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Indicator M16: Change in the abundance of indigenous plants and animals susceptible to introduced herbivores and carnivores

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Landcare Research

Excerpt from:

Bellingham PJ, Overton JM, Thomson FJ, MacLeod CJ, Holdaway RJ, Wiser SK, Brown M, Gormley AM, Collins D, Latham DM, Bishop C, Rutledge D, Innes J, Warburton B 2016. Standardised terrestrial biodiversity indicators for use by regional councils. Landcare Research Contract Report LC2109.

Prepared for:

Regional Councils' Biodiversity Monitoring Working Group

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August 2016

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Cite this report as:

Bellingham PJ, Overton JM, Thomson FJ, MacLeod CJ, Holdaway RJ, Wiser SK, Brown M, Gormley AM, Collins D, Latham DM, Bishop C, Rutledge D, Innes J, Warburton B 2016. Standardised terrestrial biodiversity indicators for use by regional councils. Landcare Research Contract Report LC2109 for the Regional Councils' Biodiversity Monitoring Working Group.

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Overview

In 2010, the Technical Group of the Regional Council Biodiversity Forum worked with Landcare Research to develop the Regional Council Terrestrial Biodiversity Monitoring Framework.[1]

This framework is designed as part of 'a national, standardised, biodiversity monitoring programme, focusing on the assessment of biodiversity outcomes, to meet regional council statutory, planning and operational requirements for sustaining terrestrial indigenous biodiversity'

The terrestrial biodiversity monitoring framework adopts the same approach as the ecological integrity framework designed by Landcare Research for the Department of Conservation (DOC) and consists of three components: (i) indigenous dominance, (ii) species occupancy, and (iii) environmental representation.[2] To inform the framework, there are four broad areas: (i) state and condition, (ii) threats and pressures, (iii) effectiveness of policy and management, and (iv) community engagement.

A standardised monitoring framework ensures that data for each measure are consistent among regional councils, which allows for reliable State of Environment reporting. Furthermore, to enable national reporting across public and private land, it is also desirable that where possible, measures can be integrated with those from DOC'sBiodiversity Monitoring and Reporting System (DOC BMRS).[3] The monitoring framework covers most categories of essential biodiversity variables[4] recommended for reporting internationally, addressing species populations, species traits, community composition, and ecosystem structure adequately, but does not address genetic composition and only in part ecosystem function.

This report contains descriptions of 18 terrestrial biodiversity indicators developed within this framework by scientists who worked with regional council counterparts and representatives from individual regional councils. Each indicator is described in terms of its rationale, current efforts to evaluate the indicator, data requirements, a standardised method for implementation as a minimum requirement for each council, and a reporting template. Recommendations are made for data management for each indicator and, for some, research and development needed before the indicator can be implemented.

The terrestrial biodiversity indicators in this report are designed to enable reporting at a whole-region scale. Some of the indicators are also suitable for use at individual sites of interest within regions. Each indicator is described in terms of a minimum standard for all

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[1] Lee and Allen 2011. Recommended monitoring framework for regional councils assessing biodiversity outcomes in terrestrial ecosystems. Lincoln, Landcare Research.

[2] Lee et al. 2005. Biodiversity inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Lincoln, Landcare Research.

[3] Allen et al. 2013. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Lincoln, Landcare Research.

[4] Pereira et al. 2013. Essential biodiversity variables. Science 339, 277–278.

councils. If implemented by all councils, each measure can then be aggregated to allow national-scale reporting (e.g., for State of Environment reports, or for international obligations such as reporting on achievement of Aichi Targets for the Convention on Biodiversity). Individual councils could add additional measurements to supplement the minimum standards recommended.

Three of the 18 terrestrial biodiversity indicators – Measures 1 ‘Land under indigenous vegetation’, 11 ‘Change in temperature and precipitation’, and 18 ‘Area and type of legal biodiversity protection’ – were implemented and reported on for all regional councils in June 2014. An attempt to implement and report two others at that time – Measures 19 ‘Contribution of initiatives to (i) species translocations and (ii) habitat restoration’ and 20 ‘Community contribution to weed and animal pest control and reductions’ – was unsuccessful because the data needed for these indicators was either not readily available or not collected in a consistent way, and investment will be needed to remedy these issues before they can be reported successfully.

13 Indicator M16: Change in the abundance of indigenous plants and animals susceptible to introduced herbivores and carnivores

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13.1 Introduction

This report concerns M16 (‘Change in the abundance of indigenous plants and animals susceptible to introduced herbivores and carnivores’) that is part of the Pest Management indicator.

Indicator M16’s reporting element is the ‘Contribution (richness, tree species basal area, and density) of palatable plant species (e.g. Forsyth et al. 2002) and indigenous birds (herbivores, insectivores, ground dwelling) in representative ecosystems’. Indicator M16 is analogous to the two Department of Conservation (DOC) indicators: 5.1.3 ‘Representation of plant functional types’ and 5.1.4 ‘Representation of animal guilds’ (Lee et al. 2005), both currently in use in DOC’s Biodiversity Monitoring and Reporting System (BMRS). The measurements of plant communities employed at national and local scales by DOC employ long-established methods (Hurst & Allen 2007a, b), and use many identical methods to those used in indigenous forests and shrublands measured as part of the Ministry for the Environment’s (MfE’s) Land Use and Carbon Analysis System (LUCAS; Payton et al. 2004; Payton & Brandon 2011).

13.2 Scoping and analysis

13.2.1 Indicator definition

Palatable plants

Palatable plant species are those on which herbivores feed preferentially, and the focus for M16 is those species that are palatable to widespread, introduced pest mammalian herbivores (e.g. brushtail possums, goats, deer, pigs, hares and rabbits). Ascribing palatability to individual plant species is best achieved through studies of diet, but there is also a growing understanding that a range of whole-plant and leaf traits are linked to the palatability of plants to herbivores. Using these traits together as an aggregated index can provide a measure of the overall palatability of vegetation at regional to national scales, and it can be used as a measure of how the overall palatability of vegetation changes in response to management. We advocate an approach that utilises responses of individual native plant species known to be palatable, especially species ‘selected’ by individual herbivores based on meta-analyses (Forsyth et al. 2002; Allen et al. 2013a), coupled with an approach based on leaf traits to place local results in regional context. Use of leaf traits also allows evaluation of change at broader scales that transcend the ranges of individual species, some of which are very narrow. An aggregated index of leaf traits across species can be applied at regional to national scales.

This does not preclude reporting of individual palatable species within regions, but limits reporting to those with a sufficiently large regional sample.

Birds

This measure focuses on bird species because they are directly susceptible to introduced carnivores and indirectly to the effects of introduced herbivores. Introduced carnivores prey upon eggs, nestlings, juveniles or adults, but they can also be competitors for food resources. Introduced herbivores can affect birds indirectly, by modifying the vegetation structure and altering availability and quality of key food resources (invertebrate, fruit, nectar, seed and other foliage components) and nesting habitats. We recommend grouping bird species according to traits related to their vulnerability to introduced carnivores, and to the impoverishment of their habitat by introduced herbivores. This can be further disaggregated to the native and introduced birds within these groupings.

Representative ecosystems

Statistics should be reported within ecosystems across the whole region. Land cover classes as defined by the New Zealand Land Cover Database (LCDB; see M1) should be used to define ‘representative ecosystems’ (e.g. natural forests, shrublands, plantation conifer forests, and pastures). The ability to report within land cover classes depends on there being a sufficient number of sampling locations to produce defensible estimates for both palatable plant species and birds. We recommend reporting only within broad classes to enable aggregation to a national scale. Some land cover types, especially natural forests and shrublands, are sampled nationally across public conservation land (DOC’s BMRS), and other land cover classes in primary production, mostly on private land, have been sampled at catchment scales for vegetation and birds in Marlborough District (R.J. Holdaway, pers. comm., Orwin et al. 2016) and, since 2015, by Greater Wellington Regional Council (P. Crisp, pers. comm.). Individual councils could choose to sample some land cover classes at greater intensity (e.g. Auckland Council presently samples natural forests at a finer sampling intensity than a national 8 × 8 km grid) or report finer units of divisions within some land cover classes (e.g. various classifications of natural forests, e.g. Wiser et al. 2011; Singers & Rogers 2014).

13.2.2 Indicator Statistic

Palatable plant species

We advocate a whole-community approach (i.e. collecting information about all plants present at a sampling location – palatable and unpalatable), and that while disaggregated data should be collected at each sample point (i.e. at the species level), indicator statistics should be reported by aggregating species (i.e. across all palatable plant species).

A standard plot size (i.e. 20 × 20 m) should be used for region-wide reporting of M16 across all vegetation types, which will ensure consistency with M2 and methods used by DOC in its Tier One monitoring across all public conservation land. The following statistics should be reported.

1) Change in the proportion of species richness of palatable species to that of unpalatable species per plot, for woody species, non-woody species, and all species combined.

2) Change in the proportion of the density of palatable to unpalatable woody species. Density is the number of individuals divided by the area (400 m^2), so density can only be calculated for palatable and unpalatable woody species.

3) Change in the proportion of the basal area of palatable to unpalatable woody species. The basal area (ba) of each woody stem is calculated from its diameter at breast height (dbh):

$$\boldsymbol{ba = \left(\frac{dbh}{2}\right)^2 \times \pi}$$

   The basal areas of all palatable and unpalatable species are summed per plot and a proportion of palatable to unpalatable species' basal areas derived accordingly.

4) Change in frequency of seedlings of palatable woody species. Frequency of occurrence can be determined by the number of seedling subplots (24 systematically located 0.75-m^2 plots per 400-m^2 plot) that seedlings of palatable woody species occupy.

5) Change in frequency of palatable non-woody species. Frequency of occurrence can be determined by the number of seedling subplots (24 systematically located 0.75-m^2 plots per 400-m^2 plot) that palatable non-woody species occupy. Regional councils could report the change in mean percentage cover (using cover-class mid-points) for non-woody species.

All of these statistics, in association with plant traits (e.g. fibre content; Forsyth et al. 2005), allow calculation of whole-plant-community-level metrics of palatability to particular herbivores (see section 13.13.1).

The emphasis is on regional reporting of M16, but this measure can also be used to evaluate effectiveness of management at local scales (e.g. Bellingham & Mason 2012; Richardson et al. 2013; see Appendix 13-1).

Bird species

For subsets of bird species, grouped according to traits associated with feeding preferences or their susceptibility to predation (i.e. feeding guilds and predation risk), we recommend reporting:

1) mean species richness (number of species present) for all species, and split by native and introduced species.

2) mean occupancy (the proportion of location occupied by a given grouping of species) for all species, and split by native and introduced species

3) mean and/or total population density (the number of individuals of a given grouping of species within a hectare) for all species, and split by native and introduced species.

13.3 Reporting Frequencies

Regional councils should adopt the same 5-yearly reporting frequency as DOC.

13.4 Reporting Hierarchies

Regional councils can report on the contribution (richness, tree species basal area, and density) of palatable plant species (e.g. Forsyth et al. 2002) and indigenous birds (herbivores, insectivores, ground dwelling) at regional scales. Statistics could be reported within broad vegetation types (e.g. natural forests, shrublands, plantation conifer forests, and pastures, as defined by LCDB; see M1), depending on the number of sampling locations. The methods described will also be useful for evaluating the effectiveness of management at key sites (e.g. those that are subject to sustained pest control).

13.5 Spatial and temporal analysis

The basic framework for regional reporting of M16 entails regional councils extending the 8-km grid used for sampling carbon in natural forests and shrublands (LUCAS) and for sampling biodiversity (the same data as used for M2, M3, M7 and M16) on public conservation land (DOC's BMRS). This will give systematic spatial coverage across all regional councils, and will allow aggreggation to a national scale. The capacity to report M16 in land cover types and ecosystems other than natural forests and plantation forests depends on investment in quantifying plant traits and, for birds across the whole landscape, the development of a defensible classification for bird traits (see section 13.9.2). To determine temporal change in M16 vegetation and bird communities can be compared either at a regional scale or within LCDB classes (where there is adequate replication) using paired *t*-tests or similar. More complex generalised linear models can incorporate environmental and biotic covariates in analyses (e.g. Bellingham et al. 2014). The greater the number of 5-yearly measurements of M16, the greater will be the confidence in determining trends. In all cases, additional power will be gained by using covariates, including environmental and biotic data, to detect change in M16.

13.6 Relationships between indicators and present patterns

The primary data for M16 will be derived entirely from data collected for M2 and M3 (Table Table 13-1). Other measures could be used to interpret any spatial and temporal trends in M16. Under the 'Weeds and animal pests' indicator, measures of the distribution and abundance of animal pests (M7) will be particularly relevant in interpreting changes in the metrics of M16. Indicator M16 could also be used to assess whether areas subject to protection policies have enhanced biodiversity outcomes relative to areas without protection, potentially in conjunction with M6 ('Biodiversity Protection') and M12 ('Changes in the extent and protection of indigenous cover or habitats or naturally uncommon ecosystems'). Such analyses, could thus inform management and policy at regional and national scales.

Table 13-1 Regional council terrestrial biodiversity monitoring framework indicators related to M16

Indicator	Measures	Element	Ecological Integrity	Driving force(PressureStateImpactResponse)	Data required and potential sources
Biodiversity Condition	Vegetation structure and composition (M2)	Presence of suitable indigenous component in all structural layers	Species occupancy	State	Element: Presence of appropriate indigenous component in all structural layers Data: Requires standardised field sampling, e.g. augmenting LUCAS plots, and agreement of focal species and parameters.
Biodiversity Condition	Avian representation (M3)	Presence of suitable bird species across trophic levels	Species occupancy	State	Data: Requires standardised field sampling and classification of birds into relevant guilds.

13.7 Assessment of existing methodologies

The field data collected for M2 and M3 is the main information required for M16. Trait-based information on palatable plant species and indigenous bird species susceptible to predation is required to allow the field data from M2 and M3 to be analysed suitably to report M16.

13.7.1 Current approaches employed by regional councils

Palatable plant species

Regional councils differ considerably in the amount of vegetation monitoring they conduct. They also use a variety of methods to monitor vegetation including photopoints, general visual assessment (captured in a report), 20 × 20 m permanent plots, 5 × 5 m relevé (‘recce’) plots, wetland monitoring plots that include a 10 × 10 m temporary relevé, 2 × 2 m permanently marked relevé plots (Clarkson et al. 2004), Scott-height frequency methods along a transect (Wiser & Rose 1997), and rapid relevés (recording a subset of species present at a site). The methods used depend on the type of area being monitored (e.g. wetlands, geothermal regions, forests) and arbitrary preference for methods employed.

Indigenous bird species

Regional councils often rely on citizen science data for information on birds. Regional councils that monitor birds use a range of sampling designs and count methods typically focussing on site-specific surveys (see M3 report). Only two regions implement regional-scale monitoring initiatives (Auckland and Greater Wellington). The five-minute bird count is the primay bird count method employed.

13.8 Monitoring objectives and sampling designs

We recommend implementing M16 regionally using the 8 × 8 km sampling framework used nationallyby DOC and MfE. This systematic sampling can be supplemented by other schemes, from unstructured (e.g. NatureWatch, eBird) to semi-structured schemes involving citizen science (e.g. Garden Bird Survey) that can add value (i.e. extending spatial and temporal inference; e.g. MacLeod et al. 2015).

13.9 Spatial and temporal scope

13.9.1 Palatable plant species

The spatial and temporal scope of measuring palatable plant species in New Zealand varies widely, broadly being either focused on individual highly palatable plant species or on the whole plant community, including both palatable and unpalatable components. Measuring highly palatable plant species alone, without context, is appropriate for palatable plant species that are highly sensitive to effects of introduced herbivorous mamals (e.g. some of the mistletoes (Sweetapple et al. 2002) and *Dactylanthus taylorii* (Ecroyd 1996)). Such examples are rare: even species such as kōtukutuku (*Fuchsia excorticata*) that can be browsed severely by possums in some parts of their range (e.g. in Wellington Region; Urlich & Brady 2005) are resilient to browsing by possums in others (e.g. Banks Peninsula). Most of the highly sensitive individual plant species that can be used as indicators of the effects of herbivores are also highly habitat-specific (e.g. Ecroyd 1996; Sweetapple et al. 2002), which restricts their widespread utility. Region-wide reporting using such species is difficult, although they can make illuminating case studies.

Many palatable plant species are naturally patchy in their distribution. Many occur in greatest abundance in recently disturbed sites, such as along natural forest margins, landslides, and in gaps caused by falling trees in forests (e.g. Sweetapple & Burns 2002; Bellingham & Lee 2006; Mason et al. 2010). These sites are typically more resource-rich (e.g. in light and often in soil nutrients). Many of these communities are not only patchy but also transient in space and time, therefore tracking young successional plant communities in which these species occur will be challenging as they mature and naturally change in composition. Furthermore, concentrating efforts in these communities alone will produce a biased view of the maintenance of palatable plant species.

Even for palatable plant species that are longer-lived and widespread, and which persist in old-growth stands, following the fates of individual plant species can be problematic. For example, kāmahi (*Weinmannia racemosa*) is a widespread, long-lived tree that is common throughout most of New Zealand, except in the far north and drier regions, and it is palatable to ungulates and possums. A recent study that followed the fate of individual kāmahi trees in old-growth forests found that mortality rates of the trees in one of two sites where possum control took place were lower than in a site where no control took place (Gormley et al. 2012). However, it is challenging to distentangle herbivory as a driver of mortality from other probable drivers (Peltzer et al. 2014). The observed mortality of kāmahi in old-growth forests could result from a legacy of past disturbances (Allen et al. 2013b). For example, forests in the central North Island are adjusting from large-scale disturbances (such as vulcanism) or more recent Māori fires. These disturbances are likely to have promoted the abundance of kāmahi, and its mortality in old-growth stands is consistent with hypotheses that predict its replacement with more shade-tolerant trees, such as tawa (*Beilschmiedia tawa*) (McKelvey 1963). A landscape-level evaluation of kāmahi populations can reveal that even in regions where its mortality is attributed by some to mammal herbivory, such as in central Westland, recruitment of young individuals in recently disturbed sites more than offsets the mortality of kāmahi trees in old-growth stands (Bellingham & Lee 2006).

These examples underscore the need for understanding the plant community within which palatable plant species occur and its stage of development. For these reasons , we advocate a whole-community approach to reporting (i.e. collecting information about all plants present at a sampling location – palatabale and unpalatable) to add interpretive value to such data as comparative abundance of palatable species, or apparent under-representation in certain life stages (e.g. low levels of seedling regeneration in forests). Community-scale evaluations also permit more nuanced interpretations, for example, that higly palatable plant species may persist in some circumstances where they are rare and co-occur with unpalatable plants species (Bee et al. 2009).

Collecting information about the entire plant community is also valuable for determining trends, since the composition of plant communities is dynamic in space and time. Drivers of change include broad-scale and fine-scale drivers. At broad scales, we can expect more rapid turnover of trees in New Zealand's more northern forests compared with those in cool temperate southern latitudes (Bellingham et al. 1999), and probably across rainfall graidents from wet to dry. The abundance and distribution of many palatable species and the dynamism of their populations are also likely to be governed by soil nutrient availability resulting from variation in geology and soils at regional scales (e.g. Reif & Allen 1988; Laughlin et al. 2015), to variation in fertility that arises from resource quality at fine scales (e.g. Richardson et al. 2008). This highlights the need to use existing environmental data (or to collect primary environmental data such as soil samples at sample points) to aid interpretation of status in trends in populations of palatable plant species. For example, the rate of change in the representation of palatable species in forests on fertile soils is more rapid than on infertile soils (Forsyth et al. 2015), and in young successional communities there can be very large differences between the biomass of palatable species in grazed and ungrazed areas over a decade, as shown in a simulated experiment (St John et al. 2012). The same applies broadly to non-forested communities.

Current national-scale evaluation of status and trends in palatable plant species extends only to natural forests. Use of consistent methods nationally through two assessments of LUCAS in natural forests (2002–2006 and 2009–2014; the latter also as part of DOC's BMRS) allows determination of population trends and size structures in palatable trees (i.e. those that reach at least 2.5 cm in diameter at 1.3 m tall) (see Bellingham et al. 2014). The emphasis on natural forests also reflects that most research investment has been made in determining the palatability of native plants species (e.g. Fitzgerald 1976; Owen & Norton 1995; Forsyth et al. 2002; Sweetapple & Nugent 2004).

Although reporting status and trends in individual palatable plant species is possible at a national scale (e.g. for palatable tree species across natural forests sampled on an 8-km grid), the same sampling intensity is likely to be inadequate for reporting the same species within many individual regions, especially those with a small area of the plant's habitat. Conversely, for some individual palatable plant species, their abundance may be sufficient in a given region but be naturally restricted to it, which mitigates against their use in determining pan-regional status and trends.

An approach that enables wider interpretation and maximises use of data is to evaluate the data provided by plot-based samples in terms of leaf traits (see Appendix 13-1, Definition of palatable plant species). Amongst the plant traits that characterise palatable plant species are thin, short-lived leaves that have high total nitrogen and phosphorus concentrations and low investment in defence (e.g. in content of fibre or defence chemicals). The information that currently supports the capacity to determine status and trends of palatable plants is biased heavily towards forests. Furthermore, established relationships between plant traits and their palatability is strong in the case of ungulates (goats and deer; e.g. Forsyth et al. 2005) but there is a key **research and development need** to determine the *plant traits that are best related to the known diets of the omnivorous brushtail possum* (as well as other locally important herbivores, e.g. dama wallabies (*Macropus eugenii*) in the Bay of Plenty Region).

Generally, the capacity to report status and trends of palatable native plants species beyond forests is limited. Many of New Zealand's non-forested landscapes below treeline have complex mixtures of native and non-native plant species, and there is poor understanding about the species that dominate successions. Introduced herbivores are likely to influence change in these ecosystems but in most of them it is unknown whether they are the predominant driver of change. Studies that determine which plant species are 'selected' and 'avoided' by a particular introduced herbivore in a particular vegetation type or geographic area are painstaking and require significant investment, and there have been few conducted outside natural forests in New Zealand (but see Glimore 1965; Flux 1967; Glen et al. 2012). Hence, the primary information on which species are palatable based on dietary studies is limited and from few sites. Moreover, determining the palatability status of New Zealand's c. 2360 indigenous plant species (de Lange et al. 2009) with respect to each of 29 introduced herbivorous mammals (King 2005) is most unlikely to happen. Ecological research worldwide during the last 15 years has seen a major movement from interpretation of species-specific (and site-specific) studies towards interpretation based on the traits of species as a means of predicting changes in plant communities in response to environmental drivers, including herbivory.

This emphasises a further **research and development need** to **determine *plant traits* in ecosystems outside forests** as the most promising means of evaluating palatability. There are plant trait data from some non-woody ecosystems (e.g. Richardson et al. 2012), but a systematic approach is needed to augment this, using protocols that are well developed and in widespread use worldwide (Pérez-Harguindeguy et al. 2013). A key goal is to identify the palatability of native plants. However, if a community-scale evaluation of palatability is to be included, it would be naïve to ignore the contribution of non-native plants, and to separate trends in palatable native species from trends in co-occurring palatable non-native species. Non-native plants are, in most circumstances, either uncommon or of low biomass in natural forests, but this is not the case in shrublands and non-woody ecosystems. Moreover, most primary production landscapes are dominated by non-native plants that, especially in agriculture, have been selected for and bred to be palatable (e.g. to ungulates), yet also resilient to grazing (i.e. their rate of production of new foliage offsets the amount consumed); examples include widespread, common pasture grasses such as ryegrass (*Lolium perenne*) and cocksfoot (*Dactylis glomerata*). Pasture species feature in the diet of pest mammals (e.g. Gilmore 1965; Harvie 1973; Nugent 1990), and a recent study showed that adjacent, high-producing, pasture grasslands boost numbers of rabbits in largely native-dominated grasslands (Norbury et al. 2013). Plantation forests provide habitat for some native palatable plant species (e.g. Ogden et al. 1997), but possums also feed directly on *Pinus radiata*, the most widespread plantation forestry species (Clout 1977). All of these features underscore the need to quantify plant traits across all species, native and non-native, across the whole landscape support the implementation of this measure.

13.9.2 Indigenous bird species

The spatial and temporal scope of different bird monitoring initiatives in New Zealand differ extensively (see M3 report). Only the bird atlases currently provide national-scale information on species distributions, with more recently established citizen science initiatives (eBird and NatureWatch) aspiring to providing similar data, albeit in a more ad hoc manner. While these data hold potential to provide information on species distribution, the power of these data sources to detect changes in bird community composition at the spatial and temporal scales of interest is still to be determined.

Currently there is no definitive database or objective classification for bird traits in New Zealand, with different researchers using their own interpretations of these data for their own specific research purposes (e.g. Elliot et al. 2010; Hoare et al. 2012; MacLeod et al. 2012a). There is a key **research and development need** to develop such a resource to ensure a **harmonised system for comparing bird traits** across jurisdictions. The Department of Conservation has collated some information to inform their own indicator development (i.e. suitable for reporting across public conservation land only). A broader view will be needed to ensure that the information that underpins M16 also includes traits that are relevant across the whole New Zealand landscape. A trait database has also been developed (Wood et al. 2016) that could provide the basis for an objective classification (see also Barnagaud et al. 2014). Some candidate traits of birds that should be considered for M16 are those that are related to:

- predation risk by carnivores, including body size, flight capabilities, and preferred nesting locations (hole-, crevice- and ground-nesters; Hoare et al. 2012; Monks et al. 2013). A recent study shows that hole-nesting (cavity-nesting) is the key trait among New Zealand's endemic forest birds that relates to contracting of their ranges (Parlato et al. 2015)

- the impoverishment of their habitat by introduced herbivores, i.e. feeding guilds (frugivores, nectar-feeders, herbivores and granivores; e.g. Elliott et al. 2010).

An example of the use of some of the traits that could be used for the reporting of M16 are shown in Fig. 13-2, that is, bird species grouped according to their feeding types and their most frequent nesting sites.

13.10 Data storage and reporting

Currently regional councils store plant and bird data in a variety of ways (e.g. excel spreadsheets, GIS databases or in published reports).

13.10.1 Palatable plant species

Some regional councils use the NVS Express application (available through the National Vegetation Survey (NVS) databank website: https://nvs.landcareresearch.co.nz/Data/dataentry) to upload data collected using the standard monitoring methods (i.e. permanent 20 × 20 m plots) or vegetation inventory (i.e. relevé) methods that underpin M2, DOC’s BMRS, and LUCAS (from which the data can support M16). NVS Express is a purpose-built Windows tool for entering and summarising vegetation data compatible with the NVS databank. Data from the NVS databank allows reporting of palatable species at a range of scales (e.g. Bellingham et al. 2014). Other methods can be added to the NVS databank, but are not currently compatible with NVS Express.

13.10.2 Indigenous bird species

Improvements in the protocols and infrastructure for capturing, managing and storing five-minute bird count data collected by regional councils are currently underway. These improvements have largely been motivated by the Biodata Services Stack project, which is developing mechanisms for federating and sharing such data among regional councils (Jerry Cooper and Jamies Lambie, pers. comm.). Whereas NVS is a suitable repository for plant community data, there is no national repository for bird species data. However, DOC is developing an appropriate system, and regional councils should consider coordinating with DOC to invest in the design and implementation of a centralised repository.

13.11 Development of a sampling scheme

To obtain regional coverage and to integrate with other initiatives, the national 8-km grid employed in LUCAS (for natural forests and shrublands, including those on private land) and DOC’s BMRS (Tier One measurement schema) provides the most cost-effective means of integration of multiple indicators. This is a systematic sampling scheme with simultaneous collection of data for multiple point-based measures at intersects of a national 8-km grid; the sampling framework and methods developed can readily be extended to include non-conservation lands, as demonstrated for Greater Wellington Regional Council (MacLeod et al. 2012b). Using the same framework across all regional council lands, collecting data for M2 (vegetation) and M3 (birds) will supply data needed to report M16 at a regional scale, and allow aggregation to a national scale. Integrating with DOC’s BMRS and LUCAS and will obviate the need for regional councils to collect data on M2 and M3 from public conservation land, and for M2 from most natural forest and shrubland sites on private land, as long as DOC and MfE continue to share the data with regional councils. Data for M2 and M3 have been collected across a range of land-use classes in Marlborough District, much of it on private land, using a grid-based systematic sampling technique during 2013 (Dr R.J. Holdaway, Landcare Research, pers. comm.; see also Orwin et al. 2016).

13.11.1 Palatable plants

The capacity to report status and trends in palatable plant species, as a component of M16, will be limited in the short term to natural forests and plantation forests within and across regions because of the biases in the available database. Investment in quantifying traits and linking these to dietary studies will enable other land cover classes to be reported. If M2 is implemented nationally, some of the key data required for reporting M16 are available (i.e. plant community composition and structure). Available data for M2 could allow status and trend of the palatable plant component of M16 to be reported more broadly than natural plantation forests, if investment is made to quantify plant traits from a broader range of plant species from ecosystems outside forests. That is, the immediate implementation of M2 throughout all landscapes in all regions would still allow retrospective application of trait-based approaches to determining changes in palatable plant species, allowing broad-scale reporting of M16.

Power analyses can be conducted to determine the sampling intensities that are likely to be adequate for reporting status and trends in individual palatable plant species; see MacLeod et al. (2012b) for examples of several palatable, native, woody plant species in the Greater Wellington Region, and Allen et al. (2013a) for examples at national and regional scales. In the Greater Wellington Region, analysis of data from forests and shrublands (LUCAS data) found a mean species richness of 7.62 ± 0.70 (SE) for those species that are selected preferentially by goats, 10.65 ± 0.68 for possum-selected species, and 10.58 ± 0.62 SE for deer-selected species (MacLeod et al. 2012b). Power analyses show that a very high sampling intensity would be needed to detect small changes (<5%) in the mean species richness of woody plant species palatable to introduced herbivores in the Greater Wellington Region (c. 544 sample points needed for goat-selected species, c. 263 for possum-selected species, and c. 222 for deer-selected species; MacLeod et al. 2012b). Much lowere sampling intensities would be required to detect very large changes (≥25%) in mean richness (c. 23, c. 12, and c. 10 sample points needed for the same sets of species; MacLeod et al. 2012b); however, such large changes in mean richness of palatable woody plants are unlikely in all but exceptional circumstances. An approach based on reporting community-weighted plant traits is likely to be more sensitive to change (e.g. Mason et al. 2010), and thus will require lower sampling intensities, although these remain to be determined for individual regions.

13.11.2 Birds

Standardised methods for collection of the primary data needed for M16 are described in detail in the report for M3. These methods include determining occupancy (of all bird species) and abundances (of more common bird species). The exact equivalent of M3 has been implemented nationally by DOC (DOC’s Measure 5.1.2; Allen et al. 2013a) throughout public conservation land (i.e. including natural forests, shrublands, and non-forested landscapes). The same methods of measuring bird communities have been implemented in agricultural production landscapes at local scales (MacLeod et al. 2012b), catchment scales (Wairau Valley), and in the Greater Wellington Region since 2014. It will not be possible to report status and trends in occupancy and density of bird species for M16 until investment is made in a defensible schema to determine the traits linked to vulnerability and habitat requirements. However, if the primary data is available from national implementation of M3, then both status and trend information to report M16 is likely to be possible across all landscapes, once a schema based on traits is available.

(i) *Occupancy*: For a given level of sampling effort, detection and occupancy probabilities vary among and within bird species (MacLeod et al. 2012a), habitats and seasons (MacKenzie & Royle 2005), with probabilities of detection ranging from 0.02 to 0.8 and occupancy from 0.02 to 0.99 (MacLeod et al. 2012b). On farmland sites sampled at various sites throughout New Zealand, there were more species (n = 51) but much fewer of these had detection probabilities ≥0.2 (35%) compared with natural forests sampled nationally (66% of 32 species; MacLeod et al. 2012b). Also, for the same species in different habitats, there are differences in detection probabilities, for example, some native passerines (e.g. grey warbler, fantail, tomtit, silvereye) were twice as difficult to detect in farmland as in natural forest, but in natural forests, introduced species (e.g. blackbird, song thrush, greenfinch) were less likely to be detected (MacLeod et al. 2012b).

For Greater Wellington Region, an 8 × 8 km sampling framework yields 127 sampling locations, and power analyses showed that it should be feasible to detect across these (1) moderate to large (>25%) changes in occupancy for 29% of native bird species at the regional scale and (2) large changes (>45%) in occupancy within forests but not in non-forest habitats (where n = 40 sampling locations; MacLeod et al. 2012b).

Once trait groups for birds are agreed for M16, similar calculations can be used to determine the adequacy of the 8 × 8 km sampling framework in any given region to report change in occupany (and shifts in community composition within trait groups) at a regional scale, and, as for Greater Wellington Region, within habitats within the region.

(ii) *Abundance*: For measuring changes in the status of widespread and common species, we expect that abundance will be more informative for measuring change than occupancy (MacLeod et al. 2012c). To estimate densities of bird numbers (as a measure of abundance, using distance detection functions based on point-count data), a minimum of c. 80 detections per species is required. Across 70 sampling locations across public conservation land, density estimates could be calculated for c. 38% of the 32 species detected (MacLeod et al. 2012a), and across primary production landscapes (sheep and beef, dairy, and kiwifruit), densities could be estimated for less than half the bird species detected (using distance detection functions based on line-transect data; MacLeod et al. 2012c). However, as more information becomes available over time, the number of species for which density estimates can be calculated should increase, as multiple measurements can be combined to generate estimates of density for each sampling event.

The precision of density estimates will vary among species, habitats and season (MacLeod et al. 2012c). This will influence the monitoring system’s ability to detect spatial and temporal changes in densities. For Greater Wellington Region, an 8 × 8 km sampling framework (n = 127 sampling locations) is sufficient to detect small (c. 5%) to moderate (c. 10%) changes in density for native species in closed habitats and common introduced species in open habitats (when coefficients of variation for density estimates ≤20% and ≥40 sampling locations are surveyed per stratum). For the same sampling design, but where species’ density estimates are less precise (21%–40%), it will only be feasible to detect moderate (c. 10%) to large (c. 20%) changes in density (MacLeod et al. 2012c).

13.12 Data management

The vegetation and bird data collected for M2 and M3 will support the ability to report M16. These data sources and associated trait-based information should be in keeping with existing protocols and data management systems.

13.12.1 Palatable plant traits

Analysis of status and trends in palatable plants can be reported in terms of individual plant species where sufficient numbers are sampled, using lists of species determined from dietary studies (e.g. Forsyth et al. 2002). The available information to support these lists is strongly biased towards natural forests.

The primary data needed to support analyses of vegetation for status and trends in leaf traits are held by Landcare Research and are being added to. This includes larger numbers of species, and data are typically added with relevant ancillary data relating to climate, soil nutrients, etc., all of which can influence leaf traits; this is especially relevant for species that have widespread distributions, some of which exhibit considerable intraspecific variation in leaf traits (e.g. Wardle et al. 2009). Most species included in the plant traits database (leaf traits included) are native woody species. Implementation of the palatable plants component of M16 has been achieved at local scales using plant traits in forest patches in the Bay of Plenty region (Bellingham & Mason 2012; Richardson et al. 2013).

13.12.2 Palatable plant species data

The vegetation data for M16 (and M2, which supports M16) should be stored in the National Vegetation Survey Databank (NVS). This facility is run by Landcare Research and is specifically designed to store vegetation survey data in the format used for M2.

Some regional councils are already familiar with the NVS express system, so using NVS express builds upon current knowledge. Using NVS was recommended because it would save regional councils costs associated with creating new databases and data storage facilities and because NVS already has refined protocols for data management, including data validation (Vickers et al. 2012a). An additional advantage of using the NVS express system is that it contains an analysis module (NVS-Analysis; Vickers et al. 2012b) specifically designed for conservation practitioners. This includes the ability to create summary statistics and analyses.

Tools to analyse palatable and unpalatable species for M16, each delineated on the basis of leaf traits, could be included as part of the NVS-Analysis module. The standardised reporting statistics could be adapted to specifically include the palatability indicator statistics for M16. There is likely to be a cost associated with development of a regional council module; for more information contact Susan Wiser (NVS manager, Landcare Research, Lincoln). Additional statistics included in NVS-Analysis can be used by regional councils to gain further descriptions of their sites, including analyses of individual species. There is a **research and development need** for development and ongoing maintenance of a **national plant traits database**.

13.12.3 Indigenous bird species

Storage of the primary data on bird occupany and abundances that are needed for M16 is addressed in the report for M3. Briefly, a system is needed that is consistent across all regional councils and also consistent with those being used by DOC. We recommend that, rather than investing in in-house skills, regional councils should capitalise on the capabilities and investment in database development, management and analytical skills currently being developed by DOC and Landcare Research.

13.12.4 Bird species traits

Until an objective classification for bird traits in New Zealand is developed (see Section 13.9.2), the scope and fields of a database needed to support the bird component of M16 are unclear. The bird trait database has been developed (Wood et al. 2016)). There is a **research and development need** for the development and ongoing maintenance of the **bird trait database** to support M16.

13.13 Reporting format

Indicator statistics can be mapped or graphed to show change in the statistics over space and time. Reporting should include data at a national scale and at a regional scale.

13.13.1 Palatable plant species

Summaries of traits of palatable species

Reporting changes in palatable species is currently restricted to forests, but the principles are generally applicable. Traits can be weighted by the abundance or proxies for biomass (such as cover or, in the case of trees, basal area) of individual species. These produce community-weighted averages for individual traits. These can be compared between measurement intervals (as in Table 13-2), and as trends once there are sufficient measurements (Statistics NZ suggest a minimum of six measurements before inferring trend). In Table 13-2, significant increases over time in this forest community's leaf phosphorus concentrations, coupled with significant declines in leaf mass per unit area, declines in defence chemicals in leaves (phenols, tannins), and declines in investment in fibre and lignin indicate a general trend towards a more palatable community over time.

Table 13-2 Leaf traits, weighted by the number of stems per plot, in 12 plots in natural forests in the Ōhope Scenic Reserve, Bay of Plenty Region, in 2007 and 2011 (mean values ± standard errors) and the mean percentage change (reproduced from Mason & Bellingham 2012). All but leaf nitrogen and cellulose concentrations differ significantly (paired *t*-tests, $P < 0.05$) between measurements.

Leaf trait	2007	2011	Percentage change
Leaf phosphorus concentration	0.127 ± 0.008	0.129 ± 0.005	+1.7
Leaf nitrogen concentration	1.60 ± 0.09	1.61 ± 0.08	+0.9
Leaf mass per unit area	94.7 ± 0.89	92.5 ± 3.9	–2.1
Leaf phenolics concentration	2.60 ± 0.46	2.50 ± 0.17	–3.2
Leaf tannin concentration	1.05 ± 0.20	0.99 ± 0.10	–5.0
Leaf cellulose content	23.1 ± 0.4	23.0 ± 0.4	–0.3
Leaf fibre content	39.9 ± 0.9	39.3 ± 0.9	–1.4
Leaf lignin concentration	16.0 ± 0.7	15.5 ± 0.6	–2.8

Summaries of individual palatable species

If samples of individual palatable plant species are adequate within a region, it is possible to report attributes of their population and, in the case of tagged tree stems ≥2.5 cm diameter at 1.3 m height, their demography (e.g. whether mortality rates exceed recruitment rates). If populations of individual palatable plant species are sampled adequately, for those species a summary table, such as Table 13-3, can be produced for a council's main report. Supporting statistical analyses should be included in technical supplementary material to the summary table (online or in an appendix).

Table 13-3 Change in abundance, demography and population structure of widespread tree species that are palatable to introduced herbivores. Key to symbols: → = remained the same between measurements; ↓ = declined significantly between measurements; ↑ = increased significantly between measurements; R = recruitment; M = mortality.

Species name	Name	Total number of stems in the survey	Basal area	Stem density	Recruitment to mortality ratio (R/M)	Changing size class structures
Pseudopanax arboreus	Lowland five-finger (whauwhaupaku)	+ 31 %	→	→	→	Yes
Pseudopanax colensoi	Mountain five-finger (orihou)	+ 9%	→	→	↑ (R > M)	→
Schefflera digitata	Patē	- 5%	→	→	→	Yes
Dysoxylum spectabile	Kohekohe	-12 %	→	→	→	→
Griselinia littoralis	Broadleaf (pāpāuma)	-3 %	→	→	↓ (M > R)	→
Podocarpus laetus	Upland tōtara	+ 6%	→	→	↑ (R > M)	→

13.13.2 Indigenous bird species

Information can be mapped for subsets of species, grouped according to their traits. For example, Figure 13-1 shows for 155 sampling locations on public conservation lands in 2013, 61% (n = 64) contained at least one hole-nesting bird species (Bellingham et al. 2013); this value includes cavity- and crevice-nesting bird species, which are of interest to DOC because, like hole-nesting species, they are vulnerable to introduced predatory mammals. Consistent with expectation, hole-nesting species occurred most frequently in forest ecosystems (40% of sampling locations) and were least frequent in ecosystems that were deforested by human activities).

Similarly, trend information can be shown for different subsets of species over time (Figure **13-2**).

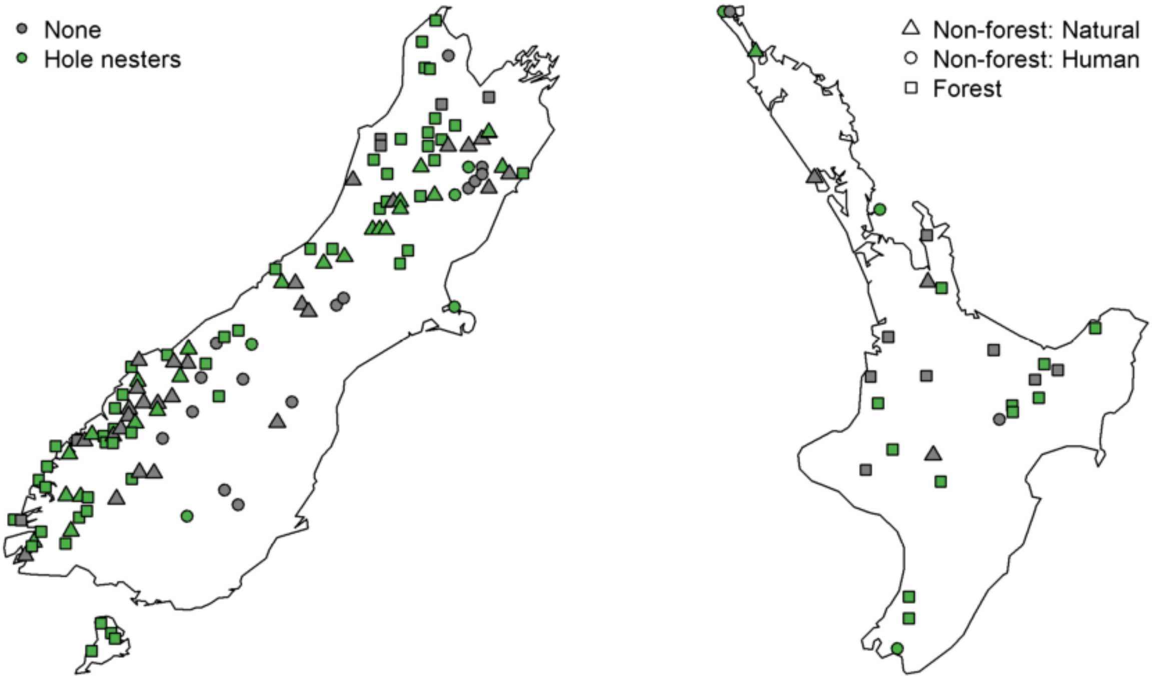

Figure 13-1. Presence and absence of hole-nesting bird species in forested ecosystems, naturally non-forested ecosystems, and ecosystems that were deforested by human activities, focusing on New Zealand's public conservation lands (Bellingham et al. 2013).

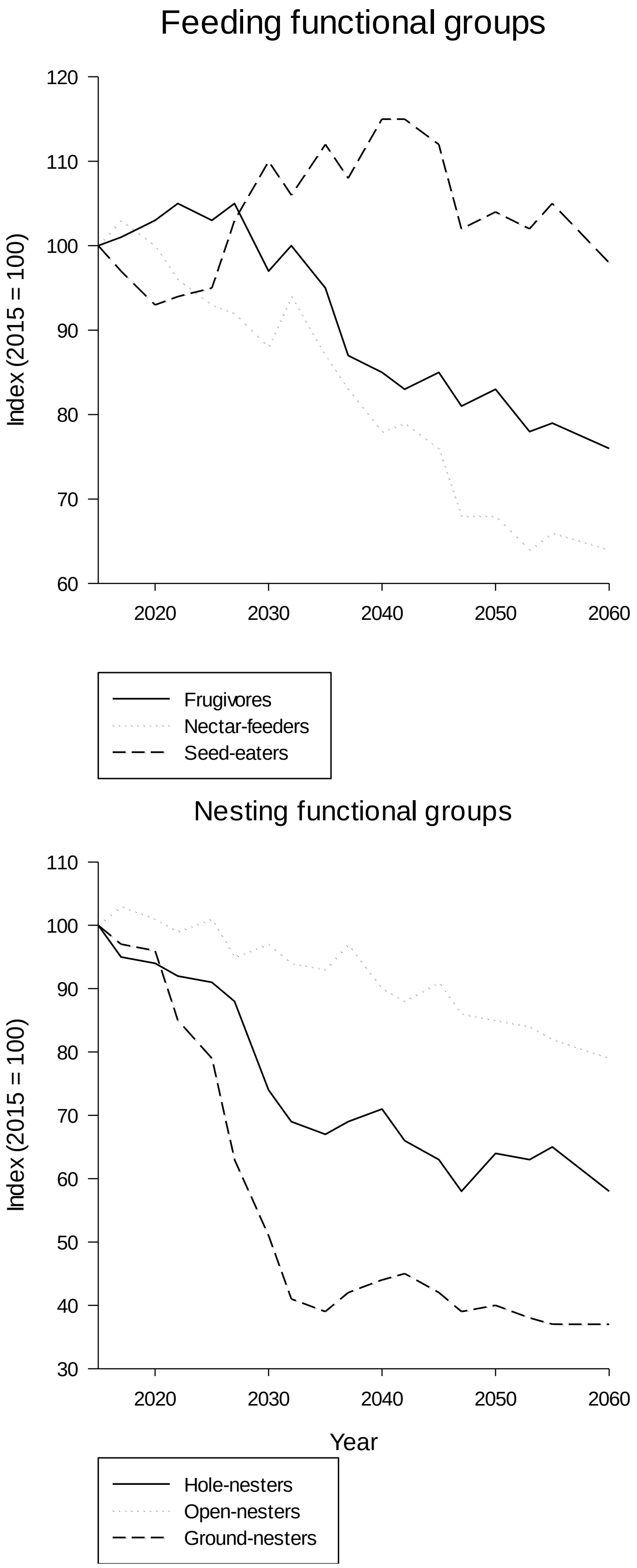

Figure 13-2 Hypothetical dataset showing trends (since 2015) in abundance of different subsets of indigenous bird species grouped according to their feeding and nesting traits and, therefore, their susceptibility to herbivory and predation, respectively.

13.14 References

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Appendix 13-1 – Definition of palatable plant species

Palatable plant species are those consumed disproportionately to their abundances by herbivores (i.e. herbivores consume them preferentially), and the focus for M16 is those species that are palatable to introduced pest mammalian herbivores, including brushtail possums, goats, deer, pigs, hares, etc. Ascribing palatability to individual plant species is best achieved through studies of diet, for example, of rumen or gut samples of mammals from which foliage is identifiable. Ascribing whether herbivores select palatable species preferentially therefore requires both information about their diets (e.g. from gut samples) and information about the relative abundance (or biomass) of species in the herbivore's habitat (e.g. Mitchell et al. 1987; Nugent & Challies 1988; Nugent 1990; Sweetapple et al. 2004; Glen et al. 2012).

The results from many of these studies have been synthesised so that a general view emerges of plant species that are 'selected' (i.e. consumed disproportionately greatly relative to their abundance) and 'avoided' (i.e. plant species that are abundant or form a great proportion of the biomass but which are seldom, if ever, consumed). Such syntheses allow greater confidence in the assignment of palatability classes and allow generalisation beyond single studies. One such synthesis pertains to the diets of introduced ungulates in New Zealand (Forsyth et al. 2002). Another (Allen et al. 2009) provided lists of species that that are 'selected' and 'avoided' by three groups of pest herbivores and omnivores: goats, deer (all deer species combined) and possums. The 'selected' and 'avoided' species lists in that study were based on a range of published papers, unpublished data and expert opinion, with a preference for field studies that measured both pest diet and the surrounding vegetation for 'selected' species and cafeteria trials for 'avoided' species. Most of the plant species listed in Allen et al. (2009) are indigenous forest species because that is where most studies have been conducted, although there are exceptions, especially in the case of possum diets (e.g. Gilmore 1965; Harvie 1973; Glen et al. 2012).

Studies in non-forested habitats have often emphasised the importance of non-native plants in the diets of possums, for example, clover (*Trifolium* spp.) in their diets in pasture (Gilmore 1965; Harvie 1973) or crack willow (*Salix fragilis*) in their diets in deforested central Otago (Glen et al. 2012). Therefore, although the focus of this measure is on indigenous plant species that are indicators of pressure of pest mammals, as more information is revealed about the ecology of pest mammals in other land uses and vegetation, a broader perspective might be taken in future as the measure is refined and developed. Regional councils may wish to invest in a project to identify palatable species in non-forest environments that are commonly found in regional councils' regions. This will be especially useful in agricultural settings, where pasture grasses that have been selected for their palatability to mammals predominate, so that interpreting change in the proportion of indigenous palatable species in this matrix is difficult.

An approach using plant traits can improve the capacity to report status and trends in palatable native plants. For example, woody native plant species in New Zealand forests that have low fibre content in their leaves are much more palatable to red deer than those with high fibre content (Forsyth et al. 2005). There is a growing understanding that a range of leaf traits are linked to the palatability of plants to herbivores. These include

1. leaf mass per unit area (LMA) where, in general, species with thin leaves (low LMA) are often palatable
2. concentrations of nitrogen (N) and phosphorus (P) in leaves, since more palatable species typically have higher nutrient concentrations
3. concentrations of defence chemicals (tannins and phenolics) in leaves, since palatable species are often poorly defended
4. fibre content of leaves, since palatable species are often low in fibre
5. lignin and cellulose content of leaves, since palatable species often have high concentrations of both (Mason et al. 2010).

Using these traits together as an aggregated index can provide a measure of the overall palatability of vegetation, which can be used as a measure of how the overall palatability of vegetation changes in response to management. For example, there was an overall change in forest composition towards a greater proportion of species with traits associated with greater palatability after intensive suppression of mammalian herbivores, especially possums, over five years at the Ōhope Scenic Reserve, Bay of Plenty (Bellingham & Mason 2012; Table 13-2). In another example from the Bay of Plenty, leaft traits were used to evaluate change in forest vegetation from the coast to the interior along the Manawahe Ecological Corridor. The vegetation was highly heterogeneous: on average any pair of plots shared only 25% of species. By using leaf traits associated with palatability, it was possible to overcome this heterogeneity: weighted mean leaf nitrogen and phosphorus concentrations increased *outside* the managed corridor relative to inside over c. 5 years, but no other weighted mean leaf trait showed a statistical difference (Richardson et al. 2013).

An example of use of leaf traits at a national scale was an evaluation of change in forest vegetation in fenced plots (to exclude browsing deer, goats, and pigs) compared with adjacent unfenced plots throughout New Zealand (Mason et al. 2010); areas were fenced between 5 and 28 years. The aggregated response of a range of leaf traits was towards a greater biomass of palatable vegetation within the fenced areas, as could be expected, but the strength of the change was not universal. The forests that showed the greatest response in the biomass of palatable vegetation were those that had been subject to recent disturbance of their canopies. Fenced areas in undisturbed, old-growth forest showed comparatively far less change towards more palatable vegetation alongside adjacent unfenced areas.

Appendix 13-2 – Aligned DOC biodiversity indicators and measures

Palatable Species

Indicator M16 focuses on the species richness of palatable plant species, tree species basal area, and density of native palatable species. The measure relates closely to DOC's Measure 5.1.3 (Lee et al. 2005), which employs three reporting statistics (Allen et al. 2009):

1. the percentage of indigenous species that are palatable
2. species-richness of palatable indigenous species
3. the percentage of plots where at least one palatable species is present (occupancy).

The Department of Conservation has also reported the size structure and density of palatable tree species (MacLeod et al. 2012).

Indigenous Birds

The DOC Measure 5.1.4 representation of animal guilds uses reporting statistics on birds, aggregated according to traits associated with nesting sites (Bellingham et al. 2013).