## Intermediate Outcome 1: The diversity of our natural heritage is maintained and restored

| **Outcome Objective 1.1** | ***Maintaining ecosystem processes*** |
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| The ecosystem processes focused on here are those concerning the flux of energy, nutrients, and living material at large scales. Biotic outcomes are therefore measured at broad trophic levels for the most part, and are underpinned by abiotic measures. An important role this Outcome Objective plays is to ensure that widespread abiotic and biotic degradation is not neglected through it not being considered critical at any site in particular. Using this suite of indicators and measures, a broad overview can be achieved of the reciprocal impact and interactions between abiotic factors (soils, land movements, fragmentation of vegetation cover) and biotic factors (net primary production, fruiting and seeding, fluctuations in abundance at trophic levels, effect on catchment water yield). The requirement for monitoring is most acute in the freshwater and marine domains because of the stress these naturally open systems are under from agricultural intensification, development along the coasts, and direct exploitation. In the land domain the effect of abiotic changes on public conservation lands can either be regarded as part of the normal cycle (for instance, regeneration after blowdown of forest) or are, for the most part, circumvented by protection measures (for instance, prohibition of tree felling). It is important to know what is happening as a background, but these measures do not contribute in a major way to annual reporting. Climate change is the exception and is dealt with separately under Outcome Objective 1.7: *Adapting to climate change*. | |
| **Indicators:**<br>**1.1.1** Substrate quality<br>**1.1.2** Ecosystem function<br>**1.1.3** Water quality and quantity<br>**1.1.4** Ecosystem structure<br>**1.1.5** Disturbance<br>**1.1.6** Land cover | |

| **Indicator 1.1.1** | ***Substrate quality*** |
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| *Description* | Substrates physically support and provide the nutrients necessary for life. However, they differ radically between the domains. Substrate data derived from the different domains tend to address differing issues. |
| *Justification* | *Land domain substrates*. While soil factors strongly affect the productivity of a given site, different ecosystems have very different productivity and, under a natural system, soil is not an ecological integrity (EI) factor of concern. This is not true everywhere in the world because deposition of sulphur and nitrogen, which is insignificant in New Zealand, in some regions exceeds local soil buffering capacity. However, soils are essential to the interpretation of many biodiversity changes which are of EI concern. |

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| | Soil carbon is also a key component of a nation's greenhouse gas inventory, and will be measured for that reason alone.<br>*Freshwater and marine domain* substrates are often rapidly accumulating or altering, are subject to extensive burrowing by marine organisms, and are readily remobilised in riverine and coastal settings. Measurements of freshwater and marine domain substrate change and composition may give essential information concerning EI. |
| *Comment* | Well established measures are available and in use. |
| *Measures* | **1.1.1.1-L** Soil structure and chemistry<br>**1.1.1.2-L** Soil carbon content<br>**1.1.1.3-FM** Sedimentation and sediment quality |

| **Measure 1.1.1.1-L** | ***Soil structure and chemistry*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.1** Substrate quality |
| Status | Final |
| **Description** | |
| *Overview* | Soils vary greatly physically and chemically over short distances. However, as long as they remain under vegetation cover, soils usually alter slowly. An exception has been the changes in soil carbon and nitrogen storage with exotic mammal pressure in New Zealand at highly used sites (Wardle et al. 2001). Soils are also costly to measure with an accuracy sufficient to detect small changes reliably. That said, soil data layers are essential for studies of ecosystem functioning: rates of regeneration, plant distributions, invasiveness by exotics, susceptibility of plants to browsing etc. are all influenced by soil nutrients and structure. Increasingly, soil carbon is viewed as a critical metric in greenhouse gas accounting as the top 1 metre of soil contains more carbon than all above-ground vegetation and in the atmosphere. Soil carbon is the target of focused research programmes coordinated by the New Zealand Agricultural Greenhouse Gas Research Centre.<br>Basic soil data layers should be maintained even if rapid change is not anticipated. Internationally, soils are recorded in nation-scale inventories, and invariably reported on when plot-based systems are used. Nutrient status of soils and microbiological health are also often recorded by direct chemical measures or biological proxies and, increasingly, by soil DNA analyses. |

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| *Data elements* | Landcare Research holds the National Soils Database, which can be accessed via https://soils.landcareresearch.co.nz/. Standard soil measures in this database are:<br>• Slope<br>• Potential rooting depth<br>• Topsoil gravel content<br>• Proportion of rock outcrop<br>• pH<br>• Salinity<br>• Cation exchange capacity<br>• Total carbon<br>• Phosphorus retention<br>• Nitrogen<br>• Flood interval<br>• Soil temperature<br>• Total profile available water<br>• Profile readily available water<br>• Drainage<br>• Macropores (shallow and deep) |
| *Scale* | National |
| *Measurement and reporting frequency* | Soil properties do not need to be measured frequently, but a large number of individual measurements are needed to characterise soil units.<br>Soil carbon will be reported as part of New Zealand's Greenhouse Gas Inventory. |
| *Data sources* | • Soil data are not systematically collected by DOC.<br>• The Land-use and Carbon Analysis System (LUCAS) plot network coordinated by the Ministry for the Environment (MfE) collects soil data under the Soil Carbon Monitoring System. |
| *Information management* | Landcare Research is responsible for managing and archiving data in the National Soils Database. |
| **Analysis** | |
| *Policy/management relevance* | Soil carbon measurement and predictive modelling are key elements in greenhouse gas emissions reporting and, as public conservation lands hold a substantial amount of soil carbon, DOC needs to be aware of changes and the implications for policy.<br>As regards EI, access to reliable soil data layers to inform biodiversity change is important. |

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| *Conceptual basis and robustness* | There is a vast literature on soil metrics and their effects on vegetation and soil life.<br>Standardised measurements are the norm. |
| *Compatibility with other agencies* | Internationally standardised measurements. |
| *Links to other OMF indicators and measures* | • M1.1.1.2-L: *Soil carbon content*<br>• M1.1.1.3-FM: *Sedimentation and sediment quality*<br>• M1.1.5.2-LFM: *Riverine and coastal alteration*<br>• M1.1.5.3-LFM: *Anthropogenic landform and substrate disturbance* |
| *Implementation and cost* | Soil analyses now are usually done by readily available accredited laboratories.<br>Cost of full soil analyses are substantial as basic collection and laboratory time for standard soil profiles is expensive. |

| **Measure 1.1.1.2-L** | ***Soil carbon content*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.1** Substrate quality |
| **Status** | Final |
| **Description** | |
| *Overview* | While soil carbon is fundamental to ecological function, it is not an important factor for EI in New Zealand on public conservation land. It only becomes an issue under intensive agriculture use. However, soil carbon is an important component of global carbon sequestration. MfE is responsible for the Soil Carbon Monitoring System (via LUCAS) to extrapolate national soil carbon stocks and estimate and report the effect of land-use change on the soil carbon pool to meet the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines. |
| *Data elements* | Soil carbon mapped at a national scale. |
| *Scale* | Emphasis is on nationally verified measurements to underpin accurate national carbon inventories. |
| *Measurement and reporting frequency* | Soil carbon does not alter rapidly in most soils, but is spatially highly heterogeneous and difficult to estimate. Hence direct soil measurements are primarily to inform soil carbon models. |

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| | Soil carbon is reported annually based on model estimates. |
| *Data sources* | LUCAS; MfE |
| *Information management* | MfE manages data and modelling estimates. |
| **Analysis** | |
| *Policy/management relevance* | Soil carbon is of minimal relevance to DOC's primary mission, but DOC needs to be aware of the issues and needs to collaborate in enabling collection of data on public conservation lands. |
| *Conceptual basis and robustness* | There is an immense international literature on soil carbon and active research programmes underway in New Zealand, including the New Zealand Agricultural Greenhouse Gas Research Centre, but primarily on agricultural soils. New Zealand measurements are in line with international best practice and this is a requirement for international reporting. |
| *Compatibility with other agencies* | Fully compatible with international carbon programmes. Percentage soil organic matter is recommended by the US National Research Council in *Ecological Indicators for the Nation* (National Research Council 2000), and the Environmental Monitoring Assistant Program (EMAP) of Environment Canada. |
| *Links to other OMF indicators and measures* | M1.1.1.1-L: *Soil structure and chemistry* |
| *Implementation and cost* | The main contribution from DOC sources is collaboration when soil carbon measures are made on public conservation land. |

| **Measure 1.1.1.3-FM** | ***Sedimentation and sediment quality*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.1** Substrate quality |
| **Status** | Final |
| **Description** | |
| *Overview* | Sedimentation threatens marine and freshwater environments via anthropogenic and natural mechanisms. The rate and cumulative effects of sedimentation are important. Benthic marine species are particularly vulnerable to sedimentation on the seabed, through smothering of photosynthetic structures, clogging of respiratory structures, or interference with the ability of species to settle, forage, |

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| | defend themselves from predators or interact with conspecifics. In New Zealand, sediment has been identified as one of the top three types of pollutants of concern in freshwater environments and is arguably the most important land-based stressor in the New Zealand marine environment (Schallenberg et al. 2011; Parliamentary Commissioner for the Environment 2012). Sedimentation associated with upstream land use is the highest ranked threat for several coastal habitats in New Zealand, including kelp forest and subtidal mud flats (Thrush et al. 2011). Across all New Zealand coastal and marine habitats, the threat of increased sediment loading is ranked third, equal with bottom trawling, after ocean acidification and increased sea temperature associated with climate change. |
| *Data elements* | Data elements will be selected in relation to the actual threat at a given site or area. They consist of a suite of measurements made at appropriate intervals at a site or across an area of concern. They include the standard components necessary to gain an overview of source and rate: grain size, accumulation rate, area covered, depth, sediment source, suspended and re-suspended sediment, bed load. Quality elements should include nutrients, most commonly nitrogen and phosphorous. These are mostly an issue with freshwater and agricultural runoff causing eutrophication. Severe problems are caused when phosphorous accumulates in lake sediments, thus providing an ongoing source even after inflow of the nutrient has been controlled.<br>In the case of widespread sedimentation in a waterway or estuary, remote sensing (or mangrove spread in the case of northern estuarine areas) can be used as a proxy for direct measurement. |
| *Scale* | Local |
| *Measurement and reporting frequency* | **Location:**<br>• Measurements for at-risk sites (e.g. outflow of sediment-laden waterways, estuarine sites with adjacent development/farming) should be made wherever possible repeatedly at the same carefully selected locations because interested parties, particularly in marine/coastal areas, will often dispute findings.<br>• Major storms and earthquakes (e.g. extratropical cyclones) should have follow-up protocol to assess potential for negative biodiversity outcomes.<br>**Frequency:**<br>• Highly variable as needs to be structured for the rate of the threatening process.<br>**Reporting:**<br>• Not a primary reporting measure; could be integrated with other measures. |
| *Data sources* | • Not systematically collected by DOC.<br>• Many data on estuarine sedimentation are available in NIWA |

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| | reports, and power companies and local authorities may monitor sensitive waterways and estuaries. |
| *Information management* | • No DOC data standards and data quality assurances are in place.<br>• Comparative data are held by NIWA. |
| **Analysis** | |
| *Policy/management relevance* | The elements in this measure are largely:<br>• Diagnostic—for surveillance monitoring to provide evidence for remedial action<br>• Evaluative for assessing remedial actions<br>• For informative background (e.g. impact of on-land activities for waterways, lakes and estuaries; impact of invasive plants such as *Spartina*; policy development around permission for dredging, substrate mining, marinas, etc.) |
| *Conceptual basis and robustness* | The monitoring techniques for sedimentation are very well established and New Zealand researchers have employed innovative techniques including isotopic analyses to determine both rate and source of sediments. |
| *Compatibility with other agencies* | Conservation agencies only consider this type of monitoring at particular locations where sedimentation is an issue. Local authority monitoring is extensive in vulnerable coastal areas and along important waterways. |
| *Links to other OMF indicators and measures* | Of broad relevance to the aquatic function are M1.1.2.2-F to M1.1.2.4-M, and more particularly to M1.2.1.1-FM: *Non-nutrient contaminants,* and M1.2.1.3-LF: *Severely contaminated land and water*. Also to M1.1.5.2-LFM: *Riverine and coastal alteration,* and M1.1.5.3-LFM: *Anthropogenic landform and substrate disturbance*. |
| *Implementation and cost* | Sedimentation monitoring is a specialised field necessitating high-resolution measurements and a good understanding of context. DOC will need to be familiar with the threats and potential techniques. Non-specialist observers are highly likely to miss significant factors. Cost is therefore high, aside from remote imagery acquisition, which, however, only gives a broad overview of change.<br>The detailed monitoring of sites impacted by sedimentation will therefore have to be justified by a high risk to EI. |

| **Indicator 1.1.2** | ***Ecosystem function*** |
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| *Description* | Measures for this indicator focus on quantifying high level and broad-scale trophic level measures of ecosystem function. |
| *Justification* | In aquatic systems, the highest trophic level—primarily large and often old fish, crustaceans, and water birds—is of major public importance as these |

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| | are the visible and harvestable components of the food chain. While such measures have always been important in the freshwater and marine domains, they are of secondary interest in the land domain. Essentially, when an intact vegetation cover is dominant at a site, ecosystem productivity change tends to be small compared with the standing biomass, and shifts of trophic level tend to be minor. Moreover, animals make up a very small part of the overall biomass. In New Zealand, while the animal portion of the biomass fluctuates in response to weather and nutrients, predator influences are still dominant. Thus a surge in seed or honeydew production will lead to a decrease, not an increase, of indigenous birds, reptiles and insects via an explosive increase of rats, stoats and wasps. For this reason, M1.1.2.1-LFM: *Ecosystem primary productivity* and M1.1.2.6-L: *Flower and fruit production* are the only direct measures of terrestrial productivity proposed. |
| *Comment* | All of the measures are widely used in New Zealand or could be readily adopted. |
| *Measures* | **1.1.2.1-LFM** Ecosystem primary productivity<br>**1.1.2.2-F** Lake biological function<br>**1.1.2.3-LF** Waterway biological function<br>**1.1.2.4-M** Marine biological function<br>**1.1.2.5-FM** Exploited species production<br>**1.1.2.6-L** Flower and fruit production |

| **Measure 1.1.2.1-LFM** | ***Ecosystem primary productivity*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | Ecosystem primary productivity is a fundamental data layer for a range of applications. Net primary productivity (NPP) is the difference between gross primary production via photosynthesis and all types of plant respiration. Because plant-fixed carbon is the energy source and substrate for all other ecosystem functions, it is a basic and useful indicator of ecosystem function. Remotely sensed NPP indices may act as an indicator of the stress experienced by canopy species, and perhaps therefore act as a generalised early warning of approaching problems due to canopy disruption and climate change. Remotely sensed methods can monitor the productivity of phytoplankton and |

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| | macroalgae and can be used to infer trophic state. Long time-series are necessary to make sense of seasonal trends, and are widely used from a regional to global scale (National Research Council 2000). |
| *Data elements* | • Remotely sensed spectral vegetation indices (terrestrial NPP)<br>• Remotely sensed ocean colour for chlorophyll-a assessment (phytoplankton biomass) |
| *Scale* | National |
| *Measurement and reporting frequency* | **Location:**<br>• Nation-wide; resolution depends on satellite imagery acquired<br>**Frequency:**<br>• NPP and phytoplankton biomass need to be recorded at monthly intervals to capture seasonal trends<br>**Reporting:**<br>• Not used for reporting |
| *Data sources* | Data commercially available |
| *Information management* | External to DOC |
| **Analysis** | |
| *Policy/management relevance* | This measure is of no routine importance to DOC. However, knowledge of and familiarity with the techniques employed and their interpretation will be of value. |
| *Conceptual basis and robustness* | Internationally and nationally used and there are active research programmes in New Zealand routinely using these data. Interpretation of the results needs specialist skills as the correlation with biomass and NPP is subject to many uncertainties. |
| *Compatibility with other agencies* | Very widely used for interpreting environmental change. |
| *Links to other OMF indicators and measures* | Of broad relevance to all measures in Indicator 1.1.2: *Ecosystem function*. |
| *Implementation and cost* | Acquisition of high-resolution satellite data is primarily a matter of cost. Analytical costs are falling due to high throughput data manipulation techniques now available. |

| **Measure 1.1.2.2-F** | ***Lake biological function*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | Presence of functional groups and their abundance at various trophic levels is a strong measure of watercourse EI. |
| *Data elements* | A number of elements have been suggested as appropriate for watercourses by Schallenberg et al. (2011).<br>• Macrophyte depth limit<br>• Macrophyte, fish and invertebrate diversity<br>• Number of trophic levels |
| *Scale* | National |
| *Measurement and reporting frequency* | The data elements are expected to show rapid changes with increased stress and should be reported on at appropriate intervals—probably in the range 5–8 years. |
| *Data sources* | NIWA; regional authorities; DOC |
| *Information management* | NIWA; regional authorities; DOC |
| **Analysis** | |
| *Policy/management relevance* | Concern over freshwater biological status is high. This measure will form part of a regular reporting on freshwater resources. |
| *Conceptual basis and robustness* | Freshwater biological metrics and indicators are well developed and have an extensive literature (see Schallenberg et al. 2011). The concept of EI was initially framed in response to concerns over freshwater status. |
| *Compatibility with other agencies* | Standard freshwater biological metrics are used universally. |
| *Links to other OMF indicators and measures* | • M1.1.3.1-LF: *Freshwater hydrology*<br>• M1.1.3.4-FM: *Water physiochemical factors* |
| *Implementation and cost* | Techniques are well understood and costed. Experienced teams are available in New Zealand to carry out this work. Best seen as part of a |

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| | freshwater observation network. |

| **Measure 1.1.2.3-LF** | ***Waterway biological function*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | Presence of functional groups and their abundance at various trophic levels is a strong measure of watercourse EI. Indirect measures such as wood decomposition and $\delta^{15}N$ changes also indicate overall biotic function. |
| *Data elements* | A number of elements have been suggested as appropriate for watercourses by Schallenberg et al. (2011).<br>• Macroinvertebrate community composition (MCI)<br>• Fish index of biotic integrity (IBI)<br>• Macroinvertebrate taxonomic richness/diversity<br>• Wood decomposition rates<br>• Presence–absence key indicator taxa |
| *Scale* | National |
| *Measurement and reporting frequency* | The data elements are expected to show rapid changes with increased stress and should be reported on at appropriate intervals—probably in the range 5–8 years. |
| *Data sources* | NIWA; regional authorities; DOC |
| *Information management* | NIWA; regional authorities; DOC |
| **Analysis** | |
| *Policy/management relevance* | Concern over freshwater biological status is high. This measure will form part of regular reporting on freshwater resources. |
| *Conceptual basis and robustness* | Freshwater biological metrics and indicators are well developed and have an extensive literature (see Schallenberg et al. 2011). The concept of EI was initially framed in response to concerns over freshwater status. |

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| *Compatibility with other agencies* | Standard freshwater biological metrics are universally used. |
| *Links to other OMF indicators and measures* | • M1.1.3.1-LF: *Freshwater hydrology*<br>• M1.1.3.4-FM: *Water physiochemical factors*<br>• M1.1.2.5-FM: *Exploited species production* |
| *Implementation and cost* | Techniques are well understood and costed. Experienced teams are available in New Zealand to carry out this work. Best seen as part of an existing freshwater observation network. |

| **Measure 1.1.2.4-M** | ***Marine biological function*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | The Marine Protected Area (MPA) environment has a superabundance of organisms, high variability of substrates, and is open to influences from the surrounding ocean, including intense commercial and recreational pressure. Direct measurement of function is time consuming and expensive. Therefore indirect, organism-based metrics are recommended which give some indication that overall biological functioning is intact. |
| *Data elements* | Functional metrics for MPAs are discussed in Thrush et al. (2011). Recommended metrics include:<br>• Organism functional trait diversity<br>• Food chain length and trophic diversity<br>• Presence of large, old organisms |
| *Scale* | Local to MPA for the most part. |
| *Measurement and reporting frequency* | Measurement frequency depends on the pressures at site. Reporting on metrics varies but usually between 1- and 5-yearly intervals. |
| *Data sources* | NIWA; DOC |
| *Information management* | DOC |

| **Analysis** | |
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| *Policy/management relevance* | There is controversy over MPAs because of their no-take provisions. Therefore, demonstrating that they actually do increase fish productivity in surrounding marine areas used by fishers is very important. |
| *Conceptual basis and robustness* | The science behind trait analysis is developing rapidly. Food chain analysis has been a part of marine assessment for many years. Large, old organisms are a readily assessed and informative metric. |
| *Compatibility with other agencies* | Presence and dominance of large organisms in marine food chains is widely used as an indicator of marine EI. |
| *Links to other OMF indicators and measures* | M1.1.2.5-FM: *Exploited species production* |
| *Implementation and cost* | Standard techniques and experienced teams are available. Should be carried out as part of a regular assessment cycle of MPAs. |

| **Measure 1.1.2.5-FM** | ***Exploited species production*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | The productivity of freshwater and inshore marine areas is taken by the public as a reliable, visible indicator of ecosystem health and, as the most valued species are often (but not always) at the highest trophic level, this assumption is usually scientifically valid. The biomass and productivity of harvested stocks, which are often fish species (e.g. whitebait, freshwater eel) but also macroinvertebrates (e.g. lobster, oysters, mussels, squid) and algae (e.g. giant kelp, *Macrocystis pyrifera*), therefore will be a reliable measure of continuing health. As regards EI, there is a conflict in that the presence of introduced salmonids (which degrade EI through predation of native fish and freshwater crayfish) is still a good indicator of a waterway in a healthy state. With regard to MPAs, increasing stocks for commercial and recreational fisheries in adjacent areas are part of the public expectation. |
| *Data elements* | • Biomass |

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| | • Stock status<br>• Catch per unit effort (CPUE)<br>• Recruitment<br>• Stock structure<br>• Growth rates |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual |
| *Data sources* | Estimates of seafood harvest are available from the Ministry for Primary Industries (MPI) for some species. Commercial fishing harvest figures are collated by MPI from returns made by licence holders. Recreational fishing take is estimated from surveys. Extensive effort has gone into stock assessment, primarily by NIWA. |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Eel, whitebait and introduced salmonid harvesting are affected by the condition of lakes and watercourses on public conservation lands and waters (PCL&W). Provision of recreational fishing opportunities is an important DOC responsibility. |
| *Conceptual basis and robustness* | Harvest of freshwater and marine organisms for human consumption is one of the few reliably measured freshwater and marine metrics as it has economic implications and estimates are often controversial. There is an extensive literature on stock measurement and modelling. |
| *Compatibility with other agencies* | Freshwater and marine stock estimates are universally made. |
| *Links to other OMF indicators and measures* | • M1.1.2.1-LFM: *Ecosystem primary productivity*<br>• M1.1.2.2-F: *Lake biological function*<br>• M1.1.2.3-LF: *Waterway biological function*<br>• M1.1.2.4-M: *Marine biological function*<br>• M1.1.2.5-FM: *Exploited species production* |
| *Implementation and cost* | Recreational fish and shellfish harvest data are already collected. Cost to DOC will depend on whether or not additional analyses are undertaken. |

| **Measure 1.1.2.6-L** | ***Flower and fruit production*** |
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| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.2** Ecosystem function |
| **Status** | Final |
| **Description** | |
| *Overview* | Most vascular plants rely on flowering and fruiting for reproduction but, although clearly essential for community regeneration, only in exceptional circumstances (such as with some rare and endangered species) is this a critical factor. The main ecological significance of this measure is rather the provision of fruit and nectar for birds and insects and the role mast fruiting has in expanding mice populations and causing subsequent irruptions of rats and stoats with deleterious impacts on native birds and insects.<br>Flowering and seed fall in beech forests has proved to be a reliable indicator of subsequent rat and stoat plagues, giving 12–14 months advance warning of the need to take control actions.<br>More widespread monitoring of flowering and fruiting across all vegetation types would be desirable to achieve a better understanding of the relationship between this factor and the EI of the ecosystem as a whole.<br>An additional benefit of flowering monitoring will be a better understanding of nectar resources for honeybees, which are of particular importance for iwi seeking return from land they hold in natural vegetation. |
| *Data elements* | • Flowering and fruit phenology<br>• Fruit/seed production: amount and timing |
| *Scale* | National |
| *Measurement and reporting frequency* | Phenological observations are only tractable if measured repeatedly at the same network of sites using strict protocols. Site density has to be sufficient to overcome the sometimes substantial spatial and temporal variation observed in natural populations. |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management* | This is a highly relevant measure in planning predator control in beech |

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| *relevance* | forests because of the importance of mast seeding as a driver of the predator–native bird prey cycle. |
| *Conceptual basis and robustness* | A great deal of research in New Zealand has been directed towards mast seeding in a range of species but most notably beeches and snow grasses.<br>World-wide phenological research is well established with protocols and analytical approaches well understood. |
| *Compatibility with other agencies* | Phenological approaches to biodiversity monitoring are now well used, in part because of their importance to global warming assessment and ecological models. |
| *Links to other OMF indicators and measures* | Relies on M1.1.1.1-L: *Soil structure and chemistry* as an explanatory variable and is strongly linked to M1.7.2.2-LFM: *Phenological response to climate regime change*. |
| *Implementation and cost* | Currently phenological data collection is expensive because of the labour involved and the lack of flexibility in the timing of data acquisition. Phenological networks will have to be well planned. |

| **Indicator 1.1.3** | ***Water quality and quantity*** |
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| *Description* | Water quality and quantity has become one of the defining environmental issues of the 21st century for New Zealand. These measures quantify water volume from catchments, ground water levels, and physiochemical status in relation to PCL&W. Factors influencing marine conditions in MPAs are also addressed. |
| *Justification* | Water quality on much of PCL&W is of secondary interest to managers mainly because undisturbed catchments have high water quality. However, in land recovering from grazing and other productive uses and conservation sites surrounded by farmland or adjacent to cities and settlements, it is essential to understand how water quality is faring. Climate change, particularly in the east, is likely to bring water stress, and changing oceanic regimes will impact MPAs. |
| *Comment* | Measures are well understood and widely applied in New Zealand. |
| *Measures* | **1.1.3.1-LF** Freshwater hydrology<br>**1.1.3.2-LF** Catchment water yield and groundwater<br>**1.1.3.3-M** Ocean regime and temperature<br>**1.1.3.4-FM** Water physiochemical factors |

| **Measure 1.1.3.1-LF** | ***Freshwater hydrology*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.3** Water quality and quantity |
| **Status** | Final |
| **Description** | |
| *Overview* | Water levels and water flow are the primary determinant of ecosystem health in freshwater systems. Water levels in lakes strongly affect shorelines and marginal vegetation, and wetlands deteriorate losing soil carbon to oxidation if water tables fall. Sufficient water flow is needed in rivers and streams to keep connectivity and maintain structural complexity such as silt-free substrates, pools and rills. |
| *Data elements* | • Lake and peatland water depth and water table<br>• Spring flows<br>• River and stream and lake hydrograph |
| *Scale* | Local |
| *Measurement and reporting frequency* | • Automated continuous measurement is desirable for water tables<br>• Telemetered sites for rivers and streams with daily measures |
| *Data sources* | Regional authorities and power companies collect basic data for most large lakes and substantial rivers. Augmentation of this data set with additional monitoring in areas of concern (e.g. drainage-affected wetlands, ephemeral wetlands, springs, low-volume streams) will be needed. |
| *Information management* | Regional authorities and power companies maintain open databases for major freshwater systems. |
| **Analysis** | |
| *Policy/management relevance* | Drought and water use will be exacerbated in the near future by climate change drying of eastern districts. If representative freshwater systems are to be kept in a healthy state in the face of rapidly increasing pressure for more water extraction, a good evidential base connecting freshwater biotic change with measured water volume and flow alteration will be needed. |
| *Conceptual basis and robustness* | Monitoring and modelling of water systems is a mature science. While assessment of underground water resources remains difficult, predicting flow and water body levels from precipitation forecasts has improved a great deal with more sophisticated models. |

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| *Compatibility with other agencies* | Water resources are monitored world-wide. |
| *Links to other OMF indicators and measures* | This data layer will contribute to many of measures for Indicator 1.1.2: *Ecosystem function*. |
| *Implementation and cost* | Given the extensive monitoring already established, DOC's approach will be a niche one, placing largely standard telemetered installations in critical locations where extra information will influence decisions. |

| **Measure 1.1.3.2-LF** | ***Catchment water yield and groundwater*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.3** Water quality and quantity |
| **Status** | Final |
| **Description** | |
| *Overview* | Vegetation cover, land use and climate change all directly affect water quantity. This is essentially a measure of how ecosystem condition is affecting downstream values. DOC needs to be aware of the consequences of its decisions, in particular those involving reafforestation of grazing land, which will reduce catchment water yield in most cases. |
| *Data elements* | Standard measures of surface and groundwater discharge from catchments and aquifers. Interpretation will be important from long-term data sets at key locations. |
| *Scale* | Local |
| *Measurement and reporting frequency* | This is a background measure relying on long-term data sets. Automated data are generally updated on a daily basis. |
| *Data sources* | Primary data are collected by regional authorities. |
| *Information management* | Regional authorities |
| **Analysis** | |
| *Policy/management relevance* | Not a key policy issue for DOC but part of a general understanding of the impact of its land-use decisions. |
| *Conceptual basis* | Very well understood monitoring system with long established |

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| *and robustness* | measurement techniques and associated modelling. |
| *Compatibility with other agencies* | Very widely used. |
| *Links to other OMF indicators and measures* | • M1.1.3.1-LF: *Freshwater hydrology*<br>• M1.1.3.2-LF: *Catchment water yield and groundwater*<br>• M1.1.3.3-M: *Ocean regime & temperature*<br>• M1.1.3.4-FM: *Water physiochemical factors* |
| *Implementation and cost* | Entirely carried out by other agencies. |

| **Measure 1.1.3.3-M** | ***Ocean regime and temperature*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.3** Water quality and quantity |
| **Status** | Final |
| **Description** | |
| *Overview* | Changes in currents, wave regimes, and frequency of storm events can have major effects on the biological functioning of marine areas. This measure ensures that sufficient background data are available for the interpretation of both short-term and long-term biological change. |
| *Data elements* | Potential elements:<br>• Remote sensing of wave height<br>• Mixed layer depth (development needed for inshore measures)<br>• Storm frequency |
| *Scale* | Local: MPA scale |
| *Measurement and reporting frequency* | • Continuous measurement<br>• Not a reporting measure |
| *Data sources* | NIWA |
| *Information management* | NIWA |
| **Analysis** | |
| *Policy/management relevance* | Largely a background measure to help assess changes in habitat and biodiversity status. |

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| *Conceptual basis and robustness* | The recommended measures are all widely accepted standard oceanographic metrics. |
| *Compatibility with other agencies* | Compatible |
| *Links to other OMF indicators and measures* | Important background contributor to M1.1.2.4-M: *Marine biological function* and M1.1.2.5-FM: *Exploited species production.* |
| *Implementation and cost* | These are standard measures that will be collected by other agencies. |

| **Measure 1.1.3.4-FM** | ***Water physiochemical factors*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.3** Water quality and quantity |
| **Status** | Final |
| **Description** | |
| *Overview* | Excessive nutrients and turbidity have a strong effect on aquatic biology. Key elements (N, P) are used as key indicators of agricultural influence on freshwater ecosystems. Clarity of the water column affects species distributions and fish behaviours and condition by limiting available light to photosynthetic structures and affecting the foraging success of visual predators. Water clarity can be affected through physical properties such as suspended sediment and chemical properties such as tannin staining.<br>Higher water temperatures with climate warming will impact fish in particular. |
| *Data elements* | The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000 Guidelines) provide a basis. A number of physiochemical properties can be routinely measured: temperature, conductivity, pH, salinity dissolved oxygen, nitrogen, ammonia, nitrates, phosphorus, Secchi disk readings, satellite imagery. |
| *Scale* | While having a strong local impact because of the widespread nature of agriculturally driven nutrient input, water quality is now largely a national-scale issue. |
| *Measurement and reporting frequency* | These elements change rapidly. At least monthly measurements to capture seasonal cycles will be needed. |
| *Data sources* | Regional authorities and NIWA collect these data. DOC collects a |

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| | limited amount of this information at sites of interest. |
| *Information management* | Regional authorities and NIWA. |
| **Analysis** | |
| *Policy/management relevance* | These metrics are necessary for PCL&W partly for monitoring stressed sites and more generally to provide an unmodified background for aquatic EI measured elsewhere. |
| *Conceptual basis and robustness* | Well established and understood measures that have been shown to be influential on aquatic ecosystems (see Schallenberg et al. 2011 and Thrush et al. 2011). |
| *Compatibility with other agencies* | Widely used in this standard form. |
| *Links to other OMF indicators and measures* | Contributes generally to marine and freshwater factors in Indicator 1.1.2: *Ecosystem function.* |
| *Implementation and cost* | These metrics are best done at the very least on a seasonal basis and in as dense a network as possible due to the high variability and multiple drivers. Long, regularly collected data sets are necessary. Therefore this is not an area where cost or coverage can be traded off against frequency. However, the standard techniques and equipment, availability of trained teams, and rapid advances in automation should ease implementation. |

| **Indicator 1.1.4** | ***Ecosystem structure*** |
|---|---|
| *Description* | This indicator attempts to capture important structural aspects of the whole ecosystem—that is, ecosystem continuity that ensures large, thriving biotic populations and presence of habitats critical to the survival of constituent plants and animals. |
| *Justification* | Worldwide, ecosystem fragmentation is seen as posing multiple interacting risks of degradation and species loss. Arguably this is less of an issue in New Zealand for land ecosystems as so much of the land that is protected is in large blocks of connected indigenous vegetation. Elsewhere, roads assist weed and pest spread and fragment the ranges of large mammals, but in New Zealand roads are vital for access for pest control and do not have a strong influence on birds or the mostly small ground-dwelling vertebrates. However, where fragmentation occurs, especially in lowland vegetation fragments, wetlands, dunelands and waterways, it can have devastating effects. Habitat availability is closely connected with fragmentation because fragmented ecosystems do not offer the same range of habitats as those connected to a larger whole. |

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| *Comment* | Both fragmentation and habitat monitoring are well established techniques internationally. |
| *Measures* | **1.1.4.1-LFM** Ecosystem fragmentation<br>**1.1.4.2-LFM** Habitat availability |

| **Measure 1.1.4.1-LFM** | ***Ecosystem fragmentation*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.4** Ecosystem structure |
| **Status** | Final |
| **Description** | |
| *Overview* | Fragmentation of once contiguous or more extensive ecosystems is arguably the second most threatening process in the New Zealand landscape after exotic predators and weeds, and acts in tandem with them. While not an issue over large tracts of PCL&W in indigenous cover, it is an issue for the small patches of wetland, forest, shrubland, grassland and river systems that have been severed from the biotic interactions that once sustained them by exotic and disturbance-dominated landscapes, which expose them to the threats of fire, drainage, eutrophication, weeds and predators. Marine populations tend to be better connected through mobile larval stages, but even so, fragmentation has to be considered. Meta populations are reduced and edge effects enhanced. Thus the ability of remnant fragments to persist intact is reduced. Fragmentation is used as a primary ecosystem index in a number of overseas reporting schemes (e.g. Ontario Ministry of Natural Resources 2002), but often at too wide a scale and too generally to have much policy relevance. To be useful in the New Zealand setting, fragmentation assessment must be focused on specific ecosystems under pressure. The assessment must be sensitive to the responses of the species involved to fragmentation and likewise their inherent ability to connect. For instance, aquatic species (fish aside) have rather good mobility; flightless insects have poor ability to move. |
| *Data elements* | Conservation-relevant ecosystem units are an essential requirement for this assessment. Remotely sensed images can be analysed using a variety of algorithms to help predict the degree to which the patches are vulnerable to a variety of threats to their integrity. However, ground-truthing is needed to establish degree of indigenous cover. Possible metrics are: |

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| | • Mapped extent<br>• Nearest neighbour distance<br>• Perimeter:Area ratios<br>• Length of connected waterway<br>• Movement rates<br>• Edge permeability |
| *Scale* | Largely national-scale for reporting, but for policy purposes best applied at ecosystem or subregional level. |
| *Measurement and reporting frequency* | National-scale assessments will rely on frequency with which underpinning databases such as the New Zealand Land Cover Database (LCDB) are updated. |
| *Data sources* | Underpinning data are available via Landcare Research for LCDB. |
| *Information management* | Landcare Research; MfE; NIWA |
| **Analysis** | |
| *Policy/management relevance* | This is a background risk measure, showing the degree to which ecosystems are fragmented. It will underpin possible policy innovations designed to reduce risk by increasing connectivity. |
| *Conceptual basis and robustness* | Connectivity and fragmentation are much discussed in the literature and measures attempting to capture them in environmental reporting are widely used. However, the work of linking real-world fragmentation with New Zealand species loss and ecosystem disruption has barely begun (Walker et al. 2006). |
| *Compatibility with other agencies* | Fragmentation indices are widely used internationally. |
| *Links to other OMF indicators and measures* | Indicator 1.1.6: *Land cover* |
| *Implementation and cost* | Implementation of policy- and management-relevant fragmentation/connectivity metrics is some way off. |

| **Measure 1.1.4.2-LFM** | ***Habitat availability*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.4** Ecosystem structure |

| **Status** | Final |
|---|---|
| **Description** | |
| *Overview* | This measure is widely used in freshwater and marine systems (Thrush et al. 2011; Schallenberg et al. 2011). It quantifies the presence of a suite of habitat components that can support a full range of species typical of an unmodified environment. Thus it represents the fundamental ability of a given site to support a flourishing ecosystem. In a stream this will be components such as the presence of gravel beds, pools, rills etc.; in a marine system, mud, rock, seagrass beds etc. It thus functions in two distinctive ways: it provides a baseline for assessing other EI measures of the biotic components for missing or reduced elements, and it measures the loss of these habitat components in modified sites. Marine and freshwater sites are subject to constant manipulation of their aqueous and substrate environments through dredging, gravel extraction, construction, channelisation, draining, edge habitat removal, etc. Most terrestrial conservation sites are either not interfered with in a way that clearly reduces habitat suites or such interference is adequately captured by M1.1.4.1-LFM: *Ecosystem fragmentation*. However, some terrestrial components may be critical for vertebrate and invertebrate habitats—such as old trees for nests or decaying trunks on the ground or riparian or lake-edge vegetation. These data can be sourced from M1.5.1.1-LFM: *Demography of functional groups*, and also M1.1.6.2-LFM: *Waterway and lake marginal vegetation*. |
| *Data elements* | Number and areal extent of habitat types, diversity indices, condition indices |
| *Scale* | Local |
| *Measurement and reporting frequency* | Frequency of measurement will be linked to rate of change. |
| *Data sources* | DOC; regional authorities; NIWA; Landcare Research |
| *Information management* | DOC; regional authorities; NIWA; Landcare Research |
| **Analysis** | |
| *Policy/management relevance* | This measure is of prime importance for site management and should be routinely collected. Once a suitable assessment of application to various site types is made, it could be reported on nationally as a key measure of EI of freshwater and marine systems.<br>Thrush et al. (2011) rank this measure as a +7 (highest) contribution to EI. |
| *Conceptual basis and robustness* | Habitat typing in freshwater and marine systems is well understood. The main obstacle to informative cross-site reporting will be replicable assessment of what habitats should be expected to be present in an unmodified ecosystem. A possible format may report grades of habit |

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| | loss from assessed unmodified state. |
| *Compatibility with other agencies* | Routine measurements in freshwater and marine habitats. |
| *Links to other OMF indicators and measures* | • M1.1.4.1-LFM: *Ecosystem fragmentation*<br>• M1.5.1.1-LFM: *Demography of functional groups*<br>• M1.1.6.2-LFM: *Waterway and lake marginal vegetation* |
| *Implementation and cost* | As a routine, well-understood measure, it is low cost and easy to implement for aquatic systems. Extra research will be needed to apply similar approaches to terrestrial systems. |

| **Indicator 1.1.5** | ***Disturbance*** |
|---|---|
| *Description* | Disturbance here is given a very wide definition as any physical or biotic event that has the potential to have long-lasting ecosystem effects, for the most part extending over decades. With regard to marine disturbance, the entire seabed of an MPA or adjacent coastal substrates is included. |
| *Justification* | Documenting disturbances is important for two reasons. First, it may reset ecosystem trajectories and it is important in subsequent monitoring and analyses to be aware that such changes began with disturbance. In the case of fragmented or rare ecosystems, a sufficiently intense disturbance (e.g. fire) may be sufficient to eliminate it. The second reason is that biotic disturbances such as toxic algal blooms, disease and invertebrate pest outbreaks can themselves indicate underlying ecosystem stressors such as land-use change, pollution, and climate change. |
| *Comment* | All of these measures are, to some extent, already monitored in New Zealand, but somewhat sporadically. |
| *Measures* | **1.1.5.1-L** Mass movement<br>**1.1.5.2-LFM** Riverine and coastal alteration<br>**1.1.5.3-LFM** Anthropogenic landform and substrate disturbance<br>**1.1.5.4-L** Extent and impact of fire<br>**1.1.5.5-FM** Toxic algal blooms<br>**1.1.5.6-LFM** Disease and invertebrate pest outbreaks |

| **Measure 1.1.5.1-L** | ***Mass movement*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |

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| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |
| **Status** | Final |
| **Description** | |
| *Overview* | Disturbance of landscape (including riverine and marine landscapes) with total or partial loss of soils or surficial sediments may result from storms, earthquakes, fire or consequences following on from anthropogenic activities such as road building. It may produce a catastrophic local loss of EI or be simply part of natural landscape regeneration. Massive tsunamis and submarine landslides have been a recurrent feature of the New Zealand coastal shelf. |
| *Data elements* | Remote sensing of slips and other landscape-scale features resulting from mass movements. |
| *Scale* | National, but investigation and measurement of features that are likely to cause ongoing local problems. |
| *Measurement and reporting frequency* | Major storms (e.g. extratropical cyclones), earthquakes, submarine mudslides and tsunami should have follow-up protocol to assess potential for negative biodiversity outcomes. Irregularly reported according to activity. |
| *Data sources* | These data are not currently collected in a systematic fashion by DOC.<br>Remote sensing imagery is readily available; coast and river changes are documented by Land Information New Zealand (LINZ). Detailed hydrographic surveys have provided baselines for submarine movements. |
| *Information management* | No DOC data standards and data quality assurances are in place. |
| **Analysis** | |
| *Policy/management relevance* | No immediate national policy or management implications, but this may change with increasing storm frequency or major earthquake sequences.<br>Area bared by mass movement provides an informative data layer for other issues such as sediment production, potential for weed spread, fire impacts, etc. |
| *Conceptual basis and robustness* | Remote sensing of mass movement is well established and widely used (Chinellato et al. 2015). Local observations and more detailed or ground-based measures needed for predictive modelling. |
| *Compatibility with other agencies* | Not widely used. |
| *Links to other OMF* | Provides background for M1.1.1.3-FM: *Sedimentation and sediment* |

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| *indicators and measures* | *quality*. |
| *Implementation and cost* | Erosion and substrate movement monitoring is a specialised field necessitating high-resolution measurements and a good understanding of context. DOC will need to be familiar with the threats and potential techniques. The detailed monitoring of sites undergoing degradation through human activity will therefore have to be justified by a high risk to EI. |

| **Measure 1.1.5.2-LFM** | ***Riverine and coastal alteration*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |
| **Status** | Final |
| **Description** | |
| *Overview* | Rivers, coastlines and seabeds are constantly altering due to natural change (storms, earthquakes, tsunamis, mudslides). The coast will be impacted by climate change, and coasts and rivers will be impacted through anthropogenic modification of water flow. It is important to keep track of these changes in as much as they affect the indigenous ecosystems they support.<br>This measure differs from M1.1.5.3-LFM: *Anthropogenic landform and substrate disturbance* in that it encompasses only natural or indirectly anthropogenic alteration (e.g. erosion, rising sea levels). Direct human-caused disturbance is under M1.1.5.3-LFM. This distinction is maintained because changes resulting from direct human activity have a simple (although politically fraught) remedy of halting the activity, whereas natural drivers of erosion do not. Natural erosion is the movement of natural material, usually through the forces of water and wind. |
| *Data elements* | • Mapped river and coastline alteration<br>• Seabed alteration in MPAs<br>• Surveys of areas of ecological importance |
| *Scale* | National, but focused on investigation and measurement of features that are likely to cause ongoing local problems. |
| *Measurement and reporting frequency* | Rivers and coastlines alter surprisingly often in some regions but are quite stable in others. Frequency of reassessment should be governed by rate of change for both sets of elements. |

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| *Data sources* | Remote sensing imagery is readily available; coast and river changes are documented by LINZ. |
| *Information management* | No DOC data standards and data quality assurances are in place. |
| **Analysis** | |
| *Policy/management relevance* | Riverine, coastal and marine seabed changes have a large potential impact not only on ecological values, but also for historic sites, and DOC infrastructure. This will provide essential background information for long-term planning. |
| *Conceptual basis and robustness* | Techniques well understood. Coastal and riverine modelling is well advanced in New Zealand. Marine seabed measure technology has undergone a revolution in recent years resulting in highly accurate topographic maps of the sea floor. |
| *Compatibility with other agencies* | Not widely used. |
| *Links to other OMF indicators and measures* | Provides background for M1.1.1.3-FM: *Sedimentation and sediment quality.* |
| *Implementation and cost* | LINZ provides the basic mapping, and regional authorities undertake assessment of riverine and coastal changes in their regions. DOC will have to only provide the intensive assessment near sites of particular importance. |

| **Measure 1.1.5.3-LFM** | ***Anthropogenic landform and substrate disturbance*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |
| **Status** | Final |
| **Description** | |
| *Overview* | Mining, dredging, trawling, marine and freshwater installations, roading, infrastructure, off-road vehicle recreation and other human activities disturb indigenous ecosystems. Where these pose a serious threat to EI, they should be documented and monitored. While direct removal of natural soils and ecosystems is a major consequence, so is enhanced sedimentation. This aspect is of particular concern in freshwater and marine situations and is addressed by this measure. |

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| *Data elements* | Repeat surveys of impacted areas |
| *Scale* | Local |
| *Measurement and reporting frequency* | Management orientated, so frequency should be consistent with intensity of threat. |
| *Data sources* | DOC |
| *Information management* | No DOC data standards and data quality assurances are in place. |
| **Analysis** | |
| *Policy/management relevance* | DOC has to set and police use of PCL&W and interact with other stakeholders in activities that affect PCL&W. |
| *Conceptual basis and robustness* | A great range of measurement techniques could possibly be used, but the most likely approach for most of these activities is visual on-the-ground assessment. |
| *Compatibility with other agencies* | Not widely used. |
| *Links to other OMF indicators and measures* | Has links to Indicator 1.1.1: *Substrate quality* and M1.1.1.3-FM *Sedimentation and sediment quality*. |
| *Implementation and cost* | This measure is more about awareness than scientific measurement. The main aim should be to achieve consistency across the assessment work that is routinely done, and analyse the size and potential impact of the issue. This should therefore impose little in the way of extra cost. |

| **Measure 1.1.5.4-L** | ***Extent and impact of fire*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |
| **Status** | Final |
| **Description** | |
| *Overview* | Fire has a fundamental influence on ecosystem status and properties and must be measured for that alone. Fire on public conservation lands, or fire from public conservation lands that affects other landowners (and vice-versa), will be a crucial input to assessing risks, DOC management and community relations. A number of agencies |

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| | are involved in fire control, and collaboration of reporting the extent of fires should be possible. Natural and human fires need to be included, and over time the data could be used to identify vulnerable environments, and loss of indigenous biodiversity in relation to fire return time and vegetation condition. |
| *Data elements* | • Number of fires, area and fuel type per fire year (1 May to 30 April)<br>• Location and impact of significant fires on public conservation land |
| *Scale* | • Reporting primarily national by fire district at moment<br>• Local public conservation land fire information and monitoring needed |
| *Measurement and reporting frequency* | The National Rural Fire Authority reports annual fire statistics. |
| *Data sources* | • National Rural Fire Authority—annual fire statistics<br>• DOC; local government; Scion |
| *Information management* | • National Rural Fire Authority<br>• DOC will need its own database for significant public conservation land fires |
| **Analysis** | |
| *Policy/management relevance* | • Needed for assessing risk to ecosystem values on public conservation land<br>• Broader statistics for DOC fire response |
| *Conceptual basis and robustness* | Fire control and fire prevalence and behaviour is well studied in New Zealand (e.g. Doherty et al. 2008). |
| *Compatibility with other agencies* | Similar fire metrics reported universally. |
| *Links to other OMF indicators and measures* | This is a background measure for Indicator 1.6.1: *Ecosystem representation and protection status*. |
| *Implementation and cost* | General fire reporting already in place in DOC. Techniques for assessing fire impact and recovery are standard. |

| **Measure 1.1.5.5-FM** | ***Toxic blooms*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |

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| **Status** | Final |
| **Description** | |
| *Overview* | Toxic marine blooms are largely a human health issue but because of effective monitoring, no human poisonings have been reported in recent years (Rhodes et al. 2013), and there appears to be no obvious anthropogenic trigger. Mats or blooms of cyanobacteria occur under conditions characterised by warm temperatures, sunlight, low or stable river flows, and nutrients. They may be an indicator under some circumstances of adverse human impacts. |
| *Data elements* | Date, location, extent and duration of blooms. |
| *Scale* | Local |
| *Measurement and reporting frequency* | Management orientated, so frequency should be consistent with intensity of threat. |
| *Data sources* | MPI; local authorities |
| *Information management* | MPI; local authorities |
| **Analysis** | |
| *Policy/management relevance* | This is primarily an issue affecting human health, and DOC should be aware of frequency and severity of outbreaks. |
| *Conceptual basis and robustness* | Rapid techniques for assessment are available. |
| *Compatibility with other agencies* | Not widely used as a conservation measure |
| *Links to other OMF indicators and measures* | Relevant to Indicator 1.1.3: *Water quality and quantity*. |
| *Implementation and cost* | Largely measured and reported by other agencies. |

| **Measure 1.1.5.6-LFM** | ***Disease and invertebrate pest outbreaks*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.5** Disturbance |
| **Status** | Final |

| Description | |
|---|---|
| *Overview* | Disease and algal and invertebrate pest outbreaks have had a substantial effect on New Zealand ecosystems in the past—for instance, mass outbreaks of seal deaths in the subantarctic islands, canopy defoliation in beech forests, sudden decline of cabbage trees etc. Increasing trade intensity with numerous potential sources of disease and associated vectors, climate change, and human disruption of ecosystems will undoubtedly result in increased episodic outbreaks of diseases important to the biota. Unusual outbreak events, even though apparently of no immediate concern, should be recorded where possible. It will be important to have baseline data so that the observed phenomena can be determined as genuinely unusual or of concern, rather than merely cyclic ecosystem fluctuations. |
| *Data elements* | • Mass mortality of indigenous or non-indigenous vertebrates. Unusual events, determined by species-specific criteria.<br>• Occurrence of diseases in native birds, reptiles, fish, invertebrates and marine mammals. Data already collected to some extent by DOC.<br>• Mass mortality of canopy trees. Careful definition required as tree mortality tends to be obvious for many years after death occurs, and natural senescence of tree cohorts is common.<br>• The majority of these events will not be uncovered by surveillance monitoring but by happenstance. It is important that they are documented adequately once discovered with determination of the biodiversity element impacted; causal event, disease or pest; area affected with some indication of intensity; and duration. |
| *Scale* | Local, aside from exceptional circumstances. |
| *Measurement and reporting frequency* | NA |
| *Data sources* | DOC will be the main repository for indigenous pests and diseases, but MPI for many recently arrived causal agents. |
| *Information management* | DOC; MPI; NIWA; Landcare Research |
| **Analysis** | |
| *Policy/management relevance* | These data are needed for two main reasons. First, to establish natural background of disease and pest outbreaks against which anthropogenically induced change can be assessed; second, to establish damage done by exotic pests and diseases which may have only episodic influence. The expense in attempting to control pests and diseases is so high that careful assessment of the risk posed is needed. |
| *Conceptual basis* | Highly sophisticated research has been done into disease and pest |

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| *and robustness* | outbreaks in managed environments, but relatively little on PCL&W. More research is needed as to what constitutes an 'outbreak' or threatening process as distinct from a background fluctuation. |
| *Compatibility with other agencies* | Disease and pest outbreaks are widely monitored and reported on internationally (e.g. spruce budworm) and by MPI in New Zealand. |
| *Links to other OMF indicators and measures* | • Indicator 1.6.1: *Ecosystem representation and protection status*<br>• Indicator 1.7.2: *Biological responses to climate change* |
| *Implementation and cost* | The major cost will be setting up and maintaining a sufficiently detailed disease and invertebrate disruption database. Year-to-year costs and implementation difficulty will vary greatly. |

| **Indicator 1.1.6** | ***Land cover*** |
|---|---|
| *Description* | Land cover and use is recorded at a very general level (e.g. indigenous forest, shrubland, plantation, agricultural grassland, built-up areas) but is a fundamental data layer that informs a wide range of other indicators and measures. |
| *Justification* | Land cover and use has a very large impact on EI through directly removing the possibility of natural ecosystems and processes, and through imposing externalities such as fire risk, invasion pathways, pollution and nutrient sources. |
| *Comment* | This is supported by a comprehensive national scheme, the Land Cover Database (LCDB). |
| *Measures* | **1.1.6.1-L** Land under indigenous vegetation<br>**1.1.6.2-LFM** Waterway and lake marginal vegetation<br>**1.1.6.3-LFM** Land, waterway and marine transformation |

| **Measure 1.1.6.1-L** | ***Land under indigenous vegetation*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.6** Land cover |
| **Status** | Final |
| **Description** | |
| *Overview* | This is a fundamental measure as nearly all conservation management decisions in some way or other rely on it. Without |

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| | indigenous vegetation cover, EI is greatly degraded, even below ground. At the moment this is largely measured at a national scale by the LCDB. It has been used in a broad-scale fashion by Walker et al. (2006) to designate threatened environments by using the intersection of Land Environments New Zealand (LENZ) Level IV environments and indigenous vegetation cover from the LCDB to designate LENZ environments as at-risk through vegetation loss. |
| *Data elements* | Proportion of land surface under various categories of indigenous cover, stratified according to environment. |
| *Scale* | National |
| *Measurement and reporting frequency* | At the moment, according to the LCDB schedule. |
| *Data sources* | Landcare Research and MfE (LUCAS) |
| *Information management* | Landcare Research |
| **Analysis** | |
| *Policy/management relevance* | Walker et al. (2006) drew attention to how LCDB/LENZ data could effectively be used to track vegetation loss and, in particular, the areas where this loss was greatest. An LCDB assessment linked to a quantitative vegetation classification based on measured plots would greatly enhance the power of this type of analysis to chart significant change. |
| *Conceptual basis and robustness* | The LCDB methodology is well established as is quantitative vegetation classification. The requirement now is to link the two so that a much more granular overview is produced. |
| *Compatibility with other agencies* | Vegetation cover and ecosystem maps are widely used. |
| *Links to other OMF indicators and measures* | Important to Indicator 1.1.4: *Ecosystem structure* and M1.1.2.1-LFM: *Ecosystem primary productivity*. |
| *Implementation and cost* | Given that the LCDB continues and vegetation plot measurements are made as part of a routine biodiversity assessment programme, the new costs are largely those of analysis. |

| **Measure 1.1.6.2-LFM** | ***Waterway and lake marginal vegetation*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |

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| **Indicator** | **1.1.6** Land cover |
| **Status** | Final |
| **Description** | |
| *Overview* | Marginal vegetation at the interface between water and land is of biodiversity value in its own right, but also exerts a strong effect on aquatic life through provision of habitats for birds, fish and invertebrates, and organic material processed within the watercourse or lake itself. Aquatic macrophytes play an important role in regulating lake ecology. These plants enhance habitat complexity and heterogeneity, which in turn provides substrate for fish spawning, sessile invertebrates and periphyton communities, and refugia for zooplankton. Macrophytes can also improve water clarity by bank stabilisation, wave moderation and by promoting the settling out of suspended sediments from the water column. Presence of tall, structurally complex vegetation also assists in reducing influx of nutrients from adjacent pasture in agricultural land. Lake margin fluctuations may be deleterious to biodiversity where a lake is managed for power generation. |
| *Data elements* | • Lake, watercourse and coastal extent in indigenous cover; non-managed vegetation; agricultural production. Basic data can be obtained from LCDB, but ground-truthing will be necessary to make definitive links with actual riparian vegetation status.<br>• Alteration to riparian and coastal habitat in at-risk sites (degrading lakes and watercourses). Measurement techniques will vary according to site and water level regime. |
| *Scale* | National |
| *Measurement and reporting frequency* | The LCDB assessments should be sufficient to give an overview of the broad categories of riparian vegetation cover, and measurement frequency will depend on the updating of this facility. Measurement of alteration of riparian habitat at at-risk sites will be repeated according to severity of the threat. |
| *Data sources* | LCDB; DOC; NIWA; Landcare Research |
| *Information management* | LCDB (Landcare Research); DOC |
| **Analysis** | |
| *Policy/management relevance* | The national-scale assessment of broad categories of marginal vegetation of watercourses, lakes and coastal areas provides a basic assessment of water bodies at risk. More detailed repeat measures of riparian vegetation change will help assess effectiveness of remedial actions. |
| *Conceptual basis and robustness* | Riparian vegetation is routinely assessed and a wide range of standard techniques are available. |

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| *Compatibility with other agencies* | Widely used (e.g. Paulsen et al. 2008). This measure, based on the LCDB, is employed by MfE in its state of the environment reporting. |
| *Links to other OMF indicators and measures* | M1.1.6.1-L: *Land under indigenous vegetation* |
| *Implementation and cost* | LCDB available; ground-truthing of riparian status and repeat measures of at-risk sites will require specialist teams. |

| **Measure 1.1.6.3-LFM** | ***Land, waterway and marine transformation*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.1** Maintaining ecosystem processes |
| **Indicator** | **1.1.6** Land cover |
| **Status** | Final |
| **Description** | |
| *Overview* | Large areas of New Zealand fall into a semi-wild category where numerous opportunities for indigenous biodiversity remain. Others are effectively alienated by intensive development. Other than the continuing degradation of natural habitats by predators (which affects mainly large-sized indigenous animals), destruction of indigenous biodiversity of all size classes and functional grouping can be mainly attributed to continuing intensification of land use (Meurk & Swaffield 2000). |
| *Data elements* | Area of land, waterways and coastal marine areas categorised according to intensity of human transformation and irreversibility of change. |
| *Scale* | National |
| *Measurement and reporting frequency* | According to updating of LCDB |
| *Data sources* | Landcare Research for the main database, but regional and central government and MPI will have numerous relevant databases. |
| *Information management* | Landcare Research, but various for other databases. |
| **Analysis** | |
| *Policy/management relevance* | Essentially this is an overview of the amount of land and water in New Zealand dominated by natural non-anthropogenically driven ecological processes. It acts as a reference layer to provide context for |

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| | landscape-scale policy. As loss of land under natural processes narrows conservation options, it could be also a reported measure for the nation as a whole. |
| *Conceptual basis and robustness* | Well explored methodology available. |
| *Compatibility with other agencies* | Agricultural and urban extent are widely reported measures. |
| *Links to other OMF indicators and measures* | • M1.1.6.1-L: *Land under indigenous vegetation*<br>• M1.1.6.2-LFM: *Waterway and lake marginal vegetation* |
| *Implementation and cost* | These data are already collected. The main cost will be analysis to make them informative with regard to EI. |

| **Outcome Objective 1.2** | ***Limiting environmental contaminants*** |
|---|---|
| A broad definition of environmental contaminant is taken here, which includes heavy metals (which may occur naturally), manufactured toxins, nutrients at levels in excess of those found naturally, plastic debris, and noise. As PCL&W are often remote from environmental contaminants – which tend to be concentrated in agricultural and built-up areas – the main concern until recently has been contamination from vertebrate toxins and pesticide residues. However, aside from this, contamination of freshwater and marine systems by toxins and nutrients is an increasing concern as even low levels can dramatically alter ecosystem functioning. The marine system is also at risk from two other contaminants of concern: marine noise and plastic debris, which can be highly detrimental to marine animals.<br>Nutrients (chemical elements and compounds essential to plant growth) become contaminants when they result in degradation of natural ecosystems, which are then replaced by the proliferation of unwanted species. This is almost entirely an issue for freshwater and marine systems and is included in M1.1.3.4-FM: *Water physiochemical factors*. | |
| **Indicators:**<br>**1.2.1** Non-nutrient contaminants | |

| **Indicator 1.2.1** | ***Non-nutrient contaminants*** |
|---|---|
| *Description* | Most of the measures and elements in this indicator are concerned with environmental toxins, the most dangerous being heavy metals, vertebrate toxins and pesticide residues from mining, agriculture and pest control. |
| *Justification* | All heavy metals are persistent, and some toxins do not break down rapidly and become incorporated in food chains, leading to toxicity and developmental problems for many species. They can affect the suitability of game for human consumption. A well-studied example is DDT, and brodifacoum persistence has created concerns. New Zealand, being a |

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| | very high user of toxins and fertilisers, has a wide range of researchers working on these issues. The conceptual basis for interpreting both nutrient and toxin content of soils and sediments is thus well understood, and highly sensitive measurement techniques are available.<br>Two very different contaminants to toxins and heavy metals are included in this indicator. Litter, especially plastic litter in the marine environment, endangers aquatic life. Noise in the marine environment has become a matter of great concern, in particular as regards cetaceans in areas well used by recreationalists. |
| *Comment* | No comment |
| *Measures* | **1.2.1.1-FM** Non-nutrient contaminants<br>**1.2.1.2-LFM** Toxins in biotic tissues<br>**1.2.1.3-LF** Severely contaminated land and water<br>**1.2.1.4-M** Marine litter<br>**1.2.1.5-LM** Noise |

| **Measure 1.2.1.1-FM** | ***Non-nutrient contaminants*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.2** Limiting environmental contaminants |
| **Indicator** | **1.2.1** Non-nutrient contaminants |
| **Status** | Final |
| **Description** | |
| *Overview* | Non-nutrient contaminants, including faecal bacteria, persistent vertebrate toxins, invertebrate pesticides, herbicides, petroleum hydrocarbons, and artificial hormones or hormone mimics may severely disrupt species and communities. Freshwater systems are particularly at risk (Fleeger et al. 2003; Kelly et al. 2010). Many have long-term impacts and may be present in the environment for decades or more. The persistence of non-nutrient contaminants in New Zealand waters has not been assessed in detail (Schallenberg et al. 2011). |
| *Data elements* | Extent, distribution, bioaccumulation of heavy metals, organochlorines, pesticide residues, and faecal bacteria. Concentration of contaminants according to the ANZECC 2000 Guidelines. |
| *Scale* | National-scale needed for persistent contaminants deriving from widespread sources that are retained within the food chain, such as those resulting from the widespread application of toxins or herbicides. However, many sources are local (mining, heavy agricultural chemical |

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| | use, sewage outlets) and additional monitoring should be based on assessment of threat. |
| *Measurement and reporting frequency* | National-scale monitoring could be done at multi-year intervals as the changes are likely to be slow. |
| *Data sources* | Regular surveys of heavy metals in estuaries are undertaken by regional and district councils. |
| *Information management* | National-scale effort on this front will be an MfE/Statistics New Zealand responsibility. PCL&W-scale monitoring will be a DOC responsibility. |
| **Analysis** | |
| *Policy/management relevance* | Freshwater issues are inevitably regional or national issues because of the movement of water across landscapes. DOC here will be mainly concerned with pollutant effects on biodiversity on PCL&W for its own measurement effort, but will work with other agencies to contribute to an overall national-level understanding. |
| *Conceptual basis and robustness* | Measurement technology is well advanced and highly reliable. While a considerable amount is known about short-term toxicity effects on the biota, much less is known about the long-term effects and possible synergistic effects of multiple stressors. |
| *Compatibility with other agencies* | Widely used metrics both internationally and in New Zealand. |
| *Links to other OMF indicators and measures* | Important to Indicator 1.1.2: *Ecosystem function* and Indicator 1.1.3: *Water quality and quantity*. |
| *Implementation and cost* | Expertise and technology are available. Could be combined with other sample-based measures to lower collection costs. |

| **Measure 1.2.1.2-LFM** | ***Toxins in biotic tissues*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.2** Limiting environmental contaminants |
| **Indicator** | **1.2.1** Non-nutrient contaminants |
| **Status** | Final |
| **Description** | |
| *Overview* | Addresses presence and persistence of heavy metals and pesticide and herbicide compounds in biotic tissues. This is essential information of great interest to the general public as to the potential |

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| | influence of environmental chemicals on the whole ecosystem, especially those used as toxins for animal and plant control. At present, brodifacoum is the pesticide of most concern, as it is long-lasting in the environment. Heavy metals are much more of a concern in freshwater and estuarine settings, but note that cadmium on agricultural lands is now approaching critical levels as a result of heavy fertiliser application. Previously used organochlorides such as DDT were highly persistent. The now widely used organophosphates break down quickly on exposure but are highly toxic to both invertebrates and humans. |
| *Data elements* | Regular but not necessarily frequent national surveys of heavy metals in tissues would be desirable for establishing background levels. Persistent pesticide residues are dependent on local use patterns, and post-control surveys from time to time to provide assurance may be all that is needed. |
| *Scale* | National and local |
| *Measurement and reporting frequency* | Infrequent |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Despite widespread and enduring public concern, there is little evidence that current levels of heavy metals and pesticide and herbicide residues on PCL&W are a danger to either the biota or humans. Nevertheless, DOC will need to be able to demonstrate this fact with up-to-date survey information. |
| *Conceptual basis and robustness* | Techniques well understood. There is a large literature on pesticide, herbicide and heavy metal effects on biota, including relevant New Zealand research (e.g. Eason et al. 2002). |
| *Compatibility with other agencies* | Heavy metals and pesticide/herbicide residues are widely measured and reported. |
| *Links to other OMF indicators and measures* | A sister measure to M1.2.1.1-FM: *Non-nutrient contaminants*. |
| *Implementation and cost* | Timing and intensity of surveys can be adjusted to fit perceived need (i.e. after large-scale pest eradication programmes). |

| **Measure 1.2.1.3-LF** | ***Severely contaminated land and water*** |
|---|---|
| **Intermediate** | **1** The diversity of our natural heritage is maintained and restored |

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| **Outcome** | |
| **Outcome Objective** | **1.2** Limiting environmental contaminants |
| **Indicator** | **1.2.1** Non-nutrient contaminants |
| **Status** | Final |
| **Description** | |
| *Overview* | There are a large number of users of PCL&W, and from time to time there are significant discharges of toxic or biological contaminant material on PCL&W, or land is added to the PCL&W that has had either industrial or heavy agricultural use. Ski field and hut operations have the potential to increase PCL&W contamination. This measure is designed to keep track of these discharges with a view to clean-up or potential on-flow effects in the future. |
| *Data elements* | • Location of outfalls and discharges on PCL&W<br>• Location and extent of land and waters considered contaminated |
| *Scale* | Local |
| *Measurement and reporting frequency* | As contamination is discovered |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | While unlikely to be a major policy or management measure, accurate tracking of contaminated sites will prevent unsuitable use of such land. |
| *Conceptual basis and robustness* | Standard measures available. |
| *Compatibility with other agencies* | A standard metric for urban and agricultural regions. Less used by agencies primarily concerned with biodiversity. |
| *Links to other OMF indicators and measures* | Generally linked with other measures in this indicator group. |
| *Implementation and cost* | Maintaining a registry of contaminated sites and point contamination should not attract excessive costs. Monitoring active contamination from human usage is potentially costly. |

| **Measure 1.2.1.4-M** | ***Marine litter*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.2** Limiting environmental contaminants |
| **Indicator** | **1.2.1** Non-nutrient contaminants |
| **Status** | Final |
| **Description** | |
| *Overview* | In aquatic environments litter presents risks to the fauna, including entanglement, smothering and ingestion. The primary concern is the effect on marine mammals and water birds through ingestion. A secondary concern is the release of plasticisers which act as hormonal mimics. This measure is ranked as of high importance in Thrush et al. (2011).<br>In the terrestrial environment is it not an EI issue but rather a matter of aesthetics. |
| *Data elements* | • Observation and clean-up data from MPAs<br>• Could be part of a general rapid survey of MPAs done on a regular basis<br>• Semi-automated analysis of litter through light detection and ranging (LiDAR) is now possible (Ge et al. 2016). |
| *Scale* | Local |
| *Measurement and reporting frequency* | Persistent problem. Unless there are large local changes in anthropogenic waste disposal, it should be part of a rolling survey. |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Plastic litter in the marine environment is a widespread issue which eventually will have to be subject to legislation and regulation. Information from MPA surveys will assist with bringing this about. |
| *Conceptual basis and robustness* | Not assessed |
| *Compatibility with other agencies* | Litter monitoring is widely carried out now. |
| *Links to other OMF indicators and* | Not closely connected to other measures. |

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| *measures* | |
| *Implementation and cost* | Easily incorporated into general MPA surveys. |

| **Measure 1.2.1.5-LM** | ***Noise*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.2** Limiting environmental contaminants |
| **Indicator** | **1.2.1** Non-nutrient contaminants |
| **Status** | Final |
| **Description** | |
| *Overview* | Because sound carries well in water and the underwater marine soundscape is of vital importance to many species—including cetaceans, many fish, and reef crustaceans—monitoring of the marine soundscape in protected areas should be considered. In the terrestrial environment noise is not primarily an EI factor (although it potentially could impact bird behaviour) but more one that detracts from human recreation and enjoyment. |
| *Data elements* | Hydrophone measures of marine noise volumes, frequencies and intensities in protected marine areas. |
| *Scale* | Local |
| *Measurement and reporting frequency* | Regular surveys of noise levels in MPAs. |
| *Data sources* | Surveys have been carried out and scientific investigations by universities. |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Eventually, with increasing popularity of MPAs for recreation, controls on noise will have to be imposed. |
| *Conceptual basis and robustness* | Research will be needed to establish thresholds beyond which harm is done to biota. |
| *Compatibility with other agencies* | Not widely adopted as a measure, but an active research area. |
| *Links to other OMF indicators and* | Noise from other participants in wilderness experiences and from machinery, helicopters, fixed-wing aircraft and drones is an important |

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| *measures* | negative factor for many. See Indicator 3.2.2: *Opportunities, facilities and services provided meet customer expectations and preferences*. |
| *Implementation and cost* | Measurements needed only during peak recreational use periods or during times of high biotic sensitivity. Further research needed. |

| **Outcome Objective 1.3** | ***Reducing spread and dominance of exotic species*** |
|---|---|
| Worldwide, the spread of exotic species is perhaps second only to physical habitat loss in its importance as regards loss of indigenous species and ecosystems. This is the critical factor threatening EI on PCL&W and one of the major spurs for volunteer or private conservation initiatives. As has been seen for wilding pines and invasive salmonids, New Zealand may be on the cusp of major ecosystem transformation in some areas. However, the very large number of invasive plants and animals, and the focus on only a few of these (mainly vertebrates), means that even basic data as to where and how many are entirely lacking for many potentially threatening species. | |
| **Indicators:**<br>**1.3.1** Exotic species occurrence<br>**1.3.2** Invasive species dominance | |

| **Indicator 1.3.1** | ***Exotic species occurrence*** |
|---|---|
| *Description* | A national-level overview of the occurrence of self-maintaining exotic species independent of their perceived risk. |
| *Justification* | The great majority of exotic species in New Zealand pose no threat to EI. However, recruitment of new pests and weeds is as likely to derive from long-established populations as from recent arrivals. Our ability to eliminate a potential threat depends on its early recognition as such. For this reason, a broader surveillance of all exotic species in the wild appears prudent. |
| *Comment* | New Zealand has a long history of documenting exotic species, but better integration of databases at a national level is needed, as well as expansion to better cover neglected groups. |
| *Measures* | **1.3.1.1-LFM** Occurrence of self-maintaining populations of exotic species |

| **Measure 1.3.1.1-LFM** | ***Occurrence of self-maintaining populations of exotic species*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome** | **1.3** Reducing spread and dominance of exotic species |

| **Objective** | |
|---|---|
| **Indicator** | **1.3.1** Exotic species occurrence |
| **Status** | Final |
| **Description** | |
| *Overview* | 'Self-maintaining' is used in this context as a criterion to exclude cultivated garden and crop species, or those in animal collections. Those cultivated or confined species which from time to time escape but do not persist are not included.<br>The Biosecurity Act 1993 provides the basis for control of exotic organisms in New Zealand. Weed surveillance in New Zealand is well established with standard near-complete flora treatments of both indigenous and vascular plants. DOC weed surveillance programmes are often regionally or locally focused to meet the needs for local information on weed distributions and persistence. The situation is not so well under control with insects and fungi. As a DOC-commissioned review stated:<br>There needs to be more funding of research on the taxonomy and ecology of fungi and insects in indigenous forests to establish a base line from which any newly introduced organisms will be recognised. In association with these baseline surveys, a structured surveillance system for indigenous forests needs to be developed so that limited resources can be deployed to look at the highest risk sites in a manner that will provide the greatest chance of detecting newly introduced pests or diseases (Ridley et al. 2000). |
| *Data elements* | • Lists by orders of all self-maintaining exotic species in the country<br>• Mapped distribution of species regarded as potential or actual risks |
| *Scale* | National |
| *Measurement and reporting frequency* | This is an underlying database which needs constant, authoritative updating. |
| *Data sources* | Numerous.<br>• Universities, museums and Crown research institutes all have collections relevant to this measure.<br>• The 3-volume *New Zealand Inventory of Biodiversity* (Gordon 2012) is an up-to-date list of accepted names of the entire biota.<br>• The New Zealand Organisms Register (founded in 2006) provides a definitive list (maintained by Landcare Research) of the over 100,000 organism names relevant to New Zealand, and this will provide the key background resource (www.nzor.org.nz). |
| *Information management* | See above |

| **Analysis** | |
|---|---|
| *Policy/management relevance* | Identification of potential threat of exotics for policy. |
| *Conceptual basis and robustness* | New Zealand has many undescribed indigenous taxa, particularly among insects and fungi. This is a handicap in producing a definitive list of exotics and so a comprehensive approach is needed. As well, the rate of new introductions (or discovery of previous arrivals or movement from cultivation to the wild) is high in some groups (e.g. plants). |
| *Compatibility with other agencies* | Having access to authoritative, updated lists of organisms is a generally accepted goal for all developed nations. To date, New Zealand appears to be the only one with a unified list (Gordon 2012). |
| *Links to other OMF indicators and measures* | Indicator 1.3.2: *Invasive species dominance* |
| *Implementation and cost* | DOC already has a substantial weed programme but this is a New Zealand-wide issue and should be handled at a national, integrated level. |

| **Indicator 1.3.2** | ***Invasive species dominance*** |
|---|---|
| *Description* | Invasive pests or weeds are here defined as exotic species that have the potential to become widespread or abundant and have disproportionate effects on native species and ecosystems. This indicator seeks to quantify the distribution and abundance of the most important of these. |
| *Justification* | Invasive pests and weeds have permanently altered New Zealand's EI through elimination of a suite of birds, reptiles, fish and invertebrates, and possibly a number of plant species. Along with vegetation clearance, waterway pollution and, in the near future, climate change, they pose the major threats to EI. Because of the difficulty of controlling pests, documenting their occurrence and abundance has taken a back seat to what has been regarded as the more important task of killing them. For instance, while there have been limited successes and some small areas have been made essentially mammalian pest-free, aside from this it is arguable that not much in the way of improvement in EI has resulted because reduction to extremely low levels is needed to protect the most vulnerable elements of the native biota. |
| *Comment* | The 2016 announcement of 'predator-free New Zealand' as an aspirational goal for New Zealand by 2050—'Our ambition is that by 2050 every single part of New Zealand will be completely free of rats, stoats and possums' (New Zealand Government 2016)—has |

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| | significantly changed the political landscape. While many pests lie outside the goal (deer, goats, thar, chamois, pigs, hedgehogs, cats, dogs, mice, trout, salmon, wasps, ants), it will still entail a very substantial ramp up in New Zealand's ability to track populations, assess reinvasion probabilities and confirm clearance. Byrom et al. (2016) state:<br>> Monitoring of non-target pests such as ship rats, and quantification of the biodiversity outcomes of TB-free ground control, have received little attention thus far, but this should become a priority if positive biodiversity benefits are sought as a secondary outcome. The increasing interest to make very large areas of the New Zealand mainland free of mammal predators … demands better quantification of the biodiversity outcomes of all existing large-scale pest-control regimes. |
| *Measures* | **1.3.2.1-LFM** Abundance and distribution of invasive pests and weeds<br>**1.3.2.2-LF** Area free of mammalian predators |

| **Measure 1.3.2.1-LFM** | ***Abundance and distribution of invasive pests and weeds*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.3** Reducing spread and dominance of exotic species |
| **Indicator** | **1.3.2** Invasive species dominance |
| **Status** | Final |
| **Description** | |
| *Overview* | Pests and weeds considered to pose a clear danger to EI will need tracking of abundance and distribution. Approximate distributions and abundances will suffice for most, but for focal species considered to pose a large and immediate risk to EI, field campaigns backed by modelling will be necessary. |
| *Data elements* | • Mapped distributions of major pests and weeds<br>• Assessments of abundance for pests and weeds subject to control |
| *Scale* | National |
| *Measurement and reporting frequency* | Tracking pest and weed distributions is a task which will need dedicated resources with specialised databases regularly updated.<br>Status of major pests and weeds does not need to be reported frequently; a decadal interval for major reassessments would probably be appropriate. |

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| *Data sources* | There is a great deal of information already collected and databased in the form of the major collections of Crown research institutes and universities; weed and pest programmes; MPI and regional and district authorities; and citizen-based efforts such as NatureWatch NZ. |
| *Information management* | DOC is responsible for data on PCL&W. Data management widely spread otherwise between the data sources. |
| **Analysis** | |
| *Policy/management relevance* | It is important to have a clear idea of the size of the pest and weed issues in New Zealand. From time to time decisions are made to attempt to halt spread into areas free of a certain pest or weed, and up-to-date distributional data will help underpin such decisions. Under Predator Free 2050 initiatives this information will be fundamental. |
| *Conceptual basis and robustness* | Mapping distributions is not straightforward as it is highly scale-dependent. Almost certainly distributional modelling will be necessary, as smaller-scale studies have shown (e.g. Ruffell et al. 2015). |
| *Compatibility with other agencies* | Weed and pest distributions are widely reported. However, as has been often commented, there is a tendency either not to collect sufficient data or not to database or analyse it nor use it in decision-making once collected (Ruffell et al. 2015). |
| *Links to other OMF indicators and measures* | • Outcome Objective 1.3: *Reducing spread and dominance of exotic species*<br>• Outcome Objective 1.4: *Preventing declines and extinctions* |
| *Implementation and cost* | This will not be a cheap measure to implement as replicated treatment and non-treatment investigations are needed. However, as large-scale pest suppression projects are underway, and more planned, it is essential that they be assessed scientifically to ensure best outcomes (Byrom et al. 2016). |

| **Measure 1.3.2.2-LF** | ***Area free of mammalian predators*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.3** Reducing spread and dominance of exotic species |
| **Indicator** | **1.3.2** Invasive species dominance |
| **Status** | Final |
| **Description** | |
| *Overview* | With the adoption of Predator Free 2050 targets, suitable metrics will be needed to demonstrate goal achievement. |

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| *Data elements* | Areas of indigenous systems with no significant predatory mammals. |
| *Scale* | While a national goal, application of this metric will necessarily be to smaller local areas. |
| *Measurement and reporting frequency* | Measurement will have to form part of Predator Free 2050 initiatives and thus measurement intensity and timing will depend on progress of these initiatives. |
| *Data sources* | Predator-free status is reported by DOC for a number of offshore islands. Various fenced reserves have also reported predator-free status. |
| *Information management* | While this will be a national effort with many contributing agencies and private firms, only DOC has at the moment the capacity to coordinate and credibly authenticate predator-free status. |
| **Analysis** | |
| *Policy/management relevance* | Progress towards this national goal will need to be rigorously assessed. |
| *Conceptual basis and robustness* | Authenticating predator-free status is not simple and probabilistic detection models are required (Samaniego-Herrera et al. 2013). |
| *Compatibility with other agencies* | Only employed on a local scale as pest eradication on the scale envisaged in New Zealand has not been tried. |
| *Links to other OMF indicators and measures* | Indicator 1.3.2: *Invasive species dominance* |
| *Implementation and cost* | Monitoring/surveillance costs are projected to be high (20% of the operational costs) but can vary according to the way the eradication is carried out. They are, nonetheless, essential to a successful eradication and must be always factored in to the overall and ongoing costs (Gormley et al. 2016). |

| **Outcome Objective 1.4** | ***Preventing declines and extinctions*** |
|---|---|
| Concern regarding decline and loss of species is now a major motivation for conservation. Globally, species extinction and security of endangered species are essential statistics. It is therefore an absolute requirement to have up-to-date and regularly assessed overviews of what has been lost, and what is at risk. It is now well appreciated that it may not be sufficient to assure the physical safety of a species if the genetic variation it preserves is much reduced. It is therefore necessary that the potential for genetic loss is assessed in various groups and minimum viable population sizes established to assist with their management. | |
| **Indicators:**<br>**1.4.1** Conservation status of indigenous taxa<br>**1.4.2** Security of threatened and at-risk taxa | |

| **1.4.3** Loss of genetic diversity |
| --- |

| **Indicator 1.4.1** | ***Conservation status of indigenous taxa*** |
| --- | --- |
| *Description* | Conservation status of all indigenous taxa according to international and national criteria. The degree of risk a given taxon is exposed to should be the lead criterion for management action. |
| *Justification* | The conservation status of indigenous taxa is one of the few systematically, comprehensively and regularly assessed factors of national biodiversity. This attention is warranted because of the unarguable finality of extinction, and the high prominence accorded species threat status in public debates over biodiversity issues. |
| *Comment* | Only one measure is presented here—the New Zealand Threat Classification System (NZTCS) listing, which is closely based on the International Union for Conservation of Nature (IUCN) Red List approach. It has 10 relevant categories, which arguably could all be measures, but this would expand the list of measures to no purpose as the NZTCS listing categories are all closely inter-related. The NZTCS is used to assign species to the IUCN Red List.<br><br>The New Zealand system is coordinated by DOC and is based on expert knowledge underpinned by a widely distributed questionnaire that takes the form of a list of questions for species in each of the 23 groups of organisms (with broad multiple choice categories for quantitative answers) assessed by a panel of 6 members. All species are assessed and placed into threat categories, including ‘Data Deficient’. The categories are consistent with those of the IUCN Red List, but have been modified to reflect New Zealand conditions. The resulting lists are posted on the DOC website and then published in a refereed journal. The aim is to have a 3-year rolling cycle of threat assessments. There is no doubt that the NZTCS is an essential EI component and performs well within the system settings. Three cycles have been completed—the last one being 2011–2014.<br><br>Threat status classifications are not without their problems. In the past, incautious use of ‘red list’ techniques has given misleading impressions because changes in knowledge and taxonomic status have been taken as representing actual changes in threat. For this reason the NZTCS leads are careful to present detailed information as to how the list changes have come about. However, the more important critique is that methodology suffers from its reliance on expert opinion and a pervasive lack of quantitative information (Breen & Middleton 2013). Given that the NZTCS assigns species to a limited number of categories, the large errors associated with expert opinion on the basis of a limited factual background means that misclassifications are unavoidable. Given the very large number of species assessed during each cycle, it is difficult to see a way around this. As Connors & Cooper (2014) have shown: |

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| | Treating conservation status as dichotomous when a continuum is more appropriate can result in the identification of suboptimal decision thresholds, which leads to taking action less often when it is needed and more often when it is not needed.<br>A programme of independent quantitative assessments of randomly selected NZTCS listings is needed to address this issue of mis-assignments. |
| *Measures* | **1.4.1.1-LFM** Status of indigenous taxa |

| **Measure 1.4.1.1-LFM** | ***Status of indigenous taxa*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.4** Preventing declines and extinctions |
| **Indicator** | **1.4.1** Conservation status of indigenous taxa |
| **Status** | Final |
| **Description** | |
| *Overview* | The NZTCS undertakes the official listing of the threat status of all indigenous New Zealand organisms on a three-year assessment cycle. |
| *Data elements* | A total of 23 taxonomic groups (not all at the same taxonomic level depending on degree of conservation interest in the group and amount of data) are assigned to the following groupings. |

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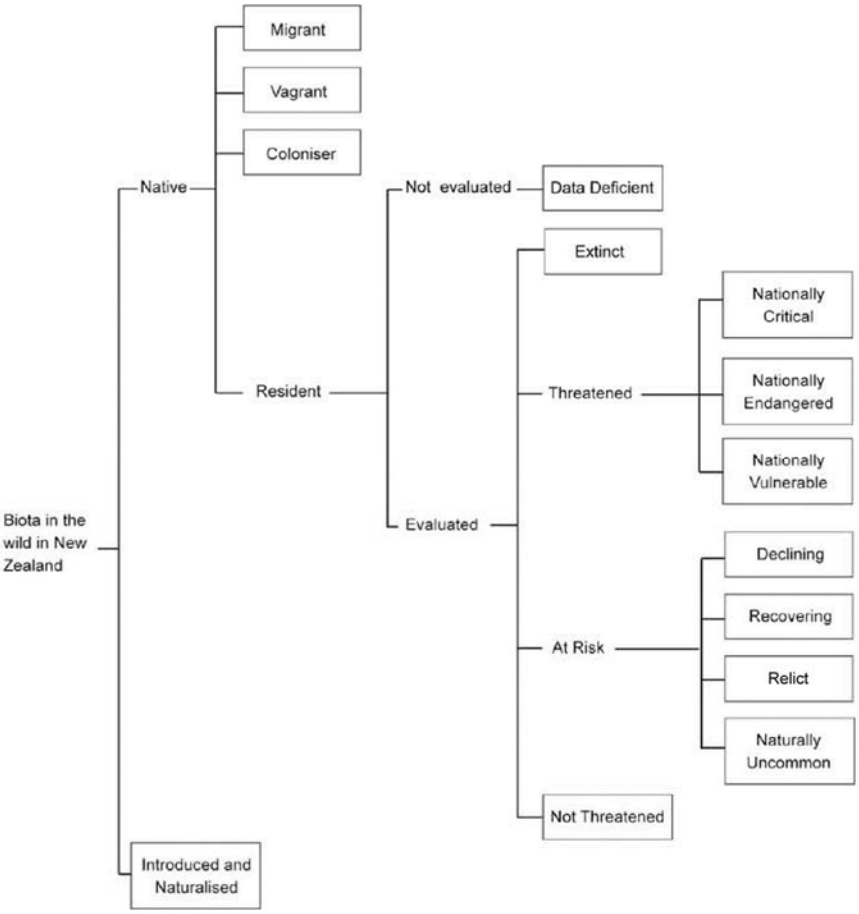
| | <br>Source: Townshend et al. (2008) |
| *Scale* | National |
| *Measurement and reporting frequency* | Three-year assessment cycle |
| *Data sources* | Data from a wide variety of sources but for the most part based on subjective assessments by experts. |
| *Information management* | Threat classification coordinated and overseen by DOC. Primary official listing is via the DOC website. |
| **Analysis** | |
| *Policy/management relevance* | Threat classification is an essential policy tool for the selection of taxa for active management. The aggregated figures are not useful as a reporting tool, as only long quantitative data series are likely to provide the highly reliable measures needed for performance measurement. Long-term trends in the lists will only become apparent after several cycles of listing. Changes in taxa under active management are the right level for performance reporting. |
| *Conceptual basis and robustness* | Threat classifications have been widely discussed and their limitations well understood. The limitations (mainly lack of data and reliance on threat categories) are more than compensated for by standard protocols and a comprehensive coverage and assessment cycle |

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| | (Rodrigues et al. 2006). |
| *Compatibility with other agencies* | The NZTCS is based on and consistent with standard international IUCN Red List procedures. |
| *Links to other OMF indicators and measures* | Indicator 1.4: *Preventing declines and extinctions* |
| *Implementation and cost* | The procedure is overseen by DOC staff, but relies extensively on volunteer experts. |

| **Indicator 1.4.2** | ***Security of threatened and at-risk taxa*** |
|---|---|
| *Description* | Quantification of trends in threatened and at-risk taxa. |
| *Justification* | It is not sufficient simply to record risk status as the rate at which species transfer from one state to another. Without quantification, verified models cannot be created to give predictive assessments of future status of species and therefore help guide action. |
| *Comment* | These measures will require substantial new investment. |
| *Measures* | **1.4.2.1-LFM** Current and predicted trends in the status of threatened and at-risk taxa<br>**1.4.2.2-LFM** Current and predicted trends in the demographics of threatened and at-risk taxa under active management |

| **Measure 1.4.2.1-LFM** | ***Current and predicted trends in the status of threatened and at-risk taxa*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.4** Preventing declines and extinctions |
| **Indicator** | **1.4.2** Security of threatened and at-risk taxa |
| **Status** | Final |
| **Description** | |
| *Overview* | The NZTCS is committed to regular updates of the conservation status of New Zealand indigenous taxa as in M1.4.1.1-LFM: *Status of indigenous taxa*. This measure summarises how many taxa have altered in threat status over a time interval (Hitchmough 2013). However, as pointed out in the Hitchmough summary, a careful analysis of data and confounding issues—such as taxonomic instability, naming of new entities, and previous incorrect assignations to threat classification—must be made. This measure focuses on the |

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| | underpinning data which permit reliable estimates of change in status. |
| *Data elements* | Elements are as per NZTCS taxon groups and threat categories. The current approach takes the categories assigned by expert opinion for a given taxon group and separates out changes arising because of real alteration in threat or trajectory. A reading of Hitchmough (2013: Table 4) shows that the data used to make these judgements vary greatly, ranging from impressionistic estimates ('huge decline in numbers') to well quantified trends ('declining at 2.8–3.7% p.a. in mid-1990s, and 87% decline since 1940s'). See further comments under 'Conceptual basis and robustness' below. |
| *Scale* | National |
| *Measurement and reporting frequency* | Three-yearly assessment cycle with published summary of changes. |
| *Data sources* | Data largely collected by DOC. |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | This is perhaps the most critical data set collected by DOC as it underpins active management decisions regarding taxa close to or on an accelerated pathway to extinction. |
| *Conceptual basis and robustness* | Over 12,000 taxa were assessed in the 2008–2011 cycle, and 3570 were listed as Threatened or At Risk. Despite these large numbers and the problems associated with distinguishing and threat classifying them, the whole process is about as robust as can be expected from the resources deployed, thanks largely to the standard protocols and the engagement of acknowledged experts in the process.<br>However, to meet the evidential standards routinely employed for other measures and indicators, a shift from expert opinion to quantification is desirable. To this end, a number of the 3570 threatened or at-risk taxa should be randomly selected and their statuses quantified to put error estimates around the expert opinion values. |
| *Compatibility with other agencies* | IUCN Red List procedures are universally employed. The NZTCS aligns well. |
| *Links to other OMF indicators and measures* | M1.4.1.1-LFM: *Status of indigenous taxa* |
| *Implementation and cost* | Quantification is not likely to be a cheap exercise because of the specialist field and quantification/modelling tools required. A rolling programme taking several groups for analysis at a time will probably be the most efficient. |

| **Measure 1.4.2.2-LFM** | ***Current and predicted trends in the demographics of threatened and at-risk taxa under active management*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.4** Preventing declines and extinctions |
| **Indicator** | **1.4.2** Security of threatened and at-risk taxa |
| **Status** | Final |
| **Description** | |
| *Overview* | There are 220 species 'under active management to improve understanding' (DOC Annual Report 2015) and 311 being managed under optimised species prescriptions. This measure is needed to show how these species are faring with the increased attention. |
| *Data elements* | Demographic data for each actively managed species. |
| *Scale* | National |
| *Measurement and reporting frequency* | The large number of species involved precludes annual population data for all but the most endangered category, Nationally Critical. Moreover, the longevity of individuals and the importance of breeding or regeneration success vary greatly between species. A demographically and threat-related time interval for censuses should be decided on individually. |
| *Data sources* | DOC is already collecting a large amount of data on threatened species under active management. This is augmented by studies carried out by the now numerous conservation-orientated university groups and Landcare Research. |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Ultimately this will be one of the most important reporting measures as it demonstrates the effectiveness of intervention. |
| *Conceptual basis and robustness* | Demographic and population viability analysis is well understood. Tools are readily available for census and tracking, and new, more effective tools are becoming available permitting automated census and tracking. |
| *Compatibility with other agencies* | Compatible with standard international practice. |
| *Links to other OMF indicators and measures* | • M1.4.1.1-LFM: *Status of indigenous taxa*<br>• M1.4.2.1-LFM: *Current and predicted trends in the status of threatened and at-risk taxa* |

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| *Implementation and cost* | While demographic analysis is not cheap, it is essential to informed management. Analytical skills are available both in-house and widely in the university and Crown research institute systems as demographic analysis is an underpinning skill for most ecological applications. |

| **Indicator 1.4.3** | ***Loss of genetic diversity*** |
|---|---|
| *Description* | Measures here will document population genetics in biota considered at high risk. |
| *Justification* | Reduction of species to low or scattered population sizes will reduce genetic diversity, which in turn may eventually increase the risk of extinction or raise their susceptibility to disease. This risk is compounded by artificial breeding or nursery programmes, which may unwittingly increase populations but decrease their genetic variability. |
| *Comment* | The measures proposed here have only been used previously in a few cases in New Zealand, most notably regarding endangered bird population. Access to much cheaper and rapid gene technology brings broader-scale monitoring within reach. |
| *Measures* | **1.4.3.1-LFM** Genetic diversity in relation to conservation status<br>**1.4.3.2-LFM** Genetics of taxa under management |

| **Measure 1.4.3.1-LFM** | ***Genetic diversity in relation to conservation status*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.4** Preventing declines and extinctions |
| **Indicator** | **1.4.3** Loss of genetic diversity |
| **Status** | Final |
| **Description** | |
| *Overview* | The relationship of genetic diversity (heterozygosity and allelic richness) to population factors of conservation concern (population viability, evolutionary potential, inbreeding, deleterious mutation accumulation) has been controversial but is now regarded as settled (Frankham 2005). Loss of genetic diversity increases the risk of extinction. However, the relationship between genetic diversity and the primary risk factors by which IUCN Red Lists are assessed is not at all clear. The issue appears to be that population factors estimated by Red List techniques do not reliably identify taxa with declining genetic |

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| | diversity (Willoughby et al. 2015). Therefore the NZTCS needs to be augmented by genetic-orientated metrics. |
| *Data elements* | Willoughby et al. (2015) suggest a methodology by which genetic estimates of endangerment can be made by calculating the effective population size, gathering estimates of heterozygosity for similar species, and applying the assumption that the critical risk level is a heterozygosity level below the 25% quantile of all species. |
| *Scale* | National |
| *Measurement and reporting frequency* | As for NZTCS listings |
| *Data sources* | Not currently collected by DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Lack of a genetic basis to the NZTCS is a major shortcoming, which this measure would rectify. |
| *Conceptual basis and robustness* | This measure relies on the solid relationship between effective population size and heterozygosity. Careful estimate of both of these should permit calculation of genetic risk. |
| *Compatibility with other agencies* | Not widely used in formal reporting. However, genetic measures are applied in many studies of taxa of conservation interest. |
| *Links to other OMF indicators and measures* | Generally useful to all indicators for Outcome Objective 1.4: *Preventing declines and extinctions*. |
| *Implementation and cost* | This measure would need to be developed through a dedicated programme. However, once the techniques and genetic databases are established, it should be relatively low cost to apply as a routine metric. |

| **Measure 1.4.3.2-LFM** | ***Genetics of taxa under management*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.4** Preventing declines and extinctions |
| **Indicator** | **1.4.3** Loss of genetic diversity |
| **Status** | Final |

| **Description** | |
|---|---|
| *Overview* | Critically threatened taxa invariably have small or small and sparse populations. Intensive management often involves breeding or nursery programmes and translocations. Inbreeding depression, loss of genetic diversity and mutation accumulation in these reduced populations can theoretically lead to an extinction vortex in which chance events have a devastating effect on weakened populations (Lacy & Lindenmayer 1995). While genetic factors have tended to be underutilised in New Zealand, there is a compelling case for routinely analysing them in all intensively managed taxa (Jamieson et al. 2006). Heterozygosity values correlate well with the ability of a population to respond to a bottleneck event, and allelic diversity is an indication of the adaptability of a population for its long-term viability. Such data can estimate both immediate and long-term extinction risk, and provide guidance for breeding selection and translocation numbers, among other uses. As the sophistication of molecular techniques increases, and the difficulty and cost of analysis decreases, other quantitative genetic factors which may correlate more closely with actual risk should be considered for addition to the routine metrics. |
| *Data elements* | Heterozygosity and allelic richness metrics for all severely reduced or intensively managed populations. |
| *Scale* | Local |
| *Measurement and reporting frequency* | Measurement frequency should depend on:<br>• The population status of the populations<br>• Longevity of the organisms<br>• Breeding system |
| *Data sources* | DOC; university research laboratories |
| *Information management* | DOC; university research laboratories |
| **Analysis** | |
| *Policy/management relevance* | These metrics are closely aligned to threatened species management and do not need to be reported as an outcome measure at this time. Once such programmes are routine, national-level surveys giving some estimate of genetic security of critically threatened species would be appropriate. |
| *Conceptual basis and robustness* | There is a vast literature on this subject, and the measurement principles are well understood, although there is still vigorous debate over interpretation. |
| *Compatibility with other agencies* | Genetic metrics widely used by recovery programmes. More general use for EI reporting appears not to be initiated. |
| *Links to other OMF indicators and* | Relevant to all indicators for Outcome Objective 1.4: *Preventing* |

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| *measures* | *declines and extinctions.* |
| *Implementation and cost* | The rapidly falling cost of acquiring molecular data and vastly improved analytical tools suggests that genetic analysis should become part of an initial assessment for threatened species. However, only for some of these, due to their breeding system, numbers and population history, will genetic factors prove to be critical, and thus the resources could be concentrated on monitoring those few that need intensive genetic intervention (i.e. through breeding programmes). |

| **Outcome Objective 1.5** | ***Maintaining ecosystem composition*** |
|---|---|
| Loss or reduction of species has a major effect on ecosystems. For instance, although loss of a shrub from an otherwise intact forest stand may appear insignificant viewed from a structural point of view, it may have major flow-on effects for invertebrates, fungi, or perhaps birds and reptiles if it provides fruit and nectar resources. Likewise, in a freshwater system, loss of a large fish may have large and detrimental effects on trophic structures. Shrinking and fragmenting range sizes are often a warning sign of less easily quantified changes in ecosystem composition occurring at finer scales. | |
| **Indicators:**<br>**1.5.1** Species composition and diversity<br>**1.5.2** Species occupancy of natural range | |

| **Indicator 1.5.1** | ***Species composition and diversity*** |
|---|---|
| *Description* | This indicator documents the species composition and diversity of ecosystems. It includes demography of functional groups as this information is essential for determination of trends. |
| *Justification* | Pests, weeds and human interference have degraded ecosystems by reducing regeneration or recruitment, and altering age structures and species composition. Globally, indicators aligned with this topic dominate biodiversity reporting; in particular, trends in large, easily noticed organisms such as birds, butterflies and trees. |
| *Comment* | An improvement from a degraded state is likely to be slow, and the following set of measures is about providing background information to guide an assessment of changes in composition. The key concept behind this indicator is the notion that there are functional plant types and animal guilds that should be expected in a region or patch if it is to be said to have EI. However, the identity and role of the components are important, so the requirements of such an indicator are not met by species diversity indices. |
| *Measures* | **1.5.1.1-LFM** Demography of functional groups<br>**1.5.1.2-LFM** Representation of functional groups and guilds |

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| | **1.5.1.3-LFM** | Abundance and demography of common and widespread taxa |
| | **1.5.1.4-LFM** | Changes in species diversity |

| **Measure 1.5.1.1-LFM** | ***Demography of functional groups*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.5** Maintaining ecosystem composition |
| **Indicator** | **1.5.1** Species composition and diversity |
| **Status** | Final |
| **Description** | |
| *Overview* | Maintaining the common, widespread indigenous plants and animals typical of a region is a major conservation goal. Long-lived ecosystem dominants can persist while failing to regenerate adequately, therefore demographic metrics are necessary. This measure focuses on quantitative sampling of common representatives of broad functional groupings to determine demographic change over time. |
| *Data elements* | The currently active element is 'canopy dominants' and the most common and important tree species are censused as part of the 8 × 8 km LUCAS 20 × 20 m plot network (Allen et al. 2013).<br>• Size distributions of woody stems with diameter at breast height (DBH) of ≥ 2.5 cm<br>• Changes in population size of woody stems with DBH ≥ 2.5 cm<br>• Size distributions of woody stems > 1.35 m tall and DBH < 2.5 cm<br>Functional types (plant species sensitive to introduced herbivores; providing a bird resource; sensitive to climate) with:<br>• Metrics concerning species richness and occupancy<br>• Size structure<br>A similar census should be carried out for the larger vertebrates in all New Zealand ecosystems, including birds, fish, lizards and fish. |
| *Scale* | National |
| *Measurement and reporting frequency* | Measurement frequency depends on the schedule for the Tier 1 monitoring network. There is little value in reporting these measures any more frequently than 5 to 10 years, depending on the focal functional group. |
| *Data sources* | DOC |
| *Information* | DOC National Vegetation Survey database |

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| *management* | |
| **Analysis** | |
| *Policy/management relevance* | This should be a key policy and management measure as the fate of the larger functional groups control the trajectory of nearly all New Zealand ecosystems: freshwater, marine and terrestrial. There has been long-standing concern in New Zealand over the health of the forests with fears of canopy collapse through possum, deer and goat herbivory, and more lately, drought and disease. This data set will provide basic background data on the key terrestrial vegetation fabric permitting assessment of threats and judging the efficacy of responses. |
| *Conceptual basis and robustness* | Survey methodologies for functional groups are well developed and reliable because they have been critical in the past for forestry, fishing and hunting. Allen et al. (2013) have provided a comprehensive overview and statistical analysis of these metrics. In their view, they provide useful, statistically valid data. |
| *Compatibility with other agencies* | Widely used both in conservation and resource management. Similar measures of forest health are used internationally and, in particular, where indigenous forests are also used for wood production. |
| *Links to other OMF indicators and measures* | This depends on aquatic measures in Indicator 1.1.2: *Ecosystem function*. Will be a background measure for M1.1.5.6-LFM: *Disease and invertebrate pest outbreaks* and Indicator 1.7.2: *Biological responses to climate change*. |
| *Implementation and cost* | These metrics are relatively expensive to obtain in the first instance because of the need to set up a national observation grid. However, once established, many biodiversity metrics can be obtained from a single visit to a grid point, and the statistical design ensures that it is robust against changes in measurement intervals and thus has considerable flexibility. Tier 1 surveying is now fully costed into the DOC budget and this will provide most of the plant functional group and bird monitoring. Lizard monitoring is not yet nationally integrated. NIWA undertakes regular fish surveys and this could provide a basis for a wider monitoring programme. |

| **Measure 1.5.1.2-LFM** | ***Representation of functional groups and guilds*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.5** Maintaining ecosystem composition |
| **Indicator** | **1.5.1** Species composition and diversity |
| **Status** | Final |

| **Description** | |
|---|---|
| *Overview* | Persistent pressure from disruptive influences such as exotic pests and weeds, fire and nutrients can dramatically alter the species composition of an ecosystem. This measure captures persistent alteration at large scales of groups of species united by a functional attribute of importance to ecosystem sustainability. |
| *Data elements* | Current elements:<br>• Palatable plant species<br>• Bird-food resource species<br>Recommended:<br>• Macroinvertebrates<br>• Fish |
| *Scale* | National |
| *Measurement and reporting frequency* | Measurements currently made as part of the Tier 1 8 × 8 km grid. |
| *Data sources* | DOC Tier 1 programme |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Slow but inexorable decline of certain functional groups has long-term implications for management policy. These metrics will also operate as excellent intermediate-term large-scale measures of how effective control or abatement actions have been, in contrast to the immediate measures of output such as hectares treated or pests killed. |
| *Conceptual basis and robustness* | Ecological measurement techniques are well developed (see Allen et al. 2013 for plant examples). The functional group concept is well established in the literature and is particularly recommended for improving modelling and prediction (McMahon et al. 2011). |
| *Compatibility with other agencies* | Functional group measures are increasingly widely used to report across a wide range of ecosystems—freshwater, marine and terrestrial (e.g. Blasi et al. 2010; Bregman et al. 2014; Edwards et al. 2014). |
| *Links to other OMF indicators and measures* | • Indicator 1.1.2: *Ecosystem function*<br>• Indicator 1.1.4: *Ecosystem structure* |
| *Implementation and cost* | Functional group analysis is a second step after systematic collection of primary data. It is important that the appropriate groups and metrics are included in the initial collection as the cost of independent surveys of single functional groups is prohibitive. |

| **Measure 1.5.1.3-LFM** | ***Abundance and demography of common and widespread taxa*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.5** Maintaining ecosystem composition |
| **Indicator** | **1.5.1** Species composition and diversity |
| **Status** | Final |
| **Description** | |
| *Overview* | The conservation focus on threatened and at-risk taxa runs the risk of ignoring changes in widespread and abundant taxa. Functional group analysis (M1.5.1.2-LFM) captures the distribution and abundance of the structural elements of an ecosystem. However, a second measure is necessary to capture changes in widespread and abundant taxa which may be nonetheless under pressure. An example is the widespread mountain tōtara (*Podocarpus laetus*), which has long been considered under pressure (Rose et al. 1992). Eels are another example (Allibone et al. 2010). Long-term trends being the major consideration, rolling surveys such as those currently carried out by the DOC Tier 1 programme are ideal. NIWA's New Zealand Freshwater Fish Database (NZFFD) covers only 5% of New Zealand waterways and needs augmentation by freshwater-focused surveys paralleling those of DOC Tier 1. While important, surveys such as those carried out by the Ornithological Society of New Zealand for New Zealand birds or the data captured by NatureWatch and the New Zealand Plant Conservation Network do not satisfy the requirements for an authenticated national scheme. |
| *Data elements* | Distribution and abundance of widespread species selected on the basis of their major or potentially major contribution to EI. |
| *Scale* | National |
| *Measurement and reporting frequency* | Measurement should be in the form of repeat surveys at fixed locations. |
| *Data sources* | Various. DOC; NIWA; Landcare Research; regional authorities; public via open data collection sites. |
| *Information management* | Dispersed at the moment, but DOC, NIWA and Landcare Research share most of the expertise and hold the current databases. |
| **Analysis** | |
| *Policy/management relevance* | That widespread and abundant species are holding or improving their status is one of the most reliable indicators of overall EI. As such, statistics on their status could be reported yearly as assessment of various groups are completed. From a policy point of view, multi-year |

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| | declining trends in key groups should be a spur to closer examination of causes and action. In the past, decline of some abundant and prominent species such as tī or kererū has been a focus of conservation action, as is now occurring with kauri. It is important to have reliable information to hand that can verify change as anecdotal accounts are often compelling but notoriously unreliable. |
| *Conceptual basis and robustness* | Standard survey techniques are available and well researched (see Leathwick, Moilanen et al. 2010; Allen et al. 2013). |
| *Compatibility with other agencies* | Widespread common species are often used as measures of overall EI. A good example is the Pan-European Common Bird Monitoring Scheme (PECBMS). |
| *Links to other OMF indicators and measures* | Shares data with Indicator 1.1.2: *Ecosystem function* and Indicator 1.1.4: *Ecosystem structure*. |
| *Implementation and cost* | Broad-scale systematic surveys are cheap for the quality and amount of data they yield but are relatively expensive to run and need dedicated, trained staff as has been demonstrated by the DOC Tier 1 monitoring scheme. Nevertheless, by bundling up numerous measures into one sampling scheme, impressive economies of scale should be possible. |

| **Measure 1.5.1.4-LFM** | ***Changes in species diversity*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.5** Maintaining ecosystem composition |
| **Indicator** | **1.5.1** Species composition and diversity |
| **Status** | Final |
| **Description** | |
| *Overview* | Species diversity is one of the key aspects of biodiversity stressed in global reporting and conservation planning at all levels (Brooks et al. 2006); in particular, the concept of 'hot spots' of biodiversity where particular emphasis is needed because of the high risk of loss through anthropogenic modification. At a national scale, **Species diversity of the nation as a whole** is covered in the 3-volume *New Zealand Inventory of Biodiversity* (Gordon 2012), which contains an up-to-date list of accepted names of the entire biota. The New Zealand Organism Register (founded in 2006) provides a definitive list (maintained by Landcare Research; www.nzor.org.nz) of the over 100,000 organism names relevant to New Zealand, underpinned by Landcare Research herbarium, invertebrate and fungal collections. This, and aspects of |

<table>
<tr><td></td><td>species loss from the nation as a whole are covered in Indicator 1.4.1: Conservation status of indigenous taxa.<br><br>At a local scale, species diversity is an inherent aspect of an ecosystem, and some are naturally species rich and others naturally species poor, so overall mapping of diversity levels gives little information in the sense of important trends. However, there is a need to untangle the interactions that lead to species diversity change:<br><blockquote>Despite some uncertainties about the mechanisms and circumstances under which diversity influences ecosystem properties, incorporating diversity effects into policy and management is essential, especially in making decisions involving large temporal and spatial scales. Sacrificing those aspects of ecosystems that are difficult or impossible to reconstruct, such as diversity, simply because we are not yet certain about the extent and mechanisms by which they affect ecosystem properties, will restrict future management options even further. It is incumbent upon ecologists to communicate this need, and the values that can derive from such a perspective, to those charged with economic and policy decision-making. (Hooper et al. 2005)</blockquote></td></tr>
<tr><td>Data elements</td><td>Time series of species assemblages from selected uncommon and reduced ecosystems.</td></tr>
<tr><td>Scale</td><td>Local</td></tr>
<tr><td>Measurement and reporting frequency</td><td>Very much depending on ecosystem, but possibly 5-year intervals. Highly stressed ecosystems with likely rapid degradation should be measured more frequently.</td></tr>
<tr><td>Data sources</td><td>Baseline surveys and repeats will have to be generated by DOC.</td></tr>
<tr><td>Information management</td><td>DOC</td></tr>
<tr><td colspan="2">Analysis</td></tr>
<tr><td>Policy/management relevance</td><td>The importance of naturally uncommon and reduced ecosystems resides very much in the fact that they harbour uncommon or now rare species—often habitat specialists. Maintaining the ‘ecosystem’ while it loses many of its species is a very real threat. In effect, this measure is complementary and could be run hand-in-hand with Indicator 1.4.2: Security of threatened and at-risk taxa, and Indicator 1.4.3: Loss of genetic diversity.</td></tr>
<tr><td>Conceptual basis and robustness</td><td>There is a vast literature on measurement of species diversity and its implications.</td></tr>
<tr><td>Compatibility with other agencies</td><td>Very widely used.</td></tr>
<tr><td>Links to other OMF indicators and</td><td>Most of the indicators under Outcome Objective 1.4: Preventing declines and extinctions.</td></tr>
</table>

| | |
|---|---|
| *measures* | |
| *Implementation and cost* | This is a costly exercise as it needs specialist input over many different groups to establish baselines. It should be trialled with a selected number of high-risk ecosystems. |

| **Indicator 1.5.2** | ***Species occupancy of natural range*** |
|---|---|
| *Description* | Accurate assessment of the natural range once occupied by indigenous species, and regularly repeated assessments of current natural range extents. Both shrinking and expanding ranges are of interest. |
| *Justification* | Range sizes relative to the original are a good proxy for the success of ecosystem management. Loss of range almost invariably means loss of the full range of genetic potential, and loss of range increases risk of catastrophic loss. Climate change will impact distributions eventually, and it is important not to confuse re-occupancy of original range with potentially disruptive spread into previously unoccupied territory. |
| *Comment* | There is a regrettable tendency in conservation assessments to pick a baseline in the near past, and measure deviations from this status. For a nation to be able to confidently assert that it has good EI, it should be able show how the current distribution of species making up the indigenous biota compares to the original range. |
| *Measures* | **1.5.2.1-LFM** Natural range occupied |

| **Measure 1.5.2.1-LFM** | ***Natural range occupied*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.5** Maintaining ecosystem composition |
| **Indicator** | **1.5.2** Species occupancy of natural range |
| **Status** | Final |
| **Description** | |
| *Overview* | ‘Natural’ range is here defined as the estimated range before the impact of predators, herbivores, exotic diseases, and clearance. It is not the ‘potential’ range, which refers to the biological capacity of the species. ‘Natural’ is preferred to ‘pre-human’ as it is the impacts that are of concern, not the timeline.<br>Monitoring of individual species abundances is a resource-hungry and expensive operation. The systematic Tier 1 monitoring programme will provide this information for a limited subset of the biota, namely |

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| | vascular plants, but even this approach will not capture the distributions of uncommon or sparsely distributed plant species. On the other hand, point occurrence data are widely available and much cheaper to collect and analyse. The concept behind this measure is to use known past ranges of taxa, as described by point occurrences, to estimate the area of range still maintained. It will thus act as a generalised metric for possible contraction of a species and therefore act as an alert system for further investigation or action. |
| *Data elements* | All biota could be considered under this measure. Clearly all cannot be assessed, as expert identification skills are scarce for all but a few groups, such as vascular plants, fish, birds and reptiles. However, the strength of the approach can be seen when data are already available (and assessed), as has been done for avian species through the Ornithological Society surveys (Robertson et al. 2007). |
| *Scale* | National |
| *Measurement and reporting frequency* | This needs careful assessment. The 35-year interval between comprehensive coverage by the *Atlas of Bird Distribution in New Zealand* is too long to guide management action but provides excellent background material for policy. The trade-off will be between comprehensive coverage and frequency. |
| *Data sources* | Virtually all scientific groups dealing with indigenous ecosystems collect these data, most notably the universities, major museums, Crown research institutes, and DOC. Amateur societies and organisations play an increasing role. NatureWatch New Zealand is an example. |
| *Information management* | Currently most of this material is archived by NIWA, Landcare Research, Te Papa, and DOC. |
| **Analysis** | |
| *Policy/management relevance* | The results of these range change surveys will have large management and policy relevance as they will be one of the best measures of changes in EI over time. |
| *Conceptual basis and robustness* | The statistical basis for range size and change inference from occurrence data is very well documented in the literature. |
| *Compatibility with other agencies* | Range changes are one of the most often reported indicators internationally because of the availability of the data, the wide participation in data collection when birds, butterflies and plants are involved, and the low cost of acquisition and analysis. |
| *Links to other OMF indicators and measures* | Shares data with M1.1.6.1-L: *Land under indigenous vegetation* and many of the measures under Indicator 1.1.2: *Ecosystem function*. |
| *Implementation and cost* | The underlying data are often acquired in the course of other activities (e.g. taxonomic revisions; park surveys) and often through volunteer effort. It is one of the most frequently recommended activities for |

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| | 'citizen science'. However, intensive systematic surveys of less well-known groups are likely to be resource-hungry and expensive. |

| **Outcome Objective 1.6** | ***Ensuring ecosystem representation*** |
|---|---|
| Ecosystems provide a basis for prioritising conservation action, as a broad representation of intact ecosystems ensures that there is at least some security for many of the plants and animals that make it up. Some ecosystems are relatively safe and self-maintaining (many alpine lakes for instance); others are at risk of annihilation (coastal dunes). This Outcome Objective provides for regular assessment of their status.<br>Ecosystems are, for the most part, human constructs—an attempt to introduce order into what can at times seem a chaotic continuum. There are many ecosystem classification systems and many ways of implementing them. Nevertheless, there is an undoubted reality in the form of more or less obvious discontinuities in the natural landscape which most classifications attempt to capture and thus there is usually some commonality. Nevertheless, it is essential that a move is made from subjective, survey-style ecosystem classifications and assessments to those based on quantitative data. | |
| **Indicators:**<br>**1.6.1** Ecosystem representation and protection status | |

| **Indicator 1.6.1** | ***Ecosystem representation and protection status*** |
|---|---|
| *Description* | These measures take a different approach to those of Indicator 1.1.6: *Land cover*, which emphasise the function of land cover as a primary contributor to landform stability, water and prevention of erosion of ecosystem function in general. These measures focus on the fact that many ecosystems have been reduced to near invisibility (e.g. intact dunelands) whereas others remain abundant (e.g. montane beech forest). |
| *Justification* | The need for a focus on ecosystems as unique entities valuable in and of themselves. |
| *Comment* | It is essential that a quantitative classification be developed and promulgated for this indicator to gain acceptance. |
| *Measures* | **1.6.1.1-LFM** Ecosystem extent<br>**1.6.1.2-LFM** Proportion of ecosystems protected<br>**1.6.1.3-LFM** Change in extent of naturally uncommon and reduced ecosystems<br>**1.6.1.4-LFM** Proportion of ecosystems remaining relative to natural extent |

| **Measure 1.6.1.1-LFM** | ***Ecosystem extent*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.6** Ensuring ecosystem representation |
| **Indicator** | **1.6.1** Ecosystem representation and protection status |
| **Status** | Final |
| **Description** | |
| *Overview* | Once indigenous vegetation cover is eliminated, most other indigenous taxa also disappear or are greatly reduced. This is an obvious outcome for many herbivorous invertebrates that have specific hosts, but it also applies to below-ground fauna such as earthworms (Bowie et al. 2016). Complex, tall forest harboured an enormous biotic diversity in pre-European New Zealand, whereas non-indigenous cover is most often grassland or low-growing fire-prone shrubland and, although there is some transference, most indigenous taxa cannot thrive in non-indigenous ecosystems. Moreover, the exact nature of that ecosystem is important. A recent classification of vegetation cover by Singers & Rogers (2014) is comprehensive and detailed and rapidly being taken up by regional authorities. However, while well suited to their information needs, it has not been mapped and relies on subjective, non-quantitative assessments. A quantitative classification is better suited to the needs of a long-term mapping programme as retrofitting vegetation types will be inevitable as information and vegetation change proceeds. A start on such an exercise has been made in Wiser et al. (2011). Freshwater and marine ecosystem classifications appear to be robustly based on biotic quantification and sophisticated modelling (Snelder et al. 2007; Leathwick et al. 2008). |
| *Data elements* | • Mapped vegetation-based indigenous ecosystem extent.<br>The New Zealand Land Cover Database (LCDB) provides the fundamental layer and this has been already used to chart changes over time (Cieraad et al. 2015). However, there has been debate as to the accuracy of the LCDB for ecological purposes (Coomes et al. 2002; Brockerhoff et al. 2008). Ground-truthing will be essential to underpin such a metric as there is no potential at the moment for a technology that could remotely sense vegetation with the necessary level of discrimination.<br>• Mapped extent of marine and freshwater ecosystems. |
| *Scale* | National |
| *Measurement and reporting frequency* | The LCDB has been updated roughly every 5 years (1996/97, 2001/02, 2008/09, 2012/13) and provides the essential base for this |

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| | measure. As this is more a policy than reporting measure, lengthy intervals between assessments would be appropriate. |
| *Data sources* | Landcare Research |
| *Information management* | Landcare Research |
| **Analysis** | |
| *Policy/management relevance* | This is one of the fundamental metrics regarding loss of EI. Retaining not just indigenous cover but also a full range of indigenous ecosystems is vital. Priority-setting for management and acquisition of new land for PCL&W will be guided by this and similar metrics. |
| *Conceptual basis and robustness* | The LCDB approach is well researched and documented. It requires more ground-truthing as at a fine scale, there is a substantial amount of error in the category assignments (Brockerhoff et al. 2008; Overton et al. 2011). Land ecosystem classification has been largely opinion-based and non-quantitative until now, and the resulting classifications have limited use aside from being a general guide. Climo-edaphic environmental classifications (e.g. LENZ), although essential for many purposes, suffer from having no direct biotic layers and thus are not congruent with vegetation-based ecosystems, however defined. Freshwater (Leathwick, Moilanen et al. 2010) and marine classifications (Snelder et al. 2007) appear to be on a sounder footing for biotic ecosystem mapping. |
| *Compatibility with other agencies* | Extent of ecosystems—defined in a multitude of ways—are usually reported. |
| *Links to other OMF indicators and measures* | M1.1.6.1-L: *Land under indigenous vegetation* |
| *Implementation and cost* | The LCDB is a costly exercise involving sophisticated equipment, satellite imagery and specialised analysis. However, it has many uses and the cost is not borne only by biodiversity budgets. The ground-truthing we recommend, however, will substantially raise the cost. |

| **Measure 1.6.1.2-LFM** | ***Proportion of ecosystems protected*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.6** Ensuring ecosystem representation |
| **Indicator** | **1.6.1** Ecosystem representation and protection status |
| **Status** | Final |

| **Description** | |
|---|---|
| *Overview* | This is an important international measure. In New Zealand some ecosystems are very well represented as protected areas (e.g. montane and subalpine forest) while others (e.g. lowland wetlands and coastal dunes) are poorly represented. Much like lowland, fertile landscapes, marine and freshwater ecosystems have a much lower level of protection, largely because of their high economic value. |
| *Data elements* | This element will require a formal, quantitative, mapped, replicable ecosystem classification overlain with the distribution of protective status and updating at regular intervals by LCDB layers with plot-based assessment of areas where ecosystem alteration or loss is indicated. Freshwater assessments will follow the national waterways classification (Leathwick, Moilanen et al. 2010). |
| *Scale* | National |
| *Measurement and reporting frequency* | This will depend on LCDB updates and freshwater waterways classifications. |
| *Data sources* | DOC; MfE; Landcare Research; NIWA |
| *Information management* | DOC; MfE; Landcare Research; NIWA |
| **Analysis** | |
| *Policy/management relevance* | Required for international reporting. Also needed for decisions around providing protection for land or waters currently lacking the same. |
| *Conceptual basis and robustness* | After years of subjective expert opinion-based classifications of ecosystems, systematic quantitative approaches are beginning to be implemented (Williams et al. 2007; Leathwick, Snelder et al. 2010; Wiser et al. 2011). These are well underpinned by the best available analytical procedures. |
| *Compatibility with other agencies* | Similar measures indicating percentage of broadly defined ecosystems or land units officially protected are widely used both internationally and in New Zealand. |
| *Links to other OMF indicators and measures* | Depends on M1.6.1.1-LFM: *Ecosystem extent*. |
| *Implementation and cost* | Quite an intensive programme of work will be needed to get an operational ecosystem classification up and running. The groundwork has been done on the analytical side, and what is needed is systematic sampling of the defined ecosystems. |

| Measure 1.6.1.3-LFM | ***Change in extent of naturally uncommon and reduced ecosystems*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.6** Ensuring ecosystem representation |
| **Indicator** | **1.6.1** Ecosystem representation and protection status |
| **Status** | Final |
| **Description** | |
| *Overview* | Broad, national-scale ecosystem classifications are not well suited to dealing with naturally uncommon and critically reduced ecosystems because of their small size and often unique characteristics. Also, these necessarily small and often fragmented ecosystems are subject to pervasive threats through accidental obliteration, pests and weeds. The IUCN has categories for assessing threatened ecosystems (short-term decline; historical decline; small current distribution or very few locations; very small current distribution). Special attention must therefore be paid to the status of such systems. In New Zealand in 2014, there were 71 identified terrestrial rare ecosystems, 45 of which are threatened under the IUCN criteria. |
| *Data elements* | National-level classification, mapping, and assessment of naturally uncommon and reduced ecosystems. |
| *Scale* | National |
| *Measurement and reporting frequency* | Not primarily a reporting measure and assessment should be done via rolling surveys. |
| *Data sources* | Landcare Research; DOC |
| *Information management* | Landcare Research; DOC |
| **Analysis** | |
| *Policy/management relevance* | This is an essential policy and management metric, as small, fragmented ecosystems are often not recognised for what they are, nor is their fragility appreciated. |
| *Conceptual basis and robustness* | Naturally uncommon terrestrial ecosystems have been well researched and a classification has been established (Williams et al. 2007). However, the issue of once widespread ecosystems now reduced to atypical fragments has yet to be addressed systematically. Much of this reduction has happened because of the massive post-human reduction of indigenous ecosystems on land suitable for agriculture or prone to fire, or in the case of freshwater systems, drainage channelisation and damming of waterways. |

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| *Compatibility with other agencies* | Widely used internationally and by New Zealand agencies. |
| *Links to other OMF indicators and measures* | Integrated into all the measures for Indicator 1.6.1: *Ecosystem representation and protection status*. |
| *Implementation and cost* | Must be regarded as part of a comprehensive ecosystem and species mapping and assessment scheme with dedicated specialists and resources. |

| **Measure 1.6.1.4-LFM** | ***Proportion of ecosystems remaining relative to natural extent*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.6** Ensuring ecosystem representation |
| **Indicator** | **1.6.1** Ecosystem representation and protection status |
| **Status** | Final |
| **Description** | |
| *Overview* | While nearly one-half of the New Zealand landmass is under some form of indigenous vegetation, a major issue is the marked reduction of certain ecosystems. Wetlands, for instance, are estimated to have lost around 90% of their original extent. The loss has been greatest on fertile lowland sites under climates suited for agriculture or settlement. Rivers, streams, springs, sandy coasts and estuaries have suffered comparable losses. Conservation suffers greatly from the 'moving goalpost' syndrome, when losses are measured solely against recent, not natural, extent. This measure is intended to act as a corrective.<br>How to classify and map New Zealand ecosystems has been a contentious issue for many years (see discussion in Singers & Rogers 2014). The majority of systems proposed for New Zealand have been qualitative and subjective (including the most recent, Singers & Rogers 2014), based on broad-scale mapping of combinations of dominant species in conjunction with broad environmental factors. Subjective, qualitative classifications pose a real problem for a long-term monitoring system as they depend on expert opinion and are therefore unstable over time and poorly defined in space (de Caceres & Wiser 2012).<br>The LENZ bioclimatic hierarchical classification Level IV has been used as a de facto system to measure biodiversity loss through estimating the degree to which indigenous vegetation cover has been lost from LENZ Level IV units, and consigning these on the basis of indigenous loss to threatened environment categories (Cieraad et al. 2015). However, these LENZ Level IV environments do not equate to, |

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| | nor are represented as, 'ecosystems', and in fact contain multiple ecosystems within them. A strictly quantitative approach has been advanced in New Zealand based on an analysis of the LUCAS 8 × 8 km grid plots (Wiser et al. 2011).<br>Marine and freshwater systems have been adequately classified (Snelder et al. 2007; Leathwick et al. 2008). |
| *Data elements* | The requirement for an acceptable element should be a quantitatively defined ecosystem and a modelled natural extent backed up where feasible with historical or palaeoecological data observations. The breadth of the ecosystem definition should be relatively broad and not rely exclusively on uncommon or rare species. Ausseil et al. (2011) have shown how such an approach can be applied to wetlands. |
| *Scale* | National |
| *Measurement and reporting frequency* | Loss of some lowland land, freshwater and estuarine ecosystem types has been proceeding rapidly, as has been demonstrated in a general way by Walker et al. (2006), and once a baseline of historical extent has been determined, regular reassessments should proceed, perhaps every decade. |
| *Data sources* | A variety of databases will be needed, including LENZ, LCDB, LUCAS and independent surveys. |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Ecosystem loss ranks next to species extinction as a fundamental measure of biodiversity degradation and loss of EI. By its focus on past extent versus present losses, this measure can be a powerful policy instrument. It has performed this role in raising the profile of wetland loss in New Zealand. |
| *Conceptual basis and robustness* | 'Ecosystem' is not a natural entity equivalent to species, but a human-devised category for understanding biodiversity. Therefore getting the basic definitions quantified and accepted will be a major challenge. |
| *Compatibility with other agencies* | Ecosystem loss is a universal metric, usually quantified at a high level (e.g. loss of wet tropical forest). MfE has wetland loss as one of its environmental measures. |
| *Links to other OMF indicators and measures* | Integral part of all Indicator 1.6.1: *Ecosystem representation and protection status*, and relies on data from Indicator 1.1.6: *Land cover* and Indicator 1.1.4: *Ecosystem structure*. |
| *Implementation and cost* | This will be a relatively costly measure as it will involve research into current and historical ecosystems and sophisticated modelling approaches. Gaining widespread acceptance of the ecosystem definitions eventually chosen will not be simple. However, the advances made with wetland ecosystem modelling show that good |

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| | progress is possible. |

| **Outcome Objective 1.7** | ***Adapting to climate change*** |
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| Climate change (which includes here sea level rise) is now recognised in New Zealand as the defining issue of the 21st century. While there are few indications that climate change over the past century (approaching 1°C warming and some 20 cm sea level rise) has yet to impact biodiversity, climate change in the past has had highly significant effects on biodiversity and is likely, in combination with direct and indirect human interference, to lead to accelerated loss of biodiversity. There is little to zero chance that the climate change predicted to result from current greenhouse gas concentrations will be halted by reduced global emissions or sequestration and some scepticism that decarbonisation and altered agricultural practices will reduce the build-up of gases before serious harm is done. Therefore, as a matter of some urgency, we need to better understand the coming biotic impacts of climate change. | |
| **Indicators:**<br>**1.7.1** Basic climate series<br>**1.7.2** Biological responses to climate change | |

| **Indicator 1.7.1** | ***Basic climate series*** |
|---|---|
| *Description* | Long-term measures of important climate factors, in particular at biotically sensitive sites. |
| *Justification* | It is important that New Zealand documents changing climate as well as possible, bearing in mind that biodiversity will be affected by highly local, episodic and seasonal changes not easily modelled at present. |
| *Comment* | Climate change is a minor contributor to altering biodiversity status at present, but this will not last given the now well-attested global trends and potential New Zealand impacts (McGlone & Walker 2011; Christie 2014; Pachauri et al. 2014). |
| *Measures* | **1.7.1.1-LFM** Climate averages, indices and extreme events |

| **Measure 1.7.1.1-LFM** | ***Climate averages, indices and extreme events*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.7** Adapting to climate change |
| **Indicator** | **1.7.1** Basic climate series |

| **Status** | Final |
|---|---|
| **Description** | |
| *Overview* | The New Zealand climate observation stations provide a broad-scale overview of change in major climate factors. Global networks are now augmented by ocean buoys and satellite observations. However, some areas are still poorly documented (for the most part remote or high-altitude sites where maintaining instrumentation is a challenge), and change on metre scales relevant to plants and animals is not well known. For example, cloud-lie on mountain ranges is regarded in some regions of the world as an important biodiversity driver but has been only rarely documented in New Zealand (see for example Wardle 1986). |
| *Data elements* | Local climate recording networks at sensitive sites (e.g. at tree line; at snowline; in drier regions) to permit seamless transition from broad-scale climate surfaces to biodiversity-relevant local scales. |
| *Scale* | National |
| *Measurement and reporting frequency* | Automated at least hourly recording of fundamental biodiversity attributes (temperature, humidity, solar radiation, precipitation, wind, soil temperature and soil moisture). |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Will be essential to provide more detailed biodiversity-relevant data from model-based projections and to give real time data for biodiversity observations. |
| *Conceptual basis and robustness* | Micrometeorological standards well understood. |
| *Compatibility with other agencies* | There is an increasing use of micrometeorological observations. |
| *Links to other OMF indicators and measures* | Fundamental data series for most indicators. |
| *Implementation and cost* | Cost, reliability and remote data-transmission and data analysis has improved dramatically in the past decade. Major cost will be access and maintenance of data networks. Where possible they should be combined with other observation networks. |

| Indicator 1.7.2 | *Biological responses to climate change* |
|---|---|
| *Description* | Compilation of time series of shifts in ecosystems, species distributions, abundances and, where appropriate, phenology, which are considered vulnerable to climate change. |
| *Justification* | While the pressures of pests, weeds, disease and land clearance/intensification have been responsible for nearly all New Zealand biodiversity loss and degradation of EI, past and present, anthropogenic climate change is already affecting biodiversity and will become vastly more important in the near future. As the Parliamentary Commissioner for the Environment (2016) states: 'There is no question that climate change is by far the most serious environmental issue we face. It will impact on the health of our sea, land, and fresh water, our unique and precious biodiversity, and our economy.' Recent reviews have indicated areas in which climate change impact is likely to be most severe (McGlone & Walker 2011; Christie 2014). Waterways and indigenous vegetation patches are likely to suffer in the drier east as this region is set to become even drier in coming years; alpine and subalpine environments will be affected by warmer temperatures and ultimately endure more pressure from mammalian predators and lose snow patch and bare ground habitats; coastal wetlands and dune fields will be impacted by rising seas and increased coastal development; and marine areas will be affected by warmer currents and ocean acidity. |
| *Comment* | Some of this climate-related biotic data should be collected in any case in order to better understand fundamental responses of biota to climate. |
| *Measures* | **1.7.2.1-LFM** Biological responses to extreme climate events<br>**1.7.2.2-LFM** Phenological response to climatic regime alteration<br>**1.7.2.3-LFM** Range shifts<br>**1.7.2.4-LFM** Ecosystems and taxa vulnerable to the adverse effects of climate change |

| Measure 1.7.2.1-LFM | *Biological responses to extreme climate events* |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.7** Adapting to climate change |
| **Indicator** | **1.7.2** Biological responses to climate change |
| **Status** | Final |
| **Description** | |
| *Overview* | With regard to biotic change, it is highly likely that extreme climate |

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| | events operating over days or years will be as influential as more gradual decadal climate trends. There are a number of likely candidates. First, drought, which can have prolonged effects on susceptible organisms but will most likely affect aquatic organisms through altering hydrological regimes and water temperature and vegetation; in particular, in areas which normally lack a defined dry season. Second, unusually warm winters, which will permit enhanced survivorship of organisms normally repressed, including some invasive insect pests such as wasps and subtropical lianas and trees. Third, seasonal fluctuations in snow-lie, and frost regime outside of the normal range. And finally, large extratropical storms and unusual storm surges along the coast, which bring the possibility of major disruption to already fragmented ecosystems. |
| *Data elements* | Time series and spatial depiction of extreme events, and their biological impact, designed to reflect the potential for biologically meaningful impacts:<br>• Drought<br>• Low water episodes in streams and rivers<br>• High temperature episodes in streams and rivers<br>• Frost frequency and intensity<br>• Geomorphic impact of intense storm events<br>New monitoring networks will be needed for climate change in alpine and remote forested regions with sparse coverage, and local studies to permit downscaling of national trends to biologically meaningful scales.<br>The LUCAS plot grid provides a basic network against which to explore climate impacts. When significant events are registered, the option of setting up post-event monitoring should be considered. |
| *Scale* | National |
| *Measurement and reporting frequency* | Continuous measurement. Reporting frequency determined by the frequency of events and the nature of the post-event consequences. |
| *Data sources* | The National Climate Database is maintained by NIWA. Geomorphic change databases are maintained by LINZ and regional authorities. |
| *Information management* | NIWA, LINZ, DOC |
| **Analysis** | |
| *Policy/management relevance* | Until now, climate change per se (as distinct from climate variability) has had little to no effect on the New Zealand biota (McGlone & Walker 2011). We therefore rely for the most part on speculation and model projections to make climate change policy and management decisions. It is therefore not surprising that no actions are contemplated at the moment. When the time comes, it is important that long time-series of contextual information are available to help |

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| | inform those actions. |
| *Conceptual basis and robustness* | It is difficult to separate out climate change effects in a biological environment that is out of equilibrium and changing rapidly. Statistical techniques are available and new ones are being developed in particular with regard to understanding biotic change in relationship to climate norms. More mechanistic models are under development to permit robust projections, but our ability in this area remains weak. |
| *Compatibility with other agencies* | Highly compatible with international developments. |
| *Links to other OMF indicators and measures* | Relies on Indicator 1.7.1: *Basic climate series*. |
| *Implementation and cost* | National-scale climate data are being collected already and are free to users. These need to be augmented with more detailed local-scale monitoring. Implementation is becoming more affordable with miniaturisation of sensors. |

| **Measure 1.7.2.2-LFM** | ***Phenological response to climatic regime change*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.7** Adapting to climate change |
| **Indicator** | **1.7.2** Biological responses to climate change |
| **Status** | Final |
| **Description** | |
| *Overview* | One of the major concerns regarding climate change is the biotic disruption caused by changes in phenology, growth or demographic patterns. New Zealand is perhaps less vulnerable to these changes because of its oceanic climate regime, which has a dampened range of climate extremes. Changes in what is an already variable phenology setting may not have the impact that they do in continental areas with clear winter–summer boundaries. But these are speculations only. Little is known about these issues in New Zealand, there are relatively few long-term data sets (Chambers et al. 2013) and unless systematic monitoring is begun, the impact of phenological change will remain obscure. |
| *Data elements* | • Generalised leaf phenology of vegetation from satellite imagery<br>• Egg laying in selected indigenous birds and reptiles<br>• Migratory bird arrivals and departures |

| | |
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| | • Emergence times in selected invertebrates<br>• Leafing and fruiting phenology in selected species |
| *Scale* | National |
| *Measurement and reporting frequency* | On-the-ground phenological measurements are time-intensive if they are to be of any use. Closely spaced visits are needed over critical periods to obtain worthwhile data. For this reason, strategically based phenological sites where numerous species will be measured are necessary.<br>Not a reporting measure. |
| *Data sources* | • There are no systematic phenological measurements being made aside from short-duration efforts associated with particular studies.<br>• The New Zealand Plant Conservation Network has initiated an on-line phenology database, but its standards are insufficiently rigorous to provide evidential data. |
| *Information management* | Not clear |
| **Analysis** | |
| *Policy/management relevance* | Phenology is likely to be of high interest as it is one aspect of the environment that the public are aware of (e.g. tī flowering times) and intuitively see as important or indicative. From a management point of view, they will have considerable influence on estimates as to the degree and rate to which natural environments are changing and they will provide the detailed basis for predictive models. |
| *Conceptual basis and robustness* | Phenological measurements have been standard ecological metrics for many years and there are detailed protocols and statistical techniques available. |
| *Compatibility with other agencies* | Very widely used internationally. New Zealand research institutes have some long-term phenological series. |
| *Links to other OMF indicators and measures* | Relies on Indicator 1.7.1: *Basic climate series*. |
| *Implementation and cost* | Phenological measures have to date been time-intensive and therefore costly to collect. New technology raises the possibility of much cheaper and more intensive collection of data. |

| **Measure 1.7.2.3-LFM** | ***Range shifts*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome** | **1.7** Adapting to climate change |

| | |
|---|---|
| **Objective** | |
| **Indicator** | **1.7.2** Biological responses to climate change |
| **Status** | Final |
| **Description** | |
| *Overview* | Range shifts are regarded as one of the strongest biological metrics for climate impacts on biota. They have important implications in that they produce new biotic combinations and may underpin long-standing biotic linkages. |
| *Data elements* | Range shifts are likely to affect first and most strongly the more vagile and temperature-sensitive elements, such as flighted insects. Plant ranges seem less likely to shift and unassisted range extensions are unrecorded to date. Tree line boundaries have remained more or less stable for at least 100 years, but demographic studies and monitoring have shown some minor alterations (Harsch et al. 2012). However, many indigenous plant species have been translocated and are apparently extending their ranges: examples are *Metrosideros excelsa* in coastal South Island and *Corynocarpus laevigatus* in southern North Island. The key issue in this measure is obtaining reliable current distributions to act as a basis for analysis.<br>• Change in selected vagile insect distributions<br>• Translocated plant spread<br>• Tree line movement |
| *Scale* | National |
| *Measurement and reporting frequency* | Most analyses appear to be post-hoc examinations of data sets collected for other purposes. Setting up a recording network solely to capture biotic range shifts is likely to be prohibitively expensive. The most cost-efficient way of proceeding will be to establish multipurpose sites where regular (5-year?) assessments of a range of biotic attributes are carried out. |
| *Data sources* | Range data are collected by a range of agencies in the course of other studies. There are no systematic distribution mapping exercises aside from the New Zealand Ornithological Society censuses. |
| *Information management* | Dispersed |
| **Analysis** | |
| *Policy/management relevance* | Range shifts are widely reported and the implications are studied by conservation agencies in a number of countries (e.g. USA and Australia). |
| *Conceptual basis and robustness* | Because of the perceived importance of range shifts, a great deal of recent effort has been put into understanding how to collect and map these data. |

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| *Compatibility with other agencies* | Widely used internationally |
| *Links to other OMF indicators and measures* | Relies on Indicator 1.7.1: *Basic climate series*, but contributes to Outcome Objective 1.4: *Preventing declines and extinctions* and Outcome Objective 1.3: *Reducing spread and dominance of exotic species*. |
| *Implementation and cost* | Not clear, as the potential scope of this measure is unknown. |

| **Measure 1.7.2.4-LFM** | ***Ecosystems and taxa vulnerable to the adverse effects of climate change*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.7** Adapting to climate change |
| **Indicator** | **1.7.2** Biological responses to climate change |
| **Status** | Final |
| **Description** | |
| *Overview* | Some ecosystems and taxa will be put at particular risk through climate change per se. Examples are some isolated alpine areas through over-growth by shrubs or trees; drying or warming of freshwater streams and springs; and coastal sand-dunes and estuarine ecosystems through sea level rise against developed or hardened coastlines. |
| *Data elements* | • Mapped at-risk elements<br>• Change over time |
| *Scale* | National |
| *Measurement and reporting frequency* | The first important issue is to determine these at-risk regions and to accurately delimit them. Re-measurement need not be frequent and possibly could be coordinated via ensuring that climate-at-risk areas be included in more general surveys. |
| *Data sources* | Not determined |
| *Information management* | Not determined |
| **Analysis** | |
| *Policy/management relevance* | Of minor policy or management importance at present, but could become critical in the near future. |
| *Conceptual basis* | Will rely on accurate climate change projections to select at-risk |

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| *and robustness* | regions and taxa. A start can be made immediately with coastal and estuarine regions as the trajectory of sea level rise is clear. Drying of freshwater systems and rising tree lines will be more difficult to assess. |
| *Compatibility with other agencies* | The Global Observation Research Initiative in Alpine Environments (GLORIA) established an international long-term monitoring programme and site-based network dealing with high-mountain vegetation and its biological diversity. Its purpose is the in-situ observation and comparative assessment of alpine biodiversity patterns under the impact of accelerating anthropogenic climate change. There are several New Zealand sites registered with the scheme. |
| *Links to other OMF indicators and measures* | Relies on Indicator 1.7.1: *Basic climate series*. |
| *Implementation and cost* | The essential first step in setting up an observation system will entail considerable investigation and resource outlay. However, as this is a long-term threat, annual remeasurement costs could be spread over many years by a phased programme. |

| **Outcome Objective 1.8** | ***Human use and interaction with natural heritage*** |
|---|---|
| Most of the indicators and measures in this Outcome Objective can be broadly assigned to ecosystem services but include only those focused on close interaction with natural ecosystems, involving personal outcomes and as experienced by people alone or in small groups. Aesthetic, ethical, cultural, spiritual, and religious aspects and learning experiences fall under this heading. While some economic activities are covered, they are typically small scale (aside from beekeeping) and often pursued in order to enjoy a close interaction with natural ecosystems and landscapes. Similar indicators and measures are included in the Millennium Ecosystem Assessments (Layke et al. 2012).<br>With regard to Māori use of forest land, a Māori-led investigation (Lyver et al. 2017) identified five culturally relevant themes or pae tukutuku (procurement of food; natural productivity; nature of water; nature of the forest; spiritual dimension) and 25 ‘indicators’ or ngā pae tata (equivalent to measures in the DOC OMF). The system proposed by Lyver et al. (2017) does not fit easily within the DOC OMF as it is based largely on qualitative or subjective metrics and has adopted a different topology, but it is easy to envisage it as part of an informative Māori and local community holistic approach to ecosystem health and integrity that could support indicators and measures in IO1 and Outcome Objective 1.8 in particular.<br>The other Outcome Objectives in IO1 deal with human interactions from the standpoint of EI and as regards ecosystem services derived from PCL&W such as those concerned with the maintenance of biodiversity and economic activities (as for instance in the provision of clean water and sequestration of carbon). IO3: *New Zealanders and our visitors are enriched by outdoor experiences* addresses recreation on PCL&W; DOC’s recreational infrastructure; recreational use volume and patterns; marketing; and both physical and economic benefits of such activities to New Zealanders. | |

| Indicators: | |
|---|---|
| **1.8.1** | Hunting and harvesting of indigenous resources |
| **1.8.2** | Hunting and harvesting of non-native species and resources |
| **1.8.3** | Human health and well-being and natural ecosystems |
| **1.8.4** | Exploration, appreciation and investigation of natural ecosystems |

| Indicator 1.8.1 | ***Hunting and harvesting of indigenous resources*** |
|---|---|
| *Description* | Documentation of the take by hunting or harvesting of indigenous species. |
| *Justification* | As these species are indigenous, even if their exploitation is legal a close watch must be kept to ensure that populations or ecosystems are not threatened. |
| *Comment* | In most countries extractive use of indigenous biodiversity is taken for granted and includes, among other biodiversity elements, timber production, fish, and game birds and mammals. Often local economic activity depends on, and conservation goals are inextricably linked to, sustainable uses. In New Zealand, the harvesting, milling and exporting of indigenous timber has been largely stopped aside from that taken under the Forests Act, which provides that native timber can only be taken from forests in a way that maintains forest cover and ecological balance. None of this logging takes place on public conservation land, although a temporary provision was made after Cyclone Ita under the West Coast Wind-blown Timber (Conservation Lands) Act 2014 for timber extraction from public conservation land. Sphagnum moss harvesting from mainly West Coast public conservation land forests occurs under licence, certain indigenous game birds (grey duck, shoveler, paradise shelduck and pūkeko) can be harvested with a game bird licence, as well as indigenous whitebait and freshwater fish. Controversy surrounds the potential harvesting of kererū—regarded as a taonga species by Māori. Few marine fish are protected, but no take is allowed in marine reserves that are managed by DOC. Clearly these activities need some overview. Tītī or muttonbird are taken from a few islands managed by Māori for this purpose and governed by an Act of Parliament. In other areas of natural but modified ecosystems, harvesting of exotic organisms may be a significant contributor to ecosystem health. |
| *Measures* | **1.8.1.1-LFM** Legal hunting and harvesting of indigenous species from PCL&W<br>**1.8.1.2-LFM** Illegal hunting and harvesting of indigenous species from PCL&W |

<table>
<tr><th>Measure 1.8.1.1-LFM</th><th>Legal hunting and harvesting of indigenous species from PCL&W</th></tr>
<tr><td>Intermediate Outcome</td><td>1 The diversity of our natural heritage is maintained and restored</td></tr>
<tr><td>Outcome Objective</td><td>1.8 Human use and interaction with natural heritage</td></tr>
<tr><td>Indicator</td><td>1.8.1 Hunting and harvesting of indigenous resources</td></tr>
<tr><td>Status</td><td>Final</td></tr>
<tr><td colspan="2">Description</td></tr>
<tr><td>Overview</td><td>Indigenous species are regularly harvested on PCL&W, or from waterways that influence the status of fish populations on PCL&W. This right is included within the Conservation Act 1987 ‘to the extent that the use of any natural or historic resource for recreation or tourism is not inconsistent with its conservation, to foster the use of natural and historic resources for recreation, and to allow their use for tourism’ (section 6(e)).<br><br>Authority for this is either provided by Fish & Game New Zealand licences or concessions. Removal of some species (e.g. whitebait and sphagnum) either may affect the viability of the resource or degrade the environment. Fish & Game New Zealand sets game bird seasons and limits to ensure the birds are not over-harvested. DOC does not have comprehensive data on catch rates of whitebait. Whitebait populations have declined from levels that were much higher historically, but the lack of catch and population data means that current trends are unknown.</td></tr>
<tr><td>Data elements</td><td>Report:<br>• Whitebait take by river catchment<br>• Sphagnum concessions and removal rates<br>• Game bird returns for indigenous species<br>From time to time, assessment of long-term trends in native fish and exploited native game birds.</td></tr>
<tr><td>Scale</td><td>National</td></tr>
<tr><td>Measurement and reporting frequency</td><td>Annual assessment for harvesting rates. Multiannual for long-term trends in populations.</td></tr>
<tr><td>Data sources</td><td>Fish & Game New Zealand monitors game bird numbers. This work includes aerial counts of swans and geese, banding of paradise ducks and the management of elaborate hunter diary systems to monitor the harvest of mallard, grey and shoveler ducks.<br><br>DOC for sphagnum and whitebait. There is no regular monitoring of whitebait catches.</td></tr>
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| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | There is no strong evidence that annual take per se of any of these species is affecting the long-term viability of either the species or its environment. However, game birds attract an enthusiastic sporting following, and whitebait and sphagnum harvesting are of strong commercial interest in the rural areas where they are mainly based. An evidence base to any potential restrictions or relaxations on regulations is therefore needed. |
| *Conceptual basis and robustness* | Well tested methodologies are available for all components. |
| *Compatibility with other agencies* | Good |
| *Links to other OMF indicators and measures* | • M1.1.2.5-FM: *Exploited species production* (whitebait component)<br>• M1.5.1.3-LFM: *Abundance and demography of common and widespread taxa*<br>• Indicator 3.4.1: *Contribution of recreation on PCL&W to local, regional and national economic prosperity*<br>• Indicator 3.5.1: *Significant conservation values are protected from hard resulting from recreation* |
| *Implementation and cost* | Fish & Game New Zealand provides the game bird information. Concessions are given out for sphagnum harvesting. Whitebait monitoring of habitat is being carried out and spawning grounds identified (Goodman 2013).<br>Additional cost will come from commission of research and multiannual reports. |

| **Measure 1.8.1.2-LFM** | ***Illegal hunting and harvesting of indigenous species from PCL&W*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.1** Hunting and harvesting of indigenous resources |
| **Status** | Final |
| **Description** | |
| *Overview* | From time to time indigenous species are either harvested without permission or species which are strictly prohibited are taken. The risk |

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| | is particularly great with MPAs because fishing regulations are resented, and no-take areas in particular. In the case of some fisheries such as snapper and pāua, the financial incentive is strong to flout the law, as it is with some high-value indigenous timbers. Violations of whitebait regulations in recent years have made up a third of DOC prosecutions. Taking of rare and endangered reptiles or plants for overseas markets is another occasional but damaging occurrence. |
| *Data elements* | • Annual reported incidents, prosecutions<br>• At longer intervals, status reports on trends and impacts of illegal activities |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual report |
| *Data sources* | DOC; MPI |
| *Information management* | DOC; MPI |
| **Analysis** | |
| *Policy/management relevance* | DOC needs to be actively enforce its regulations and needs to understand the amount of effort required to reduce offending to a low level. |
| *Conceptual basis and robustness* | Good |
| *Compatibility with other agencies* | Good |
| *Links to other OMF indicators and measures* | Measure 1.4.1.1-LFM: *Status of indigenous taxa* |
| *Implementation and cost* | These data are already collected. From time to time though, some in-depth assessment will be needed. |

| **Indicator 1.8.2** | ***Hunting and harvesting of non-native species and resources*** |
|---|---|
| *Description* | A number of introduced species are widespread in PCL&W, including game animals (various deer, pigs, goats, thar, chamois, wallaby, hares, rabbits, mallard ducks, swans, quail, salmonids, etc.), possums (introduced for the fur industry), a substantial number of birds (mainly passerines), and a range of bees (bumble species and the honey bee). The marine realm is largely free of introduced fish (aside from salmon and despite an attempt in the 19th century to introduce northern cod). A major and legitimate use of PCL&W is harvesting of introduced animals (and a few plants). This indicator documents the |

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| | extent and impact of this activity, both legal and illegal. |
| *Justification* | Despite the partial acceptance of non-native species favoured for hunting and harvesting in PCL&W, from a conservation point of view they pose a continuing although poorly understood threat to indigenous biodiversity, and their abundance and exploitation should be monitored for that reason. In marginal areas, some introduced fruiting plants or trees valued for timber (e.g. Douglas fir) occur. |
| *Comment* | None of these species are neutral with regard to EI, and some (e.g. trout, possums, goats and pigs) are unequivocally damaging to it. However, attitudes both by public and conservationists alike are ambivalent towards these exotic animals. Mostly they are not treated with the same degree of concern that rats, stoats, ferrets and cats are, and some are a much-valued game hunting resource (deer, thar, chamois, mallards, salmonids). In particular, nearly all introduced birds are not regarded as being of conservation concern. Pigs and, more controversially, wild horses are for some Māori a taonga—having been present from early in the European contact period.<br>Fish & Game New Zealand is responsible for issuing fishing and game bird licences which give the right to take fish and birds within given districts and hunting/fishing seasons should they apply, and bag limits. These apply to PCL&W aside from fishing in Lake Taupō, which requires a special DOC licence.<br>Hunting of big game and small game on PCL&W is controlled by DOC permitting of non-commercial and commercial hunting and guiding and aerial hunting. Bag limits do not apply for big game or small game, but at time of high use (either recreational tramping/biking, or hunting during the roar in the case of deer) there may be restrictions. |
| *Measures* | **1.8.2.1-LFM** Legal hunting and harvesting of non-native species and resources from PCL&W<br>**1.8.2.2-LFM** Illegal hunting and harvesting of non-native species and resources from PCL&W<br>**1.8.2.3-LFM** Illegal movement of non-native species into PCL&W |

| **Measure 1.8.2.1-LFM** | ***Legal hunting and harvesting of non-native species and resources from PCL&W*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.2** Hunting and harvesting of non-native species and resources |
| **Status** | Final |

| Description | |
|---|---|
| *Overview* | DOC is required under the Conservation Act 1987 to protect recreational freshwater fisheries and freshwater fish habitats and thus exotic salmonids introduced for that purpose. There is no explicit requirement as regards introduced mammals and birds, but DOC is required to foster recreational use of natural resources—natural here including exotic and native. Under the Game Animal Council Act 2013, the Minister of Conservation may designate herds of chamois, tahr, deer or pigs on public conservation land as of 'special interest'; that is, they can be managed for recreational hunting, provided conservation interests are provided for. Harvesting of other resources—such as possums for fur and bees for honey—is managed by concessions. All in all, this means that exploitation of non-native species as a legitimate interest to be maintained on public conservation land is a reality for exotic bees, most fish, game birds and some big game. Extirpation still applies to some fish (e.g. carp), wasps, possums, and predatory mammals such as cats and stoats, and some big game such as feral goats and wallabies. |
| *Data elements* | • Estimates of numbers of recreational hunters/fishers<br>• Estimates of catch/bags by DOC-managed region<br>• Vegetation condition and change in special interest game areas<br>• Abundance of native freshwater fish in relation to introduced salmonid numbers<br>• Impact of exotic bees on native insect pollinators |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual report |
| *Data sources* | DOC; Fish & Game New Zealand; New Zealand Game Animal Council |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | It is now clear from the provisions in the various Acts that DOC has a responsibility for maintaining recreational hunting and granting concessions for commercial activities such as possum hunting, beekeeping and hunting tour guiding. DOC therefore needs some basic information to assess how popular or remunerative these activities are and the potential impact, good or ill, on natural ecosystems, and a basis for decision-making on herds of special interest, beekeeping concessions etc. |
| *Conceptual basis and robustness* | This is a highly complex area as it involves social dynamics, estimates of resources and impact. Some of it has well understood |

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| | methodologies (e.g. estimate of fish or game stocks) and other parts less so (impact of exotic bees). |
| *Compatibility with other agencies* | Variable. Big-game hunting is closely tracked in some jurisdictions where there are bag limits. |
| *Links to other OMF indicators and measures* | • Indicator 1.8.1: *Hunting and harvesting of indigenous resources*<br>• M1.1.2.5-FM: *Exploited species production* (this will provide basic data on fish numbers)<br>• M1.3.2.1-LFM: *Abundance and distribution of invasive pests and weeds*<br>• M1.1.2.6-L: *Flower and fruit production* (basic data for honey bee management) |
| *Implementation and cost* | This complex area will be largely serviced by data series collected for other purposes as regards overall impact of exotic species but special interest herd areas will have to have their own standard vegetation monitoring. For other components, rather than continuous monitoring (e.g. of recreational hunting effort and catch), special studies done from time to time will probably be the best way forward. |

| **Measure 1.8.2.2-LFM** | ***Illegal hunting and harvesting of non-native species and resources from PCL&W*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.2** Hunting and harvesting of non-native species and resources |
| **Status** | Final |
| **Description** | |
| *Overview* | As granter of concessions and licences for commercial and recreational fishing and hunting and beekeeping, DOC must also enforce conditions. Without this, risk to other recreational users may increase (in certain heavily used areas that are also used for hunting) and ill will or even violence break-out between legitimate and illegitimate fishers and hunters. As there is no conservation value at stake, this is largely a reputational issue. |
| *Data elements* | • Reported violations<br>• Successful prosecutions |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual report |

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| *Data sources* | DOC; Fish & Game New Zealand; MPI |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | A high profile is needed on this issue or the understanding will develop that the regulations are in name only. It is particularly important where important commercial interests are involved, as is increasingly the case with the beekeeping industry. |
| *Conceptual basis and robustness* | Standard |
| *Compatibility with other agencies* | Unknown |
| *Links to other OMF indicators and measures* | Indicator 1.8.1: *Hunting and harvesting of indigenous resources* |
| *Implementation and cost* | Should be routinely collected and reported as part of everyday operations and management. |

| **Measure 1.8.2.3-LFM** | ***Illegal movement of non-native species into PCL&W*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.2** Hunting and harvesting of non-native species and resources |
| **Status** | Final |
| **Description** | |
| *Overview* | Movement of deer species, pigs, possums and trout into areas otherwise free of these animals has occurred repeatedly in the past, and anti-1080 toxin campaigners from time to time threaten to release mammalian predators into PCL&W. Likelihood of apprehension of offenders is low. |
| *Data elements* | Instances of illegal movement of non-native species into PCL&W. |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual report |
| *Data sources* | DOC; Fish & Game New Zealand; MPI; regional councils |

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| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | Aside from publicity and public education, there is little that can be done to prevent such movements. Nevertheless, the problem must be understood so that remedial action can be allowed for. The threat of re-introduction of mammalian predators into predator-free areas may undermine the Predator Free 2050 initiatives in some areas where there is strong anti-toxin feeling. |
| *Conceptual basis and robustness* | Standard |
| *Compatibility with other agencies* | Unknown |
| *Links to other OMF indicators and measures* | • M1.1.2.5-FM: *Exploited species production*<br>• M1.3.1.1-LFM: *Occurrence of self-maintaining populations of exotic species*<br>• M1.3.2.1-LFM: *Abundance and distribution of invasive pests and weeds* |
| *Implementation and cost* | Should be routinely collected and reported. |

| **Indicator 1.8.3** | ***Human health and well-being and natural ecosystems*** |
|---|---|
| *Description* | IO3: *New Zealanders and our visitors are enriched by outdoor experiences* addresses the issue of recreation on PCL&W; DOC's recreational infrastructure; recreational use volume and patterns; marketing; and both physical and economic benefits of recreation to New Zealanders. This indicator focuses less on these issues of volume, trend, infrastructure and economics, and more on exactly what it is that is valued in the natural environment by recreational users of PCL&W, and how that value is expressed. |
| *Justification* | One of the main reasons for PCL&W is the enjoyment that citizens and visitors receive from it. How well DOC's management of PCL&W delivers these benefits requires a deeper understanding of who is benefiting, why, and how their experiences can be enhanced. |
| *Comment* | An overview of the research in this area (Blaschke 2013) stressed how little is known about these benefits. Most substantive research on natural ecosystems and human well-being concerns green spaces in an urban setting where the results do suggest positive outcomes. Interestingly, in some countries over half of the recreational use of green space involves exercising dogs. However, the advantages of exposure to natural, unmanaged ecosystems (i.e. the wilderness), |

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| | which has been long assumed to be beneficial, has not been as intensively studied, although those studies that have been done record positive changes in mood and short-term health indicators such as blood pressure. Little evidence is available from New Zealand. A review of recreational hunting (Woods & Kerr 2010) showed that both in New Zealand and elsewhere, experiencing nature and social interaction with family and friends were two of the top motivations and equally important as the actual hunting outcomes. This underlines the fact that PCL&W are not just an arena for active recreation such as tramping, mountain-biking, climbing and hunting, but the natural ecosystem itself is the major attractant. |
| *Measures* | **1.8.3.1-LFM** Attitudes towards interaction with natural ecosystems<br>**1.8.3.2-LFM** Current use of PCL&W natural ecosystems for human health and well-being |

| **Measure 1.8.3.1-LFM** | ***Attitudes towards interaction with natural ecosystems*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.3** Human health and well-being and natural ecosystems |
| **Status** | Final |
| **Description** | |
| *Overview* | Blaschke (2013) recommended that New Zealanders should be surveyed as to their feelings about indigenous flora and fauna and natural areas, in relation to identity and its impact on their positive emotions and well-being. This should not be monitoring per se, but an attempt via surveys to single out what is most valued and by whom, and to better characterise the issues surrounding the settings in which these benefits are best realised. It should provide an essential source of information as regards promotion, the provision of access, and the infrastructure and regulations needed to maximise benefit. |
| *Data elements* | Single-issue survey of New Zealanders |
| *Scale* | National |
| *Measurement and reporting frequency* | No mandated frequency and no reporting requirements. Part of an ongoing investigation involving exploration of aspects of nature and well-being. |
| *Data sources* | DOC |
| *Information* | DOC |

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| *management* | |
| **Analysis** | |
| *Policy/management relevance* | This is background information to provide managers and policy analysts with firm grounds for planning interventions to increase New Zealanders' engagement with the natural world. |
| *Conceptual basis and robustness* | Well established survey techniques are available. |
| *Compatibility with other agencies* | Surveys from similar countries are available. Japan and Korea, for instance, have developed the concept of 'forest bathing'—that is, close contact with a forest environment—and have carried out research focused on this. |
| *Links to other OMF indicators and measures* | A strong overlap with Indicator 3.4.2: *Contribution of recreation on PCL&W to individual and societal well-being*. It is probably best that the physical aspects of recreation be dealt with under Indicator 3.4.2 and the engagement and emotional benefits under this measure, although clearly they intersect. |
| *Implementation and cost* | Normal requirements and costs associated with surveys. |

| **Measure 1.8.3.2-LFM** | ***Current use of PCL&W natural ecosystems for human health and well-being*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.3** Human health and well-being and natural ecosystems |
| **Status** | Final |
| **Description** | |
| *Overview* | Some New Zealanders seek out natural ecosystems on PCL&W not purely for physical recreation but to experience the ecosystem itself and to take advantage of the positive emotions such interaction may yield. We know little about these activities and in particular what sort of ecosystems are sought, how frequently they are engaged with and how many people undertake this type of activity. Volunteer activity is universally regarded as contributing to good physical and mental health and volunteering on PCL&W should be included here. |
| *Data elements* | • Surveys of New Zealanders when engaged in such activities<br>• More general surveys asking whether or not this sort of activity is engaged in or preferred<br>• Information gathered under Indicator 4.1.1: *Awareness,* |

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| | *understanding and knowledge of, and attitudes towards, conservation* |
| *Scale* | National |
| *Measurement and reporting frequency* | No mandated frequency and no reporting requirements. Part of an ongoing investigation involving exploration of aspects of nature and well-being. |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | This is background information to provide managers and policy analysts with firm grounds for planning interventions to increase New Zealanders' engagement with the natural world. |
| *Conceptual basis and robustness* | Well established survey techniques are available. |
| *Compatibility with other agencies* | Surveys from similar countries are available. |
| *Links to other OMF indicators and measures* | A strong overlap with Indicator 3.4.2: *Contribution of recreation on PCL&W to individual and societal well-being*. It is probably best that the physical aspects of recreation be dealt with under Indicator 3.4.2 and the engagement and emotional benefits under this measure, although clearly they intersect. Amount of volunteer activity is addressed under Indicator 4.1.1: *Awareness, understanding and knowledge of, and attitudes towards conservation*. |
| *Implementation and cost* | Normal requirements and costs associated with surveys. |

| **Indicator 1.8.4** | ***Exploration, appreciation and investigation of natural ecosystems*** |
|---|---|
| *Description* | The other indicators in Outcome Objective 1.8 deal with human use, health and well-being arising from interactions with natural ecosystems on PCL&W. This indicator deals with activities focused on understanding and appreciating natural ecosystems as ecosystems. |
| *Justification* | Firstly, we have activities such as bird watching, photography and general nature appreciation undertaken by the informed general public or visitors. Secondly, we have the numerous research investigations that are not commissioned by DOC and may not be in any specific way aligned with conservation goals. Understanding the first is important in finding out what motivates users of PCL&W. Understanding the second is important to make sure that the volume of research being carried out is known, that researchers are assisted in achieving their goals, and the potential |

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| | benefits for DOC realised. |
| *Comment* | A poorly explored area |
| *Measures* | **1.8.4.1-LFM** Nature appreciation<br>**1.8.4.2-LFM** Scientific investigations |

| **Measure 1.8.4.1-LFM** | ***Nature appreciation*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.4** Exploration, appreciation and investigation of natural ecosystems |
| **Status** | Final |
| **Description** | |
| *Overview* | Some New Zealanders seek out natural ecosystems on PCL&W not purely for physical recreation but to deepen their understanding or simply to record in images what they see, or in words what they discovered. We know little about these activities and in particular what sort of ecosystems are sought, how frequently they are engaged with and how many people undertake this type of activity. The rise of interest in citizen science as a way of getting New Zealanders involved in more than the appreciation of natural landscapes and biota and the associated technology (such as easy access to handheld image-capture and uploading devices, automated identification, and websites such as NatureWatch which capture, make available and analyse the data) seems in the long-term to have the potential to contribute very valuable information while increasing awareness and understanding of the natural world. |
| *Data elements* | • Surveys of New Zealanders when engaged in such activities<br>• More general surveys asking whether or not this sort of activity is engaged in or preferred<br>• NatureWatch and similar citizen science sites |
| *Scale* | National |
| *Measurement and reporting frequency* | No mandated frequency and no reporting requirements. Part of an ongoing investigation involving exploration of aspects of nature and well-being. |
| *Data sources* | DOC; NatureWatch |
| *Information* | DOC |

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|---|---|
| *management* | |
| **Analysis** | |
| *Policy/management relevance* | This is background information to provide managers and policy analysts with firm grounds for planning interventions to increase New Zealanders' engagement with the natural world. |
| *Conceptual basis and robustness* | Well established survey techniques are available. |
| *Compatibility with other agencies* | Surveys from similar countries are available. |
| *Links to other OMF indicators and measures* | A strong overlap with Indicator 3.4.2: *Contribution of recreation on PCL&W to individual and societal well-being*. It is probably best that the physical aspects of recreation be dealt with under Indicator 3.4.2 and the engagement and emotional benefits under this measure, although clearly they intersect.<br>It is closely linked to M1.8.3.2-LFM: *Current use of PCL&W natural ecosystems for human health and well-being*, as arguably such activities have impact on well-being. |
| *Implementation and cost* | Normal requirements and costs associated with surveys. |

| **Measure 1.8.4.2-LFM** | ***Scientific investigations*** |
|---|---|
| **Intermediate Outcome** | **1** The diversity of our natural heritage is maintained and restored |
| **Outcome Objective** | **1.8** Human use and interaction with natural heritage |
| **Indicator** | **1.8.4** Exploration, appreciation and investigation of natural ecosystems |
| **Status** | Final |
| **Description** | |
| *Overview* | A great deal of scientific research is carried out by universities, Crown research institutes, enthusiastic amateurs and visiting foreign scientists into natural ecosystems and biota on PCL&W. Scientific research that requires collection or physical manipulation or erection of infra-structure is controlled by DOC. However, this large quantum of research is not necessarily well known or readily available to DOC. Moreover, when selecting sites, researchers often preferentially choose non-DOC land to avoid bureaucratic procedures and to gain more freedom for the manipulations that they find necessary. Consultation with iwi can be particularly onerous for new researchers. Foreign researchers usually completely ignore or are ignorant of DOC |

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| | stipulations and collect data regardless without permit.<br>DOC needs to know more about researcher attitudes, needs and ability to access PCL&W, how research projects are chosen and whether more of this research can be nudged in the direction of DOC priorities. |
| *Data elements* | • Surveys of researchers engaged in studies on and off PCL&W<br>• Aggregation of past and current research on PCL&W in accessible form<br>• Annual report of number and status of formal non-DOC scientific investigations on PCL&W |
| *Scale* | National |
| *Measurement and reporting frequency* | Annual update of non-DOC investigations |
| *Data sources* | DOC |
| *Information management* | DOC |
| **Analysis** | |
| *Policy/management relevance* | This is background information to provide managers and policy analysts with a comprehensive overview of past and current research on PCL&W, and information to improve the amount, quality and relevance of that research. |
| *Conceptual basis and robustness* | Standard methodology |
| *Compatibility with other agencies* | Unknown |
| *Links to other OMF indicators and measures* | This measure deals with research underpinning many of the other indicators in IO1. |
| *Implementation and cost* | Normal requirements and costs associated with surveys and data capture and storage. Requirements for updates for approved investigations could be handled via standard forms for contributing organisations. |