Manaaki Whenua
Landcare Research

Native biodiversity and Regenerative Agriculture in New Zealand

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‘Think piece’ on Regenerative Agriculture in Aotearoa New Zealand: project overview and statement of purpose

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Find the full project overview, white paper and topic reports at ourlandandwater.nz/regenag and www.landcareresearch.co.nz/publications/regenag

This report is one of a series of topic reports written as part of a ‘think piece’ project on Regenerative Agriculture (RA) in Aotearoa New Zealand (NZ). This think piece aims to provide a framework that can be used to develop a scientific evidence base and research questions specific to RA. It is the result of a large collaborative effort across the New Zealand agri-food system over the course of 6 months in 2020 that included representatives of the research community, farming industry bodies, farmers and RA practitioners, consultants, governmental organisations, and the social/environmental entrepreneurial sector.

The think piece outputs included this series of topic reports and a white paper providing a high-level summary of the context and main outcomes from each topic report. All topic reports have been peer-reviewed by at least one named topic expert and the relevant research portfolio leader within MWLR.

Foreword from the project leads

Regenerative Agriculture (RA) is emerging as a grassroot-led movement that extends far beyond the farmgate. Underpinning the movement is a vision of agriculture that regenerates the natural world while producing ‘nutrient-dense’ food and providing farmers with good livelihoods. There are a growing number of farmers, NGOs, governmental institutions, and big corporations backing RA as a solution to many of the systemic challenges faced by humanity, including climate change, food system disfunction, biodiversity loss and human health (to name a few). It has now become a movement. Momentum is building at all levels of the food supply and value chain. Now is an exciting time for scientists and practitioners to work together towards a better understanding of RA, and what benefits may or not arise from the adoption of RA in NZ.

RA’s definitions are fluid and numerous – and vary depending on places and cultures. The lack of a crystal-clear definition makes it a challenging study subject. RA is not a ‘thing’ that can be put in a clearly defined experimental box nor be dissected methodically. In a way, RA calls for a more prominent acknowledgement of the diversity and creativity that is characteristic of farming – a call for reclaiming farming not only as a skilled profession but also as an art, constantly evolving and adapting, based on a multitude of theoretical and practical expertise.

RA research can similarly enact itself as a braided river of interlinked disciplines and knowledge types, spanning all aspects of health (planet, people, and economy) – where curiosity and open-mindedness prevail. The intent for this think piece was to explore and demonstrate what this braided river could look like in the context of a short-term (6 month) research project. It is with this intent that Sam Lang and Gwen Grelet have initially approached the many collaborators that contributed to this series of topic reports – for all bring their unique knowledge, expertise, values and worldviews or perspectives on the topic of RA.

How was the work stream of this think piece organised?

The project's structure was jointly designed by a project steering committee comprised of the two project leads (Dr Gwen Grelet[1] and Sam Lang[2]); a representative of the New Zealand Ministry for Primary Industries (Sustainable Food and Fibre Futures lead Jeremy Pos); OLW's Director (Dr Ken Taylor and then Dr Jenny Webster-Brown), chief scientist (Professor Rich McDowell), and Kaihāpai Māori (Naomi Aporo); NEXT's environmental director (Jan Hania); and MWLR's General Manager Science and knowledge translation (Graham Sevicke-Jones). OLW's science theme leader for the programme 'Incentives for change' (Dr Bill Kaye-Blake) oversaw the project from start to completion.

The work stream was modular and essentially inspired by theories underpinning agent-based modelling (Gilbert 2008) that have been developed to study coupled human and nature systems, by which the actions and interactions of multiple actors within a complex system are implicitly recognised as being autonomous, and characterised by unique traits (e.g. methodological approaches, world views, values, goals, etc.) while interacting with each other through prescribed rules (An 2012).

Multiple working groups were formed, each deliberately including a single type of actor (e.g. researchers and technical experts only or regenerative practitioners only) or as wide a variety of actors as possible (e.g. representatives of multiple professions within an agricultural sector). The groups were tasked with making specific contributions to the think piece. While the tasks performed by each group were prescribed by the project lead researchers, each group had a high level of autonomy in the manner it chose to assemble, operate, and deliver its contribution to the think piece. Typically, the groups deployed methods such as literature and website reviews, online focus groups, online workshops, thematic analyses, and iterative feedback between groups as time permitted (given the short duration of the project).

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[1] Senior scientist at MWLR, with a background in soil ecology and plant ecophysiology - appointed as an un-paid member of Quorum Sense board of governors and part-time seconded to Toha Foundry while the think piece was being completed

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Native biodiversity and Regenerative Agriculture in New Zealand

Contract Report: LC3954-17

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1 Introduction

This paper addresses two related questions:

- How can native biodiversity be included within a Regenerative Agriculture (RA) farming system in New Zealand?
- Can native biodiversity be used as an indicator of successful regenerative farming practices in New Zealand?

To start with, I define what I see the concept of RA encompassing. I then discuss New Zealand's native biodiversity, and especially how it differs from parts of the world that are often used as models for applying RA in New Zealand. I then look at biodiversity conservation in pastoral farming landscapes and outline some principles for implementing biodiversity conservation on New Zealand farms, including regenerative farms. I finish by discussing how we can use native biodiversity as an indicator of successful regenerative farming practices.

The terms 'native biodiversity' and 'biodiversity' are used interchangeably throughout this article to refer to those species that occur naturally within New Zealand, and they include the plant, animal and fungal species that are found on land, in waterways and in soils. These differ from exotic biodiversity, which comprises species that were accidentally or deliberately brought to New Zealand by people, and include plants and animals important to farming (clover, sheep, etc.), plant and animal pest species (possum, blackberry etc), and other exotic species that are part of modern New Zealand rural landscapes (chaffinch, dandelion, etc).

2 What is Regenerative Agriculture?

Regenerative agriculture is a complex set of principles and practices, difficult to define, but usually understood to involve 'a set of farming principles and practices that enrich soils, improve watersheds, enhance ecosystem services such as soil carbon and nitrogen sequestration, improve biodiversity, and promote farmer and livestock welfare' (www.pureadvantage.org).

A broader definition that encompasses the human elements of RA is:

> the application of an ecological approach to the agricultural landscape with a particular focus on the health of our soil, plants, animals and people, and an expectation of similar or improved profitability. Regenerative farming encourages a mindset of continuous improvement, takes into account that every farm and farmer is different, and recognises the connection between the health of our farms and the health and resilience of our communities, waterways, biodiversity and climate. (Maury Leyland Penno)

Many different types of land management practices make up regenerative farming (Massey 2017) including:

- short-duration, high-intensity grazing with long rest (spell) periods (holistic or cell grazing)
- diverse pastures, including grass and forb species with different growth forms and rooting depths
- minimal soil disturbance, including direct drilling and no-kill cropping systems
- carbon-rich soil inputs (mulch, biochar, etc.)
- minimal use of artificial inputs such as pesticides and fertiliser
- landscape-scale water retention systems (especially in Australia)
- more trees within farmed landscapes (agroforestry and silvo-pastoral systems).

It is difficult to define regenerative farming as any one management practice because it can involve one or more of the above practices implemented on any particular farm to different degrees. There is no single set of management actions that all regenerative farmers adopt, nor do all regenerative farmers implement any one management action in the same way. Having said that, one key focus of most regenerative farming is soil health, and especially enhancing soil biological activity and building soil carbon and fertility (Masters 2019; see also Lehmann et al. 2020). However, regenerative farming is more than just about soil: it is also about the whole environment (biodiversity, water, carbon, etc) and has a strong social component, involving farmers reconnecting with their land and, as a result, having higher levels of mental well-being (Massey 2017).

There has been some debate about the ability of New Zealand soils to sequester additional carbon as a result of regenerative farming practices, as they already have relatively high carbon stocks compared with other countries practising RA (Whitehead et al. 2018). But while increasing soil carbon may be less important in New Zealand than elsewhere, RA practices that focus on soil health will also result in reduced soil loss (erosion). This is likely to be critical in New Zealand, as ongoing soil loss (and loss of associated nutrients) from our pastoral and arable farming systems is a major issue (Basher 2013), both for areas where soil is lost from (farm paddocks) and for the sites, and especially waterbodies, where this soil and its associated nutrients ends up.

The way that regenerative farming practices might interact with soil health are summarised in Figure 1.

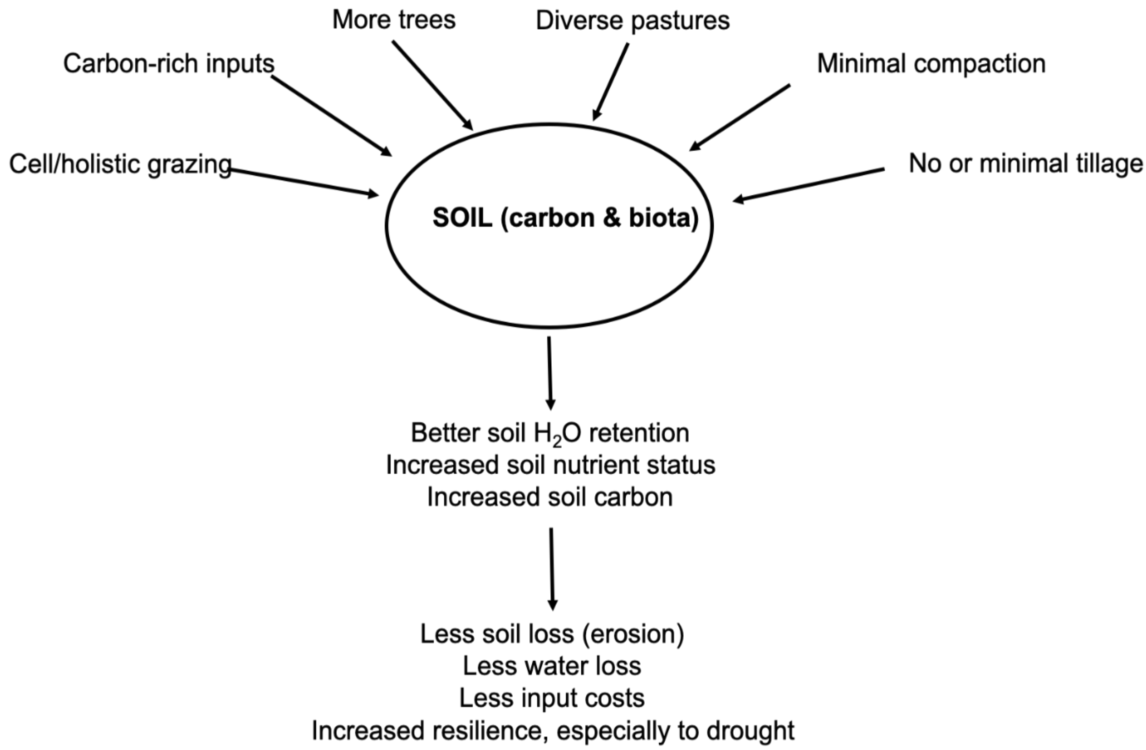

Figure 1. The diversity of approaches used in RA and their outputs and outcomes from a soil health perspective.

Two approaches to farming related to RA are permaculture and organic farming. Permaculture is based on a set of 12 design principles that focus on whole-systems thinking (Holmgren 2002; Appendix 1), while organic farming involves using organic fertilisers and natural pesticides. Although not the same thing, the principles of permaculture can inform the practice of regenerative farming, although not all regenerative farmers will follow the permaculture principles. Regenerative farmers are also not necessarily organic farmers, nor are all organic farmers regenerative. However, the reduced use of artificial inputs (pesticides and fertilisers) is a key feature of regenerative farming.

While the RA management practices that farmers apply vary from farm to farm, it has been suggested that there is a set of common underlying principles that characterise how most regenerative farmers implicitly or explicitly think about their land management (Gordon 2020):

- thinking holistically
- having an understanding of complex adaptive systems
- being comfortable with ambiguity
- having the capacity for continuous, transformative learning
- making place-based decisions within bioregions
- understanding that humans and cultures are co-evolving with their environments
- acknowledging and involving diverse ways of knowing and being in landscapes.

In many ways the essence of the regenerative approach to farming can be seen as a focus on resilient environmental, economic and social systems (*sensu* Walker et al. 2004). In order to be resilient, an ecological approach to farm management is required that focuses on the whole system, and especially on the interconnection between different parts of the system. Being adaptive, adopting a process of continuous improvement, and working with nature are central to resilience. Resilience can provide a unifying concept for regenerative farming – building resilience to environmental, economic, and social stressors rather than focusing on just one aspect of the farm system, such as soils.

3 New Zealand's native biodiversity

Many of the principles and practices of RA were developed outside New Zealand and are based on ecological systems and native biodiversity in these regions. It is therefore important to consider the nature of native (indigenous) biodiversity in New Zealand before discussing the relationship between regenerative farming and biodiversity here. A few key points are central to this (MfE 2019; DOC 2020).

- Most of New Zealand, including almost all the areas that are used today for pastoral farming, were covered by woody vegetation, with smaller areas of wetlands, prior to human settlement.
- This woody vegetation primarily comprised tall, temperate rainforest dominated by conifer (rimu, tōtara, kahikatea, mataī, kauri) and angiosperm trees (tawa, kāmahi, pūriri, rātā, tītoki, hīnau, red beech, silver beech, etc.). In drier areas (low rainfall or shallow, freely draining soils), shorter-stature and more open forest and shrubland would have been present, but the predominant vegetation cover was still woody.
- Prior to human settlement, grassland was largely restricted to above the alpine tree line or to the limited areas of recently disturbed sites such as alluvial surfaces.
- Apart from three species of bat, New Zealand lacked native terrestrial mammals, with the herbivore guild comprising birds, lizards and invertebrates and the predator guild comprising birds and reptiles.
- As a result of the virtual lack of mammals, much of New Zealand's flora and fauna are not well adapted to dealing with mammalian herbivory and predation.
- The majority of New Zealand's native species (plants, animals, fungi) are endemic; that is, they are found nowhere else in the world.
- Human settlement of New Zealand (c. 1280 CE) was very late on a global scale. As a result, there are still trees present in our remnant forests today that established before humans reached New Zealand, and many native species are still adjusting to the pressures of settlement.
- The drivers of biodiversity loss in New Zealand have changed over time (Table 1). While habitat loss had a devastating impact on New Zealand's biodiversity during the early phases of both Polynesian and European settlement, it is relatively unimportant today. The key driver of biodiversity decline now is the impact of invasive plant and animal species. Alongside this, global climate change is becoming an increasingly important driver. Climate change affects biodiversity both through shifts in long-term averages (e.g. drier or warmer) and through increases in extreme events (such as

flooding and windstorms). In the future, synergistic or interacting effects between different drivers will also become increasingly important (e.g. climate change exacerbating the impacts of invasive species by facilitating species to expand their ranges).

Table 1. Key drivers of native biodiversity change in New Zealand's terrestrial and freshwater ecosystems over time

Driver / time period	*Māori*	*Early European*	*Current*	*Future*
Habitat loss	High	High	Low	
Over-exploitation	Moderate	Low		
Invasions	High	High	High	High
Pollution		Low	Low	Low
Climate change			Moderate	High
Synergistic effects		Low	Low	High

With human settlement, the extent of the original vegetation has been considerably diminished such that only about 10% of the original wetlands and 35% of the original forests remain (DOC 2020). With habitat loss and the impacts of invasive plant and animal species, we have also lost significant numbers of species, especially birds, and many that survive are much less abundant now than they were historically. In those parts of New Zealand where pastoral farming is the predominant land use (50% of the New Zealand land area), much of the remaining native forest and wetland occurs on farmland rather than public conservation land (e.g. sheep and beef farms contain 25% of the remaining native vegetation in New Zealand; Pannell et al. 2021). If we are to sustain native biodiversity in these areas, we need to work with farmers and their farming systems to achieve this (Norton et al. 2020).

It should be noted that native species are not always uniformly 'good' or 'desirable'. A native species can be a desired species in some situations, but a weed or pest in other situations. For example, plants, such as the native vine pōhuehue (*Muehlenbeckia australis*) can be problematic in small remnants of native forest as they respond to the high light levels by climbing up and smothering remnant trees. The grass grub beetle (*Costelytra giveni*, previously known as *Costelytra zealandica*) is one of several native insects that also create challenges for farming and are often considered as pests.

4 New Zealand native grasslands and holistic grazing

It is important to recognise that many regenerative farming practices, especially those associated with holistic grazing, were developed in countries with native mammalian herbivores and where native grassland species are adapted to mammalian herbivory (Savory 1983). Africa, North America, and Australia are or were all characterised by large numbers of mammalian herbivores that evolved with grassland ecosystems. Examples include elephants and antelope in Africa, bison and deer in North America, and the extinct megafuana of Australia. Holistic grazing involves large numbers of livestock (sheep and cattle) grazing a grassland for a short time period, often only one or a few days, before being moved on and the grassland being left ungrazed (rested or spelled) for a much longer time period (often months). This type of grazing is thought to mimic the way large mammals (e.g. bison in North America) would have grazed naturally. A recent global meta-analysis suggests that intense grazing with long rest periods may well result in more positive outcomes for native biodiversity compared with other grazing systems, such as set stocking (McDonald et al. 2019).

In New Zealand, native grassland was largely restricted to above the alpine tree line (generally above 1,200–1,400 m) prior to human settlement (McGlone 2001), but with deforestation associated with Polynesian settlement, native grasslands expanded downslope (often to below 500 m), forming the extensive grasslands encountered by early European pastoralists. Although largely induced, these grasslands still have high biodiversity conservation values (flora and fauna), and in the eastern South Island high country they are also important for livestock grazing (particularly extensive merino grazing).

In considering the potential of using holistic grazing in New Zealand's native grasslands, it is important to recognise the different ways that birds and mammals feed. While mammals cut foliage with their teeth and manipulate it within their mouths, birds tend to clamp and pull foliage and are unable to manipulate it. Because of the absence of mammals in New Zealand, there is strong evidence that the New Zealand flora has not evolved adaptations to mammal browse, and so the outcomes from mammal grazing will be different from bird grazing (Forsyth et al. 2010).

One example of this is leaf abscission (shedding) in grasses (Antonelli et al. 2011). Leaf abscission increases biomass production but also makes grasses more palatable to mammals. It has been suggested that the rarity of leaf abscission in grass floras globally is because of mammalian grazing pressure. However, the incidence of leaf abscission in New Zealand grasses, especially in the Danthonioidae (which includes the snow tussocks), is significantly higher than elsewhere in the world (55% of species in New Zealand cf. 20% globally; Antonelli et al. 2011). It is likely that the absence of mammals in New Zealand has been a major factor conferring an evolutionary advantage to leaf-abscising grasses because of their increased productivity.

Several studies have highlighted the vulnerability of New Zealand grasslands to mammalian grazing (sheep, cattle, deer, chamois, tahr; e.g. Lee et al. 2000; Tanentzap et al. 2009). High sheep numbers led to a shift from snow tussocks to short tussocks early in the period of European pastoralism (O'Connor 1982), and within remaining snow tussock grasslands, local elimination of tussocks from areas of high animal density is common (e.g. by tahr; Cruz et al. 2017). Many native species are also rare or absent from areas with ungulate grazing, often being restricted to sites such as bluffs or islands, which are inaccessible (Norton 1995). This vulnerability is almost certainly due in part to a general lack of adaptations against mammalian herbivory in the New Zealand flora (including leaf abscission in grasses).

Given the susceptibility of New Zealand's native grasses to mammalian herbivory, short-duration high-intensity grazing, even with long rest periods, will not be ecologically viable in native grasslands. A more sustainable approach for New Zealand native grasslands will require a focus on extensive and seasonal low-intensity grazing for short time periods, with long periods of spelling (within or even between years) as is currently practised in the South Island high country with Merino sheep. This is similar to what is referred to as transhumance elsewhere in the world: the movement of livestock between (usually remote) seasonal pastures, such as occur at different elevations.

New Zealand forests are also not adapted to mammalian grazing (Coomes et al. 2003; Forsyth et al. 2010). Multiple studies have documented the adverse impacts of introduced ungulates (farmed and feral) on forest ecosystems, including loss of palatable species within the browse zone and changes in soil physical and biotic properties (Wardle et al. 2001; Smale et al. 2008; Burns et al. 2011). Mammalian grazing within our native forests will therefore lead to changes in composition and structure, alter successional development, and potentially lead to forest collapse.

5 Implications of regenerative farming for biodiversity conservation

In considering the implications of regenerative farming for biodiversity conservation in New Zealand, it is important to again emphasise that the predominant pre-human native vegetation in pastoral farming areas was temperate rainforest and associated wetlands. From a biodiversity perspective, holistic grazing systems are not going to confer any direct biodiversity advantage in New Zealand environments where native plants dominate (e.g. in grasslands dominated by native tussock grasses) and will result in declines of native species in these systems (as discussed in the previous section). But, given that the majority of New Zealand's pastoral systems are based on exotic grasses and forbs, holistic grazing is appropriate and may well have a range of other advantages, including increased soil carbon sequestration, higher ground cover (and hence reduced soil erosion), better drought resilience, and reduced use of artificial inputs like pesticides and fertilizer, all of which have the potential to have positive flow-on effects for native biodiversity (e.g. through enhanced water quality and reduced across-edge effects on native remnants).

Internationally, there has been considerable discussion on land sparing and land sharing as two ways of conceptualising how we might manage native biodiversity within agroecosystems (Phalan et al. 2011; Fischer et al. 2014; Kremen 2015). Land sparing involves setting some areas aside permanently for conservation while other areas are intensively developed for food and fibre production. Land sharing (also called wildlife-friendly farming) involves managing the whole landscape in a manner that is good for biodiversity, while also producing food and fibre. The consensus seems to be that both are likely to be important. While land sparing and land sharing can be seen as opposite ends of a continuum of approaches to biodiversity management within agroecosystems, the relative importance of either is strongly influenced by both the socio-ecological history of the area under consideration and the scale at which landscape elements are being considered.

We can sustain and enhance native biodiversity in New Zealand's pastoral farming systems through both land sparing (taking land out of production) and land sharing – managing the farming system in a way that is sympathetic to biodiversity (e.g. reduced use of pesticides and fertiliser, retaining and planting scattered native trees in paddocks, using native species in woodlots, erosion plantings, and shelterbelts). Native biodiversity (whether in a 'spared' or 'shared' model) can also directly benefit farming by providing shade and shelter, nutrient and sediment retention, enhanced water quality, habitat for beneficial insects, etc. But in managing native biodiversity in either a 'spared' or 'shared' model, we need to be thinking at a landscape scale because native biodiversity functions at scales larger than patches or even farms (e.g. seed dispersal and seasonal bird feed resources), as do the many threats to native biodiversity (e.g. plant and animal pests).

For most New Zealand pastoral farms, land sparing occurs at the scale of the management unit (areas within the farm that are set aside from grazing). Even in this case, there can be some sharing in the sense that the way the unit or paddock is managed, even if the primary objective is grazing, can also benefit biodiversity (reduced soil erosion, no cross-boundary spread of artificial inputs, etc.). However, the way we manage at the scale of the farm is very much land sharing or wildlife-friendly farming.

The basic on-farm management practices for biodiversity in New Zealand pastoral systems are fundamentally similar between conventional and regenerative farmers, and include (adapted from Norton & Reid 2013):

- fencing to keep livestock and feral animals out of sensitive areas (e.g. forest remnants and wetlands)
- strategic grazing to control weeds and maintain/enhance native tussocks and shrubs for shelter and shade
- control of plant and animal pest species (which also has major farm production benefits)
- active (planting and seeding) and passive (natural regeneration) restoration of native habitat to buffer, connect and expand existing natural areas
- hydrological manipulations to reinstate wetlands and stream courses, or to keep invasive predatory fish out of key habitats for native fish
- generally increasing native biodiversity by incorporating native plants in shelterbelts, homestead gardens, etc.
- using native biodiversity for direct economic returns (e.g. tōtara for timber and mānuka for honey)
- using exotic plants as food for native animals and as nurse crop for native regeneration.

While managing native biodiversity need not differ between conventional and regenerative farms, the underlying philosophy of regenerative farming means that the farm is seen as an integrated system. This recognises the interconnections between all the different parts of the farm and the activities undertaken on the farm, as well as the direct and indirect benefits that native biodiversity can have for the farm. This differs from the (perhaps) more 'black and white' perspective of some/many conventional farmers, who are more likely to see biodiversity conservation and farming occurring in spatially separate parts of the farm (a strict land-sparing model).

Perhaps the biggest difference from a biodiversity conservation perspective is the way that a regenerative farmer might think about their land and its management. This involves consciously thinking about biodiversity in redesigning the farm to be regenerative (Massey 2017); i.e. biodiversity is seen as central to farm design, not as an afterthought. This doesn't mean that farms will be turned into national parks, far from it. But it does mean that in farming the land, strategic thinking about how native biodiversity can be enhanced through farm design and management, and how native biodiversity can benefit the farm, is critical. This is, in essence, taking a wildlife-friendly approach to farming.

For example, rather than simply fencing off sensitive parts of the farm from livestock grazing, this involves thinking more holistically about the whole farm layout. This requires long-term strategic thinking about how the farm can be optimised for both biodiversity conservation and farm productivity. Allied with this is a programme of continual improvement based on ongoing reflection on the links between the environmental, economic, and social components of the farm, informed by objective monitoring of all components of the farm, including native biodiversity.

Regenerative farming is most likely to differ from conventional farming in terms of biodiversity conservation in the following areas:

- no or little pesticide and fertiliser used, so there is less chance of unintended impacts on remnants of native habitat, including wetlands
- a willingness to plant trees (and other long-lived plants), whether native or exotic, more widely across a farm so there is more habitat for native species, especially birds
- more likely to be willing to revisit whole-farm layout to optimise for multiple values, including biodiversity (less black-and-white thinking regarding production versus non-production areas)
- viewing the farm and landscape as an interconnected system and hence appreciating more subtle values such as biodiversity, as well as appreciating the deeper values of enhancing biodiversity, including values important to tangata whenua.

6 Implementing biodiversity conservation as part of regenerative farming

I believe there are several key principals or elements to managing native biodiversity in New Zealand farming systems generally, and regenerative farming specifically (adapted from Norton & Reid 2013).

6.1 Principle 1 – Think about how native biodiversity might be on your farm in the future

What state do you, your family, and/or your community want for native biodiversity on your farm and in your wider landscape in 30–50 years' time? What are your biodiversity goals? Think long term and think big. If we are not ambitious in our thinking, we are unlikely to shift from the status quo, but at the same time we need to temper this with a healthy dose of realism in terms of what we can achieve.

It is important to remember that in rural New Zealand we are not managing our land as national parks or wilderness reserves. We are managing native species within working landscapes, and the outcomes from a strict nature conservation perspective are going to be different from what might be achieved in an ecosanctuary or similar. That is neither good nor bad: it's just what it is (Norton et al. 2020). The goal is to sustain and enhance native biodiversity to a level that is important to you, your family and/or your community and that contributes to regional and national biodiversity conservation goals. Agroecosystems are particularly important for doing this because they typically occur in areas where historical habitat loss has been greatest and where there is little other native biodiversity remaining (Pannell et al. 2021).

6.2 Principle 2 – Clearly identify the factors that are currently limiting or threatening native biodiversity now and that may do so in the future as you seek to achieve your goals

These factors need to be addressed before you can achieve your goals. Examples include grazing, hydrological changes, lack of food resources, lack of nesting opportunities, weeds, predators, funding, regulation, and public perception. Unless these limiting factors are fully addressed, biodiversity conservation will not be successful (Hobbs & Norton 1996). For example, removal of domestic grazing animals may be insufficient if feral grazers such as goats and deer are still present.

It is also important to recognise that several factors may be limiting native biodiversity at one place. For example, while predator control is essential to improve habitat quality for native birds, their restoration in agroecosystems will not be successful unless food and nesting resources are available, and habitat connectivity is sufficient for them to move around the landscape. Addressing one of these factors in isolation is not sufficient to restore native birds.

6.3 Principle 3 – Take a spatial approach to farm planning that is not constrained by the current farm layout

Approach biodiversity conservation as a spatial planning exercise: look at your farm, think about how it is laid out, and be willing to change that layout (which may need to be staged over several years). How do different parts of your farm interact? Be aware of what is going on beyond your farm and how this interacts with your farm. At the same time, think about the opportunities your farm has for biodiversity conservation more widely and the opportunities that occur in the wider landscape for your farm (environmental and social, e.g. a large area of native bush adjacent to the farm, or a motivated local community willing to help). But it is also important to recognise that the wider landscape can contain constraints to what you want to achieve (e.g. adjacent plantation forests can contain animal pests such as pigs and deer that can affect native biodiversity on your farm).

6.4 Principle 4 – Implement adaptive biodiversity management at multiple scales across the whole farm

In managing native biodiversity, think about remnants, connectivity, and the matrix. All are important. Be adaptive, change in response to what you learn, and be prepared to do this as a long-term exercise. Recognise that biodiversity benefits farming and farming benefits biodiversity, and that biodiversity conservation does not preclude economic use of native species (e.g. tōtara for timber or mānuka for honey). And it's not about planning for this year or next year: it's about thinking 30−50 years out with your planning.

6.5 Principle 5 – Continually monitor biodiversity outcomes and use this as the basis to refine management.

Focus on the biodiversity outcomes from your management, not on the operational work done, and use this information to inform future management (adaptive management). Outcome monitoring of biodiversity is critical, both to help you understand the consequences of your management actions, but also for telling your story more widely (to stakeholders, markets, etc.).

So what might regenerative farming mean at the farm scale for the average hill-country sheep and beef farm in terms of native biodiversity? It could mean:

- more diverse pastures with short duration stocking and long spell periods rather than set stocking – benefits accrue through increased ground cover, reduced fertiliser and pesticide use, less nutrient and sediment loss, and all of this reducing adverse effects on native biodiversity in areas adjacent to the pasture (streams and wetlands, forest remnants etc)
- greater abundance of native trees and herbs (e.g. harakeke) within and between paddocks, creating more habitat for native species (nectar, invertebrates, connectivity, nesting, etc.)
- native trees used in woodlots and/or native regeneration managed for timber and biodiversity (e.g. tōtara), again resulting in more native biodiversity in the landscape
- connected and buffered stream/wetland systems that provide habitat on the farm and help filter nutrients and sediments, enhancing downstream habitat quality
- remnant and regenerating areas of native habitat managed proactively to sustain and enhance their values, including plant and animal pest control
- well-connected native woody vegetation across farms through native remnants, riparian zones, natives in shelterbelts, etc. – this is especially important for mobile species such as birds, but also for ecological processes such as seed dispersal
- utilising and enhancing native grassland and shrubland blocks for shelter for lambing, calving, etc.
- more attention on plant and animal pest control – this is critically important across all habitat types
- diverse homestead gardens that are both a show case for native biodiversity but also a key ecological component of the connected farm
- ongoing outcome monitoring of native biodiversity (as opposed to operational monitoring).

The focus in all of the above is on having core areas or nodes for native biodiversity (forest remnants, wetlands, homestead garden) linked through a well-connected farm landscape (riparian zones, shelterbelts, etc.) that is integrated with native habitats and species in the wider landscape.

Native birds are a key component of New Zealand's biodiversity: they are distinctive, sensitive to broader ecosystem health, and are what help define our landscapes. Native birds, especially mobile species, also provide an excellent illustration of how regenerative farming can benefit native biodiversity. The dramatic decline of many native bird species in New Zealand reflects their evolution in an environment that lacked mammalian predators (rodents, mustelids, possums, cats). Predator control is essential to improve habitat quality for native birds, and the Department of Conservation undertakes predator control operations such as Battle for our Birds for this reason, targeting large areas of extensive native forests. The long-term persistence of species such as kākā, kiwi, and mohua is strongly dependent on these operations.

The situation is more complex in agroecosystems, and predator control alone is not sufficient to sustain or enhance many native birds. Their restoration also requires that food and nesting resources be available, and that habitat connectivity is sufficient for them to move around the landscape. Mobile birds such as kererū and tūī utilise a range of different food resources throughout the year, and if these are not available it is not possible to sustain them within an area. Some native species such as kākā and kākāriki are hole nesters and require suitable large trees with cavities to be able to nest. For many of our obligate or facultative forest species (e.g. North Island brown kiwi and toutouwai), crossing even short distances of open pasture can be a major barrier, which means enhancing connectivity is essential for sustaining them in rural landscapes. Regenerative farmers can greatly enhance habitat quality for native birds because of the way they view their farms – practices such as reduced pesticide use, increasing the amount of woody vegetation, and viewing farms as interconnected units can greatly benefit these species.

7 Can native biodiversity be used as an indicator of regenerative farming?

If the principles and management practices outlined in the previous sections are implemented, then native biodiversity will be enhanced on farms. While the best conventional farmers manage their land in a way that enhances native biodiversity, regenerative farmers are likely to consistently have enhanced on-farm native biodiversity (terrestrial and aquatic) because of their philosophical approach to land management. So, can native biodiversity be used as an indicator of regenerative farming? Yes, it can, and in the New Zealand context three sets of indicators can be used to quantify the benefits of the application of the regenerative farming principles and management practices discussed here.

7.1 Cover and composition of native vegetation

Regenerative farming that follows the practices outlined here will result in enhanced native vegetation. Photo-points provide a relatively simple and objective tool for tracking change in on-farm native vegetation through time. In essence, photo-point monitoring involves taking repeat photos of the same scene from the same place for several years. Although photo-points can't provide detailed information on all the plant species present, they are ideal for assessing the broad effects of management (e.g. stocking pattern or fencing) on native vegetation cover and on the dominant species present. As such, they are a very useful tool to track the effects of your management on native biodiversity (using vegetation as a surrogate).

One of the key reasons for undertaking photo-monitoring is that it provides a simple but objective way of recording change. No matter how good we think we are at observing change, our own assessments are influenced by our perceptions of what we think should be happening, an inability to fully recall what conditions were like in the past, and a failure to compare exactly the same place or in the same season. Further information on photo-monitoring is provided in Appendix 2.

7.2 Native avifauna (birds)

The presence and abundance of native birds are also very good indicators of environmental condition and the effects of farm management, and it is highly likely that regenerative farming will result in enhanced native bird abundance. Native birds include a range of feeding guilds, including herbivores (e.g. kererū), insectivores (e.g. piwakawaka, toutouwai, riroriro), nectivores and frugivores (e.g. korimako, tūī, kererū), and carnivores (ruru, kārearea). As such, their presence and abundance provide a good indicator of the broader ecosystem health on your farm. However, it is important to recognise that the abundance of native birds is driven by a range of factors, including predation pressure (mustelids, cats, possums, etc.), competition (with exotic birds), resource availability (e.g. food and nesting sites) and habitat connectivity. Not all of these can be influenced by the management you are doing on your farm, and for more mobile species like kererū or tūī, factors beyond the farm can be as important for determining on-farm bird presence and abundance as factors under your direct control. Notwithstanding this, indices of native bird presence and abundance can be an important part of on-farm biodiversity monitoring, and can utilise traditional counts (Appendix 3) or take advantage of recent advances in acoustic monitoring (see for example www.cacophony.org.nz).

7.3 Aquatic biodiversity

The health of waterways is an excellent indicator of broader environmental conditions in the catchment the stream or river drains, and hence can be used to quantify the benefits of regenerative farming. Water quantity and quality (e.g. dissolved nutrients and sediments) are already monitored on many farms, and while measurements of water chemistry can be useful, they do not necessarily provide a good picture of overall waterway health or the biodiversity that occurs in the stream, and require regular and relatively expensive water sampling to obtain a good picture of what is happening.

A range of alternative approaches for monitoring waterway health are available and include (i) the Stream Health Monitoring and Assessment Kit (SHMAK), (ii) the Stream Health Check list originally developed by Russell Death & Miranda Polglase from Massey University and recently updated for Beef+Lamb NZ (https://beeflambnz.com/knowledge-hub/PDF/FW2-

our-plan-template-stream-health-check.pdf) and (iii) Environmental DNA (eDNA). Each method has advantages and disadvantages depending on your personal situation, nature of your farm and resources available. The SHMAK system was developed specifically so that farmers could monitor both short-term impacts and long-term trends in waterway health. This focuses on the abundance and composition of aquatic fauna, especially invertebrates. Because the aquatic fauna live in the stream for many months and are also influenced by the nature of the surrounding vegetation (e.g. the adult phase of some stream insects requires adjacent woody vegetation in order to reproduce), they are an excellent integrative index of overall environmental health on a farm (see Appendix 4). eDNA can be used to gain a comprehensive overview of the biota present in waterways (see for example www.wilderlab.co.nz) and offers a relatively low-cost method for monitoring waterway biota.

It is likely that the condition of all of these indicators will improve with a change from conventional to regenerative farming practices and the measurement of these indices can be used to assess the success of regenerative farming in enhancing native biodiversity.

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Appendix 1. The 12 design principles of permaculture (from Holmgren 2002)

1. Observe and Interact: By taking the time to engage with nature we can design solutions that suit our particular situation.
2. Catch and Store Energy: By developing systems that collect resources when they are abundant, we can use them in times of need.
3. Obtain a Yield: Ensure that you are getting truly useful rewards as part of the work that you are doing.
4. Apply Self-Regulation and Feedback: We need to discourage inappropriate activity to ensure that systems can continue to function well.
5. Use and Value Renewables: Make the best use of nature's abundance to reduce our consumptive behaviour and dependence on non-renewable resources.
6. Produce No Waste: By valuing and making use of all the resources that are available to us, nothing goes to waste.
7. Design from Patterns to Details: By stepping back, we can observe patterns in nature and society. These can form the backbone of our designs, with the details filled in as we go.
8. Integrate Don't Segregate: By putting the right things in the right place, relationships develop between them and they support each other.
9. Use Small, Slow Solutions: Small and slow systems are easier to maintain than big ones, making better use of local resources and produce more sustainable outcomes.
10. Use and Value Diversity: Diversity reduces vulnerability to a variety of threats and takes advantage of the unique nature of the environment in which it resides.
11. Use Edges and Value the Marginal: The interface between things is where the most interesting events take place. These are often the most valuable, diverse and productive elements in the system.
12. Creatively Use and Respond to Change: We can have a positive impact on inevitable change by carefully observing, and then intervening at the right time.

Appendix 2. Photo-point monitoring guidelines

Photo-points provide a relatively simple and objective tool for tracking change in native vegetation on a farm through time. In essence, photo-point monitoring involves taking repeat photos of the same scene from the same place for several years. Although photo-points can't provide detailed information on all the plant species present, photo-points are ideal for assessing the broad effects of your management (e.g. stocking pattern or fencing) on native vegetation cover and hence on native biodiversity. As such, they are very useful for helping you review your biodiversity management and for showing others the changes that have resulted from your management. One of the key reasons for undertaking photo-monitoring is that it provides a simple but objective way of recording change. No matter how good we think we are at observing change, our own assessments are influenced by our perceptions of what we think should be happening, an inability to fully recall what conditions were like in the past, and a failure to compare exactly the same place or in the same season.

Photo-points can be used to follow changes in both overall vegetation cover (landscape photo-points; Figure 2) and vegetation composition (close-up photo-points; Figure 3). The latter can be used to track changes in shrub or tussock density, or forest understorey condition. The strength of photo-points is that they are cheap and easy to do, and can be established and managed by the farmer. Depending on how they are set up and repeated, it is also possible to extract some quantitative information from them, at least for dominant species (e.g. by counting the number of tussocks or shrubs present).

Figure 2. Landscape photo-point showing change in vegetation cover on a retired sheep and beef farm over 13 years (2005 left, 2018 right). Note the increase in shrub cover on the hillside in the top right and restoration plantings below this, and the changes to the two ponds, especially expansion of raupō in the left-hand pond. Māhoe is also now dominant in the vegetation on the spur in the foreground, where it was less important in 2005. The flats in the middle distance were cut for balage not long before the 2018 photo was taken.

Figure 3. Close-up photo-point sequence showing little change in fescue tussock grassland over 13 years. Note tape lines (estimated in 2018) for reference.

There are some simple steps that can be taken to obtain a successful sequence of photos that allow interpretation of vegetation cover through time (Table 2).

Table 2. Key issues for photo-monitoring

Issue	*Explanation*
Permanently mark photo-points	This ensures photos are always taken from the same place – best done using a metal standard driven into the ground, as fences, buildings and trees can be moved.
Take original photos when repeating photos	This is essential to ensure the same view is photographed each time (e.g. angle, inclusion of key features, etc.): memory is not very reliable! Having a camera with the ability to zoom is helpful to make sure that the area captured in the image is the same each year.
Take photos at the same time of year	Photos are best taken in early summer (November/December) after the spring growth flush but before vegetation starts to brown off through the heat and dry of summer. This reduces seasonality differences.
Develop a series of photos over several years	A single unusual season can result in misleading results, so building up a sequence of images over several years (4–5) avoids this.

The approach to taking landscape and close-up photo-points is slightly different. Landscape photo-points are best for illustrating changes in major landcover types like shrubland or forest, and should include whole hillsides or similar large areas in the image. Accurate repeat photos and subsequent comparisons are best done when the image includes some distinctive features like ridges or rock bluffs. It is also important to ensure the view being photographed will not be blocked out by changes in the foreground in the foreseeable future (e.g. tree growth or new buildings).

Close-up photo-points provide more detailed information on dominant species and their cover abundance at a particular site. For these, permanent reference points such as metal standards allow precise locations for accurate comparisons between years. Close-up photo-points are best located within areas of vegetation that are typical of the more general conditions in the paddock or block of interest, and should be relatively uniform with respect to vegetation, landform, and management regime, and preferably on the mid-slope. They should also be at least 20 m away from structures (fences, water troughs, shelterbelts, tracks, buildings, etc.), as these can modify grazing animal behaviour and hence vegetation. Finally, the site should be one that will not be disturbed in the foreseeable future (e.g. through cultivation).

Drones also provide an excellent way to obtain aerial images of remnants and other biodiversity areas that are hard to photograph from the ground (Figure 4). With modern drones it is possible to program them so they take a photo from the same place and in the same direction each time, which greatly increases their value.

Figure 4. Drone image of Hawke's Bay forest remnant (photo: Adam Forbes).

Where metal standards are used to mark photo-points, these need to be driven well into the ground to avoid being knocked over by cattle. Use of short standards driven in until only about 10 cm protrudes (and with protective caps fitted) can be an alternative, but this is only practicable where there is no chance of them being hit by a vehicle or bike.

Figure 5. Panorama of four images of high-country farmland taken from the same spot (Otago).

The number of photo-points established will vary depending on the size of the property and the amount of native biodiversity present. Too-few photo-points will not provide sufficient information on overall property condition, while too many will most likely result in their never being properly analysed. For landscape photo-points, several photos can be taken from the same place (a panorama; Figure 5). Depending on the size and nature of a property, the number of landscape photo-points is likely to range from 5–20 per property. The number of close-up photo-points will depend on the vegetation present and management issues that might apply on the farm. If the farm has some tussock grassland, then close-up photo-points are very good for tracking changes in tussock density. Close-up photo-points are also great in bush remnants or regenerating forest, such as kanuka, to track change in their understorey vegetation through time (Figure 6).

Figure 6. Close-up photo-point showing rapid re-growth of māhoe under a kānuka canopy over 3 years with grazing animal retirement. Note background trees for reference.

Once established, photo-points should initially be rephotographed annually for 4 or 5 years to establish a good baseline, and then at least every other year to develop a long-term sequence. Where possible, photo-points should be established close to access routes (e.g. farm tracks), as this will substantially reduce the amount of time required to access them. The position of photo-points should be marked on your farm map (e.g. in FarmIQ), ideally having been recorded using a GPS, as well as marking them on the ground. Depending on the size of the property and the type of access available, photo-points should be able to be photographed in 1 or 2 days.

Photos need to be properly annotated and stored once they have been taken. This is important for two reasons: (1) because the longer they are left the more likely they will be deleted, misplaced or lost; and (2) because the observers' memory is best immediately after the photos were taken. Monitoring data, including photo-point images, should be treated the same as farm financial records in terms of backups.

It is important that you, as the land manager, have 'ownership' of your biodiversity and the way your management interacts with it, and photo-monitoring is an ideal way to do this. You should be actively involved in establishing, repeating and interpreting photo-point monitoring. However, in interpreting the results of any monitoring, including photo-points, it is important to recognise that farm management is not the only factor that influences native biodiversity, and the results of monitoring need to consider other potential influences (e.g. factors beyond your control, such as pest species and drought). The greatest value of photo monitoring comes from long-term sequences of photos, so make it a priority to keep up with the monitoring.

Appendix 3. Bird monitoring guidelines

Native birds are a distinctive feature of most sheep and beef farms, with a wide range of birds present across a diversity of habitats, including grassland, riverbeds, wetlands, shrubland and forest (Table 3). Many are iconic species, and part of what makes New Zealand distinctive and their conservation a priority for New Zealand. There is also a range of introduced bird species that are common across rural landscapes.

Table 3. Common native birds found on farms

Habitat	*Common native birds*
Riverbeds, lakes, ponds & wetlands	Paradise shelducks, scaup, pūkeko, grebe
Forest and shrubland	korimako/bellbird, tūī, kererū, piwakawaka/fantail, riroriro/grey warbler, ruru/morepork
Grassland	Pipit, banded dotterel
Widespread species	karearea/falcon and kāhu/harrier

The presence and abundance of native birds can be useful indicators of environmental condition and the effects of farm management. However, it is important to recognise that the abundance of native birds is driven by a range of factors, including predation pressure (mustelids, cats, possums, etc.), competition (with exotic birds), resource availability (e.g. food and nesting sites) and habitat connectivity. Not all of these can be influenced by farm management, and for more mobile species like kererū or tūī, factors beyond the farm can be as important for determining on-farm bird presence and abundance as factors under the control of an individual farmer. Notwithstanding this, indices of native bird presence and abundance can be an important part of on-farm biodiversity monitoring, and these notes provide guidance on how you can do this on your farm.

The most common approach to monitoring native birds in New Zealand involves either 5-minute bird counts at a stationary point or walked transects of defined length or time, with the number of birds seen or heard, and their approximate distance from the observer, recorded. These observations are then used to develop indexes of bird conspicuousness that can be compared through time to assess trends in bird abundance. However, these methods require good bird identification skills, including identifying birds by their calls, and are not recommended for on-farm monitoring.

There has been a growing interest in making acoustic recordings of bird calls and then using computer software to analyse these data to quantify the species present and their abundance. While this approach will mean that anyone with a suitable acoustic recorder can monitor bird counts, the technology, and especially the software to recognise calls, is not yet at a stage where this can be undertaken routinely (although it may well be within the next decade). The Cacophony Project (www.cacophony.org.nz) is pioneering this work in New Zealand and will accept acoustic recordings of bird calls now, but cannot yet provide a breakdown on species presence and abundance aside from kiwi and ruru (as of October

2021). Even with this approach, you still need to ensure monitoring is consistent in terms of time period monitored and when and where it is undertaken (see below).

The method for on-farm bird monitoring recommended here is to develop a simple index for one or a few distinctive birds that can be used to track changing bird activity across your farm. As is the case with all monitoring, there are a few simple rules that will make the results of your bird monitoring useful:

- Undertake bird monitoring at the same place each time you do it. Ideally these sites should be clearly marked on the ground (e.g. with a tag in a tree) and recorded on the farm plan.
- Record birds for the same length of time at each monitoring period (e.g. 5–10 minutes).
- Undertake your monitoring at the same time of day, at the same time of year and under similar weather conditions (best done in fine weather in spring/early summer and within 1–2 hours of first light).

A range of birds can be assessed (Table 4), but if you have bush remnants it is suggested you use simple bellbird/tūī activity counts as an index of bird activity (unless you are really good at bird calls, don't try to separate bellbirds and tūī based on calls). Have two to four sites around your farm in or adjacent to areas of bush or other woody vegetation (it could even be your homestead garden), and spend 5–10 minutes listening and recording all birds heard or seen (this is best done in late spring/early summer). Try to be objective and count the actual number of birds if at all possible. If you have an acoustic recorder, make a recording at the same time, as this can be analysed in the future. It is recommended that you repeat this bird monitoring on at least three consecutive mornings under similar weather conditions, so you build up a picture of overall bird activity.

You could do similar monitoring for your wetlands (e.g. ponds), recording the species and number of birds seen at the same time of day for 3 days. For rare birds like kea, grebe or falcon/karearea, you could simply record them whenever you see a bird, noting where it was on the farm and the time and date.

Table 4. Examples of birds that could be monitored on farms

Bird	*Methods*
Bellbirds and/or tūī	Record the number of individual birds heard in forest remnants, or even around the homestead, at least once each year, making sure that the month and time of day, and weather conditions, are broadly similar, and that records are made from the same place each time (probably best done for 5–10 minutes, three or four times during 1 week).
Water birds	Same as above, but counting the number of individuals of each species present on a waterbody (e.g. scaup and pūkeko) at a set time.
Karearea/falcon	Note all sightings, including date and location on the property for this iconic bird.
Rare birds	Note all sightings, including date and location on the property, for rare birds like kea and grebe.

On most farms the best approach is likely to be a mix of formal counts (e.g. bellbird/tūī and/or water birds), supplemented by incidental observation of rare or unusual species. There is also merit, if you drive or walk a standard route regularly or at the same time of year (e.g. mustering), to keep a count of particular species along that route. A really good resource to help you identify birds is the New Zealand birds online website (www.nzbirdsonline.org.nz), which covers native and exotic birds with excellent photos and audio recordings of their calls, and a tool to help you identify birds.

As with photo-monitoring, your records of bird counts and observations need to be properly annotated and stored once they have been taken. This is important for two reasons: (1) because the longer they are left the more likely they will be deleted, misplaced or lost; and (2) because the observers' memory is best immediately after the observations were made. Monitoring data should be treated the same as farm financial records in terms of backups.

It is important that you as the land manager have 'ownership' of your biodiversity and the way your management interacts with it, and monitoring is an ideal way of doing this. The bird monitoring system proposed here has been designed so that you can be actively involved in establishing, repeating and interpreting the monitoring. However, in interpreting the results of any monitoring, including bird monitoring, it is important to recognise that farm management is not the only factor that influences native biodiversity, and the abundance of birds can be affected by factors beyond your control, such as pest species and availability of habitat on adjacent properties. The greatest value of any monitoring comes from long-term sequences of observations, so make it a priority to keep up with the monitoring.