*) and guano groundsel (*Senecio sterquilinus*). Declining species include shore cress. Naturally uncommon species include (*Anisotome latifolia*), Buchanan's orache, Cox's fescue (*Festuca coxii*), *Leptinella lanata*, *L. plumosa*, *Pleurophyllum criniferum*, Antipodes groundsel (*Senecio radiolatus* subsp. *antipodus*), *Stellaria decipiens* var. *angustata*, Chatham Islands poa (*Poa chathamica*), muttonbird poa (*Poa foliosa*) and *Poa ramosissima*. During their nesting season, burrowing seabirds such as petrels, prions, and shearwaters share their burrows with the threatened ancient reptile, the tuatara (*Sphenodon punctatus*). The seabirds' guano helps to maintain invertebrate populations that are a primary food source for the tuatara, including beetles, crickets, and spiders.

Seabird colonies (except for black-backed gulls, which have increased since European colonisation) are threatened by predation by invasive mammals and domestic pets; disturbance from grazing stock, off-road vehicles and people; and encroaching urbanisation. Exotic weeds are present, but with the exception of the grasses mentioned above, these are mostly transient.

Marine mammal rookeries and haul-outs

Marine mammal rookeries and haul-outs in coastal areas compact soils and enrich them with nutrients. Historically, they would have occurred on a wide range of substrates from sand dunes to bedrock and might have supported a wide range of vegetation, as animals inhabited coastal scrub and dune vegetation.

Haul-outs would once have been found along much of the New Zealand coast, as they still are on remote subantarctic islands. On the mainland they are now restricted to rocky sites occupied by colonies of New Zealand fur seals, which are widely scattered along the coastline, for example on the Kaikoura coast,

at Cape Foulwind in Westland, and at Cape Palliser in the North Island.

Threatened and rare plants include the nationally critical coastal peppergrass. Nationally vulnerable plants include Cook's scurvy grass (*Lepidium oleraceum*), New Zealand water cress, coastal cress and *Lepidium naufragorum*; recovering plants include Chatham Island speargrass (*Aciphylla traversii*); and relict plants include orache (*Atriplex australasica*) and Chatham Island button daisy. Naturally uncommon plants include *Senecio repangae* subsp. *repangae*, *S. marotiri*, *S. carnosulus*, Buchanan's orache, and Mokohinau groundsel (*S. repangae* subsp. *pokohinensis*). Vagrant plants include *Senecio australis*. Threatened and rare fauna include the Fiordland skink (*Oligosoma acrinusum*).

Enhanced fertility encourages weed invasion, although this probably does not directly threaten native plants because they are so sparse due to the impacts of the marine mammals.

FUTURE DIRECTIONS: INCORPORATING ECOSYSTEMS MADE UNCOMMON BY HUMAN ACTIVITY

We have shown how the typology for naturally uncommon ecosystems has greatly increased awareness of their character and importance and has provided a framework for understanding the degree to which they are threatened. This typology, however, does not encompass all threatened ecosystems and there are limits to its application.

First, each ecosystem is defined by an aspect of the environment that is extreme. This means some ecosystems may be widely distributed, sometimes across different climatic zones, so they may support a wide range of vegetation types and be biologically quite heterogeneous with different biological communities at different sites (e.g. shingle beaches, moraines). In contrast, others may be more narrowly circumscribed and distributed (e.g. old tephra plains, gumlands).

Second, ecosystems that were once common but have had their distribution reduced because of human activity are not included in the typology. Some of these are highly threatened and are also very important from a conservation perspective. Such ecosystems include coastal forests, many wetland types (including riparian margins/ecotones with forest), and dense lowland podocarp forests with tall rimu (*Dacrydium cupressinum*), mataī (*Prumnopitys taxifolia*), tōtara (*Podocarpus totara*), and kahikatea (*Dacrycarpus dacrydioides*).

To address these issues, two activities are required. First, to allow conservation priorities to be better set we need comprehensive biological data to determine the heterogeneity within each of the defined ecosystems. Clearly, ecosystems with highly heterogeneous biodiversity across sites will require more extensive protection and management than more uniform ecosystems. Data like these would allow policymakers to assess the adequacy of current protection and management strategies in conserving the biodiversity of different naturally uncommon ecosystems. Second, a typology of ecosystems that were once common but are now rare would complement the existing typologies and help promote the protection and conservation of all uncommon ecosystems.

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