# HE KETE HAUORA TAIAO

# A BICULTURAL ECOLOGICAL ASSESSMENT FRAMEWORK

By

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# Tuhinga whakarāpopoto: Abstract


Ka mau tonu ngā taonga tapu o ngā matua tupuna

Koinei ngā taonga i tuku iho, na te ātua

Hold fast to the treasures of the ancestors

For they are the treasures that have been handed down to us by God'

(Dymond, 2013, p. 274)

Ecologists, resource managers, landowners and iwi generally strive to manage biodiversity on their whenua as obliged by legislation. This may include restoration, protection, the mitigation of negative human impacts, or the prevention of further habitat loss. Mainstream ecological science and resource management (ERM) usually guides management decisions and provides evidence of management effectiveness. However, ecological science can struggle with stochastic and complex biological systems. Māori have hundreds of years of environmental knowledge and understanding that could be utilised by mainstream resource managers to enhance society's combined knowledge. An assessment tool that places mātauranga at its core can introduce a Māori perspective, privilege Māori knowledge, enable holistic co-management, re/introduce social values and create a common ground on which the two paradigms can connect.

He Kete Hauora Taiao is an environmental assessment framework for terrestrial habitats constructed on Māori ecological health indicators by applying them to quantitative ecological scientific data. He Kete Hauora Taiao is built on the Driver – Pressure – State/Condition – Indicator – Response framework (K. F. D. Hughey, Cullen, Kerr, & Cook, 2004). Māori ecological perspectives or ariā (indicators, perspectives or concepts) are placed at the 'condition' level. Ariā include concepts such as mauri, whakapapa, tapu, wairua and mahinga kai which are linked to environmental structures, processes, functions and services. These ecological indicators can then be assessed with recognised qualitative scientific tools, metrics and targets. ESAT, Ecological State Assessment Tool, is a database that accompanies He Kete

Hauora Taiao and enables quantitative ecological data to be viewed through a Māori perspective and weighted according to its relevance to management objectives.

Creating a new bicultural environmental assessment framework required the exploration of the intersection between Māori ecological knowledge (MEK) and ERM. To my knowledge this is the first MEK based ecological assessment framework created specifically for terrestrial habitats and the first one to attempt to quantify MEK ecological indicators, relate them to ecology and resource management metrics and develop an interface between the two epistemologies. He Kete Hauora Taiao and ESAT (Ecological Statement Assessment Tool) are valuable resource management tools. Together they can create resource management programmes informed by a Māori value framework and are tailored to specific whenua, iwi agendas and political reporting and management requirements. He Kete Hauora Taiao spans the intersection between ERM and MEK, enabling communication and translation. MEK may provide context to scientific data and the scientific data may help augment understanding of MEK. Combined, MEK and ERM may create a powerful force that could vastly improve our resource management and conservation efforts. He Kete Hauora Taiao is a framework that could be engaged with by territorial authorities, iwi kaitiaki and landowners nationwide to automatically build te ao Māori into our management practices.

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Aroha Nui
Sara Belcher

> Tihei Mauri ora, Ki te wheiao, ki te ao marama
> We share the breath of life as fellow seekers of enlightenment (Henry & Pene, 2001, p. 234).

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# Glossary of Māori words

Sources for this Glossary include Moorfield (2020).

| **Kupu Māori** | **Meaning** |
|---|---|
| Awa | A waterway such as a river or stream |
| Hāngi | Earth Oven |
| Hauora | Healthy, well and vigorous |
| Hinengaro | Mind, thought, intellect, consciousness |
| Īnanga | Whitebait (small silver freshwater fish) |
| Ipukarea | Ancestral home, homeland |
| Iwi | Kin group, tribe or nation |
| Kaimoana | Seafood |
| Kaitiaki and Kaitiakitanga | Guardian/ship, steward/ship |
| Kanohi ki te Kanohi | Face to face |
| Kanorau | Diverse or varied |
| Karakia | Chant or prayer |
| Kaumātua | Respected elder |
| Kaupapa | Policy, plan, topic or agenda |
| Kete | Kit or basket |
| Koiora | Life |
| Korowai | Cloak or cover |
| Kotahitanga | Unity and solidarity |
| Mahinga Kai | Cultivated food |
| Mana | Authority and prestige |
| Mana whenua | Territorial rights and jurisdiction |
| Manu | Bird |
| Maramataka | Māori lunar calendar and planting almanac |
| Mātauranga | Wisdom, knowledge and understanding |
| Maunga | Mountain |

| | |
|---|---|
| Mauri | Life force or life principle |
| Moana | Ocean or large lake |
| Mokopuna | Grandchild |
| Mōteatea | Lament |
| Motu | Country |
| Muru | Social deterrent |
| Noa | Common |
| Ngahere | Forest |
| Ngangara | Creeping things such as lizards and insects |
| Pakiwaitara | Story, legend folklore, narrative |
| Papa tua nuku | Mother earth |
| Patupaiarehe | Fairy folk |
| Pepeha | Quotation |
| Rāhui | Temporal or spatial prohibition restricting access |
| Rangatira | Highly ranked individual such as a chief or noble |
| Rangatiratanga and Tino rangatiratanga | Chieftainship, self-determination and sovereignty |
| Raranga | Weave and plait |
| Reo | Language |
| Ritenga | Customs and protocols |
| Rohe | Region |
| Rongoā | Medicine |
| Roto | Lake |
| Taiao | The natural world, environment |
| Taonga | Treasures and prized property |
| Tapu | The sacred, restricted and forbidden |
| Tautoko | Support and advocate |
| Te ao Māori | The world of Māori |
| Tikanga | Procedure, custom and lore |
| Tohu | Instructions, guides and targets |
| Tohunga | Expert |

| | |
|---|---|
| Tuhinga whakarāpopoto | Abstract |
| Tupuna | Ancestor |
| Tūrangawaewae | The place to which you belong |
| Ture | Societal guidelines |
| Wāhi taonga | Special place |
| Wāhi tapu | Sacred place |
| Wahine | Woman |
| Waiata | Song or chant |
| Wairua | Spirit or soul |
| Wānanga | Learn and teach |
| Whakairo | Sculpt or carve |
| Whakapapa | Genealogy |
| Whakataukī | Proverb |
| Whanau and Whanaungatanga | Family and familial connection |
| Whāngai | Foster and care for |
| Whare wānanga | House of higher learning – University |
| Whenua | Land |

# Acronym List

| | |
|---|---|
| DoC | Department of Conservation |
| DPAEIR | Driver – Pressure – Ariā – Ecological Element – Indicator – Response |
| DPSIR | Driver – Pressure – State – Indicator – Response |
| ERM | Ecological resource management |
| ES | Ecosystem services |
| ESAT | Ecological State Assessment Tool |
| EVP | Ecologically viable population |

| | |
|---|---|
| GWRC | Greater Wellington Regional Council |
| HVP | Harvest viable population |
| IUCN | International Union of Conservation of Nature |
| KCP | Kosmos – Corpus - Praxis |
| MEK | Māori ecological knowledge |
| MM | Mātauranga Māori |
| MMI | Eco-morphological index |
| MVP | Minimum viable population |
| OECD | Organisation for Economic Co-operation and Development |
| RTC | Residual Trap Catch |
| TEK | Traditional ecological knowledge |

# Ūpoko Tahi – Te pea

# Chapter One – The potential

> Doing nothing is not an option; our environment and economy are in danger of declining and we must find alternative ways of managing our catchment to ensure that future generations inherit a vibrant catchment, environment and lifestyle (Ruamahanga Whaitua Committee, 2018, p. 8)

What happens when conservationists (resource managers and scientists) and Indigenous knowledge practitioners co-manage biodiversity? How can we all define our needs and agendas while not deferring to or appropriating the 'other'? Should we give Indigenous knowledge precedence in order to 'level the playing field' and ensure equity? A biodiverse, resilient and sustainable ecosystem is a common goal for conservationists, but how can we work together to achieve it? As a Māori ecologist, I see these questions as key to achieving effective resource management in Aotearoa New Zealand. In Aotearoa resource management means conserving species, managing biodiversity and managing conservation estate. Having open, respectful and candid conversations that value all epistemologies may ensure we do not undermine this objective (Dwyer, 1994, pp. 95-96). There is a need to examine the intersection between the worlds of mātauranga Māori, Māori knowledge, in particular Māori ecological knowledge (MEK) and mainstream Western science, in particular the epistemology of ecology and resource management (ERM).

Ecological science and resource management (ERM) and ethno-science, Traditional Indigenous Ecological Knowledge (TEK), essentially share a common origin and they function to refine our understanding of the world (Ellen, 2004, pp. 425-426). They share a paradigm of knowledge acquisition and assimilation (Gratani et al., 2011, p. 8). Science of any sort is a descriptor of human experience and observation (Cobern & Loving, 2001, p. 55). All science epistemologies can be considered classification systems providing ways of predicting and explaining observed natural phenomena as well as a framework for accumulating knowledge (Howes & Chambers, 1979, p. 5). We all observe, experiment, interpret and conceptualise our place in the world using our senses (C. Becker & K. Ghimire, 2003; C. D. Becker & K. Ghimire, 2003, p. 10). The difference between ecological science and Indigenous ecological knowledge resides in the epistemology and cosmology of the observer, reflecting their social views and cultural norms (Gratani et al., 2011, p. 8; Tsosie, 2012, pp. 1140-1141). Traditional ecological knowledge tends to embody respect for the environment and cultural beliefs, values and practices, while ecological science and resource management values empirical truth, multidimensionality and universality (Bohensky & Maru, 2011, pp. 5-6).

Navigating both epistemologies may be critical for the management and mitigation of the biodiversity losses and climate transformations we are currently experiencing and for the benefit of our social, cultural, economic and environmental wellbeing (Bart, 2006, p. 541). Creating a synergy between traditional knowledge and science could help build better ecosystem management practices by improving research depth, decision quality and by increasing social capital (Barrios et al., 2006, pp. 249-250; E. Bennett & Zurek, 2006, p. 276; H. Huntington, Callaghan, Fox, & Krupnik, 2004, p. 18). Exploring the intersection between MEK and ERM can help identify the overlap between the two epistemologies and discover how they can augment and support one another. This may assist in the creation of a framework that incorporates both MEK and ERM ecological indicators, methodologies and knowledge for the benefit of effective resource management. Current wai (waterway) focused environmental assessment frameworks featuring both MEK and ERM generally do not attempt to apply Māori ecological indicators to mainstream science methodologies and effectively maintain the gap between the two (Fenemor et al., 2011, p. 317). While these frameworks combine MEK and ERM to varying degrees, they generally fail to rationalise, relate or correlate the two knowledge systems satisfactorily nor do they cater to terrestrial habitats.

A framework or tool that can evaluate Māori ecological indicators using qualitative ecological data would be valuable. This framework should privilege MEK, placing it foremost in a central position with ERM in a supporting role. Privileging MEK is the only way to ensure that it is valued and incorporated into resource management decisions, elevating it to an equal mana with ERM. This framework should support and validate both paradigms, taking care not to appropriate or repackage MEK for consumption by scientists or resource managers (Thrupp, 1989, p. 14). Repackaging MEK into western models may distort the knowledge rendering it inappropriate for local needs (Thrupp, 1989, p. 14).

This thesis will examine the differences between Indigenous ecological knowledge, particularly Māori ecological knowledge and quantitative ecology, exploring the intersection between them. This exploration will facilitate the construction of an ecological assessment framework based on MEK concepts and indicators, linking them to related quantifiable scientific concepts and this will allow for the reciprocal translation of mātauranga and science. Creating an ecological assessment tool that melds the two epistemologies, will facilitate co-management and co-science and establish two-eyed seeing (Hatcher, Bartlett, Marshall, & Marshall, 2009). A framework that achieves this will need to be built using a kaupapa Māori ideology because mātauranga would need to be privileged. This privileging means an assessment framework must be built from a Māori cosmological standpoint. Combining two different paradigms that are sometimes in conflict and not letting one annex the other is a challenge. Each should be able to continue to operate from its own cosmological standpoint. This may be the key to realising effective and true co-management and resource management utilising combined cultural knowledge.

In this first chapter, I will discuss my own positionality and explain how being a Māori scientist provides me with a view of the world that enables me to develop a framework that can combine MEK and ERM paradigms. I will then explore kaupapa Māori research and explain how I have applied this tikanga to the development of an ecological assessment framework, He Kete Hauora Taiao. Chapter 2 will examine the cosmologies that created TEK and ERM and what epistemologies and ontologies have devolved from them. Chapter 3 examines the resource management paradigm influenced by mainstream science. Chapter 4 examines the resource management paradigm of Indigenous Knowledge Practitioners and in particular of Māori. Chapter 5 explores the ecology of Aotearoa New Zealand and the current legislative and ecological landscape we operate in. Chapter 6 investigates the ecological drivers and pressures threatening our native biodiversity and ecology and the concepts/values/indicators that Māori use to assess the health of the environment and will form the foundation of the new ecological assessment framework, He Kete Hauora Taiao. Chapter 7 examines the ecological elements and the scientific indicators and metrics that may be used to assess aspects of the Māori ecological indicators. He Kete Hauora Taiao will link the Māori values and concepts (ariā) to mainstream science ecological processes and functions. Chapter 8 examines the application of He Kete Hauora Taiao using Ecological Sate Assessment Tool (ESAT), a database developed to capture scientific quantitative data and view it through a Te Ao Māori lens by applying ariā to weighted datasets. Chapter 9, the concluding chapter, discusses the outcomes of this research and the learnings, teachings, take-home messages and recommendations for the future.

## Two-eyed seeing - Bridging the conceptual gap

> The survival of planet Earth may be dependent on Western Science's ability to acknowledge and utilize the principles of Indigenous Science. Cross-cultural exchange and collaboration through participatory research might ensure such utilization. (Colorado, 1988, as cited in Cajete, 2000). Indigenous Science, then, would be recognized as an equal but different source of knowledge, [that is] not measurable through a Western Worldview (Cajete, 2000, p. 291) (Hatcher et al., 2009, p. 145)

We may need both science and traditional knowledge to face the challenges of rapid environmental change and biodiversity loss (Cobern & Loving, 2001, p. 64). Indigenous knowledge provides valuable hypotheses, social contexts and problem-solving capacity and can deal with ecological complexity and scale and provide adaptability and social integration. Science offers the quantification of the natural world and the testing, application and modelling of that data (Moller, Berkes, Lyver, & Kislalioglu, 2004, p. 11; Wenzel, 1999, p. 117). Indigenous knowledge can provide important information on population viability, distribution patterns and behavioural ecology and can provide baselines and insights into the extent of human-induced changes (D. Fraser, Coon, Prince, Dion, & Bernatchez, 2006, p. 1; H.

Huntington et al., 2004, p. 19). There is sometimes tension between the two epistemologies, but it is precisely because of their differences that they can and should complement one another (Bohensky & Maru, 2011, pp. 5-6; Tripathi & Bhattarya, 2004, p. 3). Indigenous knowledge may improve capacity, extend the resource base and link research to place. Science can then utilise that knowledge more broadly over time and space (E. D. G. Fraser, Dougill, Mabee, Reed, & McAlpine, 2006, p. 115; Moller et al., 2004, p. 11).

Indigenous knowledge offers local, relevant indicators that can ensure management is more adaptive and generally will have community investment (financially and emotionally). Including the community's knowledge and experience in decision making encourages democracy, addresses power imbalances and facilitates public licence to operate (G. Brown, Smith, Alessa, & Kliskey, 2004, pp. 162, 178). Introducing Indigenous concepts such as mauri (life force) into resource management could improve our management of complex social and ecological dynamics (Ti Kipa Kepa Brian Morgan, 2006, p. 8; Satterfield, Gregory, Klain, Roberts, & Chan, 2013, p. 104). Indigenous harvest methods and pasture management methods may improve management outcomes (Monson, 2004, p. 106). Practices such as intercropping create food web complexity, conferring natural biocontrol benefits (Altieri, 1999, pp. 21,26).

In Canada, knowledge of the ecology of the arctic fox (*Vulpes lagopus*) and the greater snow goose (*Chencaerulescens atlantica*) have been augmented by the inclusion of TEK (Gagnon & Berteaux, 2009, p. 1). The two knowledge systems concurred on fox migration dates, den establishment and site selection and the timing of goose moulting and migration but, differed on goose abundance. Science reported a healthy population increase while the Indigenous respondents reported a decline. The scientific monitoring reported slight decreases at specific sites but extrapolated an overall increase, while the Indigenous people with generalised knowledge of multiple sites argued the population was in decline (Gagnon & Berteaux, 2009, pp. 15-16). The veracity of either stance has yet to be determined but what is of interest here is that one knowledge system used specific, localised, intensive monitoring and the other used generalised knowledge of the entire population at the landscape level to make their deductions.

Two-eyed seeing is seeing the world simultaneously from two points of view. In this case, it is viewing natural resource management using both mainstream science and traditional knowledge worldviews. Two-eyed seeing is a way to integrate science and Indigenous knowledge. Both pedagogies are afforded equal significance, importance and value and domination of one over the other is avoided. The result is that both epistemologies create a new understanding. For example, Indigenous practitioners and ecologists and forestry managers may each value a forest in very different ways. Two-eyed seeing should allow conceptualisation of that forest's intrinsic as well as its extractive value. Berkes (2004, p. 627) suggests one value system is not prioritised over the other and both are afforded equal relevance, however, one may still be privileged over the other. Decisions can then be made based on all of the forest's values, not just the monetary one, which is usually prioritised. Ideally, two-eyed seeing respects, supports and legitimises both viewpoints and brings them together, allowing each access to the other (Hatcher et al., 2009, p. 146). My own whakapapa and educational background place me in a privileged position to be able to understand science and mātauranga Māori. This means I can view environmental management through both lenses. My positionality enables me to construct an ecological assessment framework that links mātauranga and science and I would like to think that I am in a position to effect two-eyed seeing.

## My positionality

> ….Pluralism is the civil engagement of our differences and disagreements about what is most importantly true. Against the monism that denies the variety of truth, against the relativism that denies the importance of truth, and against the nihilism that denies the existence of truth, we intend to nurture a pluralism that revives and sustains the conversation about what really matters, which is the truth (Cobern & Loving, 2001, p. 65)

Wahine Māori who also whakapapa to Europe, myself included, can feel caught between two worlds and sometimes feel they don't have enough of each to fully belong to either. Although we may sometimes feel like interlopers and imposters, we are the new breed of 'dusky maiden', educated and empowered (McKinley, 2005, p. 482; Tamaira, 2010, p. 1). We are hybrids of both biology and culture (McKinley, 2005, p. 485). We may be cut off from our whenua, tikanga, cultural heritage and language but we always carry these things in us (McKinley, 2005, p. 488). I recognise that my whakapapa conveys in me a connection with the whenua and this is what drew me to study ecology. I have always known that my view of the natural world was holistic and reverential and came from a deep-seated need to kaitiaki Papa-tūā-nuku and give back to her. Like Barbour and Schlesinger (2012, p. 37), I found my studies provided me a valuable opportunity to re-connect to my Indigenous landscapes and identity. I have rediscovered buried parts of myself. Mainstream science provided me with a detailed understanding of ecological mechanisms and gave me names for processes, functions and components but I derive the environmental, social, spiritual, cultural and cosmological context for those ecological mechanisms from my whakapapa. I believe that being brown and wearing a white coat is a means of influencing the practice and authority of science and enhancing our own knowledge and truth (Cobern & Loving, 2001, p. 53; McKinley, 2005, p. 494).

I sit astride the intersection of Māori and Western knowledge. I can be like the kārearea (the New Zealand Falcon *Falco novaeseelandiae*), facing the challenges of the divided knowledge head-on with talons extended or like the pīpīwharauroa (the shining cuckoo *Chrysococcyx lucidus*), by inserting myself into the system, changing it from within and making it my own. This analogy was given to me by a keynote speaker at a hui I recently attended and it made me see the value and necessity of both approaches. I see myself as building a conduit between both worlds through which communication and understanding can flow. I am a wahine Māori who is also a trained ecologist, and as such, I am a Māori who is a scientist, not a scientist who is Māori.

A cross-cultural paradigm for ecology could assist scientists to understand what concepts like whakapapa and mauri mean to ecology by making them, or at least some aspects of them, quantifiable. Conversely, it may also help Māori to decipher scientific vocabulary and discourse by explaining how ecological concepts pertain to their mātauranga. Examining the common ground that links the two epistemologies could rediscover how Māori define, measure and interpret environmental change and how environmental change impacts Māori wellbeing (G Harmsworth & Gadgil, 2002, p. 10). When concepts like mauri are used, there is often an attempt to quantify them with some form of ranking or categorisation system and they remain separate from the science.

Many scholars argue that in order to undertake Indigenous research you must be part of the culture you are researching (Te Rire, 2012, p. 60). If you are not one of the people you are researching, you will probably be doing more harm than good (Nadasdy, 1999, p. 16). This may be true and although whakapapa makes us Māori, there is no blood percentage quota or test of reo or tikanga aptitude to measure Māori-ness. Being Māori is likely a feeling of identity, a personal affiliation, whakapapa to an iwi, a connection to the whenua and I believe it is a worldview (S. Weaver, 1997, p. 389). H. N. Weaver (2001, p. 248) viewed indigeneity as a continuum from integrated/bicultural through to assimilated. Where you sit on that continuum is influenced by your genetic heritage, kinship ties, appearance (skin colour), upbringing, geographical location, cultural knowledge, education, language and sense of belonging and affiliation (H. N. Weaver, 2001, pp. 248-249). H. N. Weaver (2001, p. 249) goes on to argue that rather than trying to place ourselves along a cultural continuum, we need to be individuals that belong to one complex and sometimes conflicting cultural fusion.

We must all construct our own individual and collective identities (S. B. Awatere, 2008, pp. 45-46; H. N. Weaver, 2001, p. 249). In fact, defining indigeneity and labelling it could actually fragment and marginalise Indigenous people, silencing their voices. We should use both traditional knowledge and science so communities can fully realise their potential to respond to ecological changes and threats and to allow multiple voices and perspectives to be heard (Dawoe, Quashie-Sam, Isaac, & Oppong, 2012, p. 96), particularly the voices of women and children, which are often among the last to be heard (Gonzalez y Gonzalez & Lincoln, 2006, p. 7). Hearing and heeding all voices can great a hybrid knowledge that can engender more efficacious monitoring, policy and management decisions (M. S. Reed, Dougill, & Taylor, 2007, p. 250).

## Investigating the intersection between Māori ecological knowledge and Western ecology and resource management.

> Science by itself cannot change the world, but science plus the vision and action of leaders can—and that is what we seek (Daily, Kareiva, Polasky, Ricketts, & Tallis, 2011, p. 12)

Current ecological frameworks, such as the Mauri Model and the Cultural Health Index (discussed in Chapter 4), that feature mātauranga tend to be limited to mahinga kai, ranking mauri or the identification of cultural heritage sites. Mahinga kai is only useful as an indicator if Māori are still utilising the resource or will be able to in the future. Habitat degradation, land tenure change and the threatened status of native species all make this challenging if not impossible. These issues are further discussed in Chapter 5. Mauri is often assessed by using a ranking system in an attempt to express this esoteric concept quantitatively. This may apply a quantitative value to mauri but does not help non-Māori scientists and resource managers understand what mauri is. Any deficiency in understanding the concept of mauri may mean it is insufficiently valued in the mainstream paradigm. The identification of important cultural sites may be a necessity, but doing so does not guarantee that these sites are then prioritised for management. If the value of a site from a Māori perspective cannot be conveyed effectively to mainstream resource managers it may be overlooked. All of these issues are explored in later chapters.

There may be a need for science and mātauranga to be accessible simultaneously in one framework. Such a framework would ideally consider MEK and ERM indicators from a single perspective and that perspective will ideally be a combination of both worldviews, effectively creating a new joint paradigm. An ecological assessment framework that uses both MEK and ERM indicators may not only allow this but could enable interpretation of the two ontologies. The need for an assessment framework that places MEK in a position of equality with mainstream science appears to be increasing as resource managers and scientists try to build co-management relationships with iwi partners. Being active, effective partners in co-management situations is not only legally required under the Treaty/Te Tiriti but may also be a moral obligation and necessary for improving the wellbeing of Māori. The legislative framework and the impact of colonisation on natural resource management are discussed in detail in Chapter 5.

This thesis is written using the Greek ethno-ecology framework, the Kosmos – Corpus – Praxis (KCP) complex. The cosmological worldview – kosmos - that underpins the epistemology and ontology of mainstream science and mātauranga is explored first (Chapter 2). Next, the body of ecological and resource management – the corpus – of the two paradigms is examined (Chapter 3 and 4). Then I consider a new framework and put it into practice and apply it – praxis (Chapters 5-8). The ethno-ecology framework used by Māori is the baskets of knowledge. This framework and how it fits alongside the KCP complex is discussed in Chapter 2. When creating this new ecological assessment framework and constructing ESAT I have considered the three key elements required for the development of a kaupapa Māori resource management policy framework, as described by G Harmsworth (2002, p. 4). The first of these elements requires the definition of management goals, needs and objectives. For me, this involved defining the pressures that impact ecological and social wellbeing. The next element is the identification of the important Māori values relating to the project and exploring the relevant Māori environmental indicators. The final element is developing the method of implementing the strategic objectives and this is the development of He Kete Hauora Taiao and ESAT.

## Decolonising knowledge

> We do not need to wait for the colonizer to provide us with money or to validate our vision of a free future; we only need to start to use *our* Indigenous languages to frame our thoughts, the ethical framework of *our* philosophies to make decisions and to use *our* laws and institutions to govern ourselves (Alfred & Corntassel, 2005, p. 614)

Cobern and Loving (2001) extensively and critically discuss the process of knowledge colonisation and its impacts. They posit that when science acts as the gatekeeper of knowledge, it displaces Indigenous knowledge, affording only a narrow view that diminishes the legitimacy of Indigenous knowledge and creates 'epistemological homogeny' and 'cultural imperialism'. This may result in our disenfranchisement from our knowledge and therefore ourselves (Salmón, 2000, p. 1332). Historically, science has been a tool to modernise the 'deficient' and 'superstitious' Indigenous knowledge (Cobern & Loving, 2001, pp. 53,58). Traditional knowledge is often broken down, slotted into Western epistemology and assimilated. The bits that will not fit are often discarded (S. Weaver, 1997, p. 390; Weir, 2012, p. 59).

Merely labelling knowledge as science imparts a level of power and authority to it that facilitates access to resources and political influence (Cobern & Loving, 2001, pp. 51-52). One way power is gained is by controlling the collection, funding and facilitation of research (Ens et al., 2015, p. 144; Mahuika, 2008, p. 1). Even the process of writing and discussing traditional knowledge in English can cause it to lose its voice, perspectives and principles and can lead to Eurocentrism (Hart, 2010, p. 5; Hatcher et al., 2009, p. 145; Thrupp, 1989, p. 18). Knowledge colonisation is/was done in the belief that a more correct, technologically advanced knowledge system was being imparted to Indigenous people. Many presumed that the superiority of their social organisation was demonstrated by their control over nature and they advocated for the right to research for the 'benefit of all' (Cobern & Loving, 2001, pp. 53-54). No epistemology is better or more correct than another and none should hold dominion over knowledge, although some may claim this and use their colonial education system to supplant the Indigenous knowledge with their own 'superior' knowledge (Cobern & Loving, 2001, pp. 53, 65).

Traditional knowledge should not require documenting, securitising, or adherence to strict methodologies for validation. Time has already validated it (M. J. Christie, 1990, pp. 60-61). Having to prove your knowledge within another cultural framework can be, among other things, offensive, unfair, demeaning and annoying to Indigenous people (Ellen, 2004, p. 434; Gonzalez y Gonzalez & Lincoln, 2006, p. 11). Scientists are not expected to reframe their knowledge into another language or measure it against another worldview (Ellis, 2005, p. 72). Contemporary research in mainstream academia, including the sciences, is often a performance-based exercise. Performance-based research success is often measured by citation and publication rate rather than its uptake by the community. This may discourage long-term research as it may disadvantage and discourage applied and practical disciplines, interdisciplinary research, research with multiple authors, young researchers and it tends to encourage self-promotion (Roa, Beggs, Williams, & Moller, 2009).

Traditional knowledge should be valued in its own right. Trying to integrate traditional knowledge into a science framework automatically positions traditional knowledge as ancillary to the primary knowledge system (Hardy & Patterson, 2011, p. 76; Henry & Pene, 2001, p. 238). Indigenous people must be able to trust that their knowledge and worldview will be treated with respect and not appropriation (Gomez-Pompa & Kaus, 1992, p. 277; M. S. Reed et al., 2007, p. 55). Anyone conducting Indigenous research should be mindful that researching Indigenous knowledge is a privilege and the knowledge should be protected. The primary focus and consideration of the researcher working with privileged knowledge is to protect the integrity and dissemination of that knowledge (Baker, 2009, p. 6; Ens et al., 2015, p. 144).

Research that decolonises is defined as research that redistributes power to the Indigenous community, privileges Indigenous knowledge, is performative (dissemination is performance-based and communicates narratives, employs traditions and produces art), and includes a variety of viewpoints and methodologies (Baker, 2009, pp. 3-4). Decolonising research should validate Indigenous knowledge, ensuring its continued relevance. It emancipates the knowledge and the people by empowering them to enact their own agendas from their own epistemologies (Baker, 2009, pp. 3-4). Decolonising research requires methodologies that, according to L. T. Smith (2012, p. 4), 'gain self-determination, decolonisation and social justice', employing Indigenous protocols, teachings, methodologies, politics and contexts (L. T. Smith, 2012, p. 4). Decolonising research is different from cross-cultural research. Cross-cultural research is done in partnership between 'research allies'. It may be done by a researcher external to the Indigenous community but is done for an Indigenous community, respecting their history, struggles and tensions. It aims to understand cultural differences and redistributes power (Baker, 2009, p. 6; Hardy & Patterson, 2011, p. 83).

The process of decolonising knowledge involves first comprehension, then contextualisation and finally valuing of the other knowledge system in its own right (Gratani et al., 2011, p. 8). Decolonisation is mostly a process with no set path or milestones and has no endpoint, rather, it gradually shifts the reality of Indigenous people. Decolonisation involves reconnection to our land, language, histories, morals, ethics and lore, cultural calendars, important food sources, important geographical features, sites and traditions (Forster, 2012, p. 70; Gadgil & Berkes, 1991). It is freedom from fear, it is self-sufficiency and means 'rebuilding our community one warrior at a time' (Alfred & Corntassel, 2005, p. 613). Decolonising knowledge and decolonising research may be confronting because it requires the acceptance of another worldview and requires the relinquishment of power and control (Barbour & Schlesinger, 2012, p. 37). Decolonising knowledge should privilege the knowledge of Indigenous people and be emancipatory. Exclusion at any point leaves Indigenous communities feeling exploited, censored, unrecognised and used in someone else's agenda (Barbour & Schlesinger, 2012, p. 40).

Decolonising knowledge can put us on the path to enculturation (the gradual acquisition of cultural cosmology and norms by an individual or another cultural group) through cultural self-awareness and understanding (H. N. Weaver, 2001, pp. 248-249). The decolonisation of Indigenous knowledge, including mātauranga, involves the struggle to legitimise knowledge and remove the requirement for it to be validated within a framework that is more suitably applied to scientific qualitative data (Cole, 2017, p. 133; L. T. Smith, 2012, p. 108). Decolonising knowledge shifts our resource management paradigm towards a more holistic, adaptive epistemology more sympathetic to biodiversity and features integrated and adaptive catchment management and Indigenous co-management partnerships (Fenemor et al., 2011, p. 314; G Harmsworth, 2002, p. 1). Local knowledge understands and can provide information on local conditions and biodiversity through a socio-cultural lens and employs adaptive management practices (Dick, 2012, p. 128; Sutherland, Gardner, Haider, & Dicks, 2013, p. 1; D. H. Walker, Sinclair, & Thapa, 1995, p. 238; Xu et al., 2005, p. 20). Local knowledge generates hypotheses and science tests them (Chalmers & Fabricius, 2007, p. 1; Failing, Gregory, & Harstone, 2007, p. 49).

The ethos in Aotearoa was that if Māori became absorbed into European culture, Māori culture might be saved from extinction and that Māori would benefit from a more advanced knowledge and the care of a civilised benefactor (Hamer, 1992). Decolonising mātauranga legitimises a Māori cultural approach to understanding the physical world (Cole, 2017, p. 133) and requires kaupapa Māori research methodologies. It is done by Māori for Māori to meet Māori objectives (Baker, 2009, p. 6). For Māori, decolonising research should mean that Māori define our own research goals and parameters, apply our own indicators and conduct monitoring according to tikanga. Māori ecological knowledge may then become a valid and respected way to understand the natural world.

## Kaupapa Māori research

> We do not speak for Māori. Rather we speak as scholars that wish to use Māori values and processes in the way we discover or co-produce knowledge in the ways described by Smith (1999), Harmsworth (2001), Allen et al. (2009 this issue), and Moller et al. (2009) (Roa et al., 2009, p. 233)

Māori have expressed dissatisfaction with research done on their behalf using non-Māori methodologies (Baker, 2009, p. 7). Kaupapa Māori research can fill perceived gaps that are not being met by the current research paradigm (Barnes, 2000, p. 13). Kaupapa Māori research is defined by its effect rather than the methodology employed (Baker, 2009, p. 2). Kaupapa Māori research may promote tino rangatiratanga. It utilises Māori epistemology, revitalises, supports and secures mātauranga Māori. It is philosophically guided by mātauranga, kaupapa, mauri, wairua, tapu and tikanga and is rooted in rangatiratanga, whakapapa, pūkenga-tānga (expertise) and kotahitanga (Baker, 2009, p. 2; 2012, p. 89; Cole, 2017, p. 139; Shayne Walker, Eketone, & Gibbs, 2006, pp. 333-334). Kaupapa Māori research is owned by Māori, uses Māori cultural frameworks and tenets and empowers Māori (Pacey, 2005, p. 4; Shayne Walker et al., 2006, p. 336). It normalises Māori epistemologies whilst critically engaging with scientific ones (L. T. Smith, 2012, p. 187). Kaupapa Māori research takes place in whare wānanga and uses Māori theory and methodology to explore, learn and articulate knowledge from a Māori perspective (Forster, 2012, p. 57; L. T. Smith, 2012, p. 131). Space should be created in academic institutions to embed kaupapa Māori research practices.

Kaupapa Māori research creates a safe space for both the researched and the researcher (Baker, 2009, p. 8). Culturally safe research is culturally relevant research, mentored by kaumātua or tohunga, upholding the mana of the community, not just the mana of the research (Henry & Pene, 2001, p. 236; L. T. Smith, 2012). The research should support and prioritise the community's agenda and appropriate new technologies for its own purpose, giving knowledge back to the community being researched (G Harmsworth & Tipa, 2006, p. 4; Witten, Parkes, & Ramasubramian, 2000, p. 376). If the research comes from within the researched iwi, it is more likely to meet the needs of that iwi and be culturally safe, promote access, networking and relationship building and it will uphold the tikanga and kaupapa of the iwi (Baker, 2012, p. 89).

Kaupapa Māori research can foster engagement and build communication, goal sharing, trust and capacity on both sides (Bohannon, 2007, p. 907). Kaupapa Māori research should be controlled by the researched, not the researcher. A kaupapa Māori researcher should question why and how the research is being done, for whom and by whom, what the outcome will be, what and who it will benefit, who will own the research and who will have access to it (Baker, 2009, p. 3; Pacey, 2005, p. 6; L. T. Smith, 2012, p. 175). The relationship with the community is central and ideally, the research is conducted face to face (kanohi ki te kanohi) (L. T. Smith, 2012, p. 158; Shayne Walker et al., 2006, p. 336). The community should control the knowledge dissemination (Barnes, 2000, p. 14; Mauro & Hardison, 2000, p. 1267), and the researcher should be prepared to disclose as much information about themselves as they receive (Baker, 2009, p. 7).

When done properly, kaupapa Māori research may challenge the dominant research paradigm and enable Māori to re/gain conceptual, methodological and interpretive control of the research. The researchers may then honour Māori knowledge and interact with it with a degree of self-awareness (Hart, 2010, p. 10; Voyde & Morgan, 2012, p. 219; Shayne Walker et al., 2006, p. 335). Simply identifying as Māori does not automatically make research kaupapa Māori, rather, it is the epistemological framing used that is crucial (Barnes, 2000, p. 14). If a non-Māori undertakes kaupapa Māori research they will probably operate from their own cultural perspective (M. Christie, Fazey, Cooper, Hyde, & Kenter, 2012, p. 75). A person can't avoid operating from their own cultural perspective (Shayne Walker et al., 2006, p. 335). They may, however, position themselves as a non-Māori person involved in kaupapa Māori research. Crossing the divide between traditional knowledge and science can be done by people trained in both tikanga, formal research and academic writing and who are ideally bilingual (Ellis, 2005, p. 74).

While the research methodology used to build He Kete Hauora Taiao is not entirely kaupapa Māori, it does meet some of the criteria that I have discussed above. The methodology this research employs does not need to be embedded in a particular iwi. In fact, doing so could restrict the scope of the ecological assessment framework that I have created. I want the ecological assessment framework I create to be applicable nationally, for any iwi. It will be designed so that individual iwi, hapū and even non-Māori resource managers and scientists can access mātauranga Māori ecological health indicators in a way meaningful to them. In this way, He Kete Hauora Taiao can be adapted to suit the needs of any iwi and is not limited to any particular iwi. I, therefore, did not have to research any iwi specifically, be embedded in a particular iwi or hapū, or have a kaumātua mentor me for this research. Mentors for this research included specific iwi kaitiaki and national experts from scientific institutions like Landcare Research Ltd. These mentors were the interview subjects that helped identify and explore Māori ecological indicators. I will describe my mentor selection and interview techniques in Chapter6, when the methodology for how He Kete Hauora Taiao is constructed is described.

As I am investigating the intersection between Māori ecological knowledge and ecology in the context of conservation and natural resource management, it is not strictly possible for this research to be guided entirely by tikanga. Nonetheless, this research has several kaupapa Māori research qualities. This research is guided by mātauranga Māori. Likewise, mauri, wairua, whakapapa and many other Māori values are effectively built into this assessment framework. By building this tool on a foundation of mātauranga and having mainstream science supporting the mātauranga, I hope that I am supporting rangatiratanga and kaitiakitanga and providing a safe space for the mātauranga, in a way that respects the knowledge and empowers and engages the iwi, hapū and kaitiaki, while enabling scientists to engage with the mātauranga. Given our colonial past, the interface between science and mātauranga Māori could be particularly important if we are going to reconcile the two epistemologies and preserve mātauranga as a living knowledge system (Stephenson & Moller, 2009, p. 139). It is a privilege to work in this space because being a Māori scientist requires a unique skill set, an ability to employ two-eyed seeing and I hope this adds value to both worlds.

Understanding the interface between mātauranga and mainstream science could be a necessary part of decolonising mātauranga, bringing it to the fore and making it a part of mainstream resource management. The knowledge gained from research in this space is transformed and transformative through understanding, creativity, inspiration and engagement (Cooper, 2012, p. 68). Indigenous-focused and kaupapa Māori research may enable us to re-examine our assumptions, perceptions, methods and procedures. It may improve cultural depth and interpretive ability. Kaupapa Māori research, such as was undertaken in the co-management example below, can be more flexible and favour biodiversity outcomes. Māori ecological knowledge, like other Indigenous knowledge bodies, adapts easily to changing environmental conditions and places a high value on biodiversity because of its wairua, mauri and whakapapa connections. This can better prepare us to face ecological challenges such as climate change (Ellis, 2005, p. 67; Houde, 2007, p. 10; D. H. Walker et al., 1995, pp. 224-245). It may yield insights into relationships and foster cultural understanding and development, giving voice to all and producing emergent approaches and perspectives (Schreiber, 2000, p. 667). Kaupapa Māori research that changes and grows the researcher personally, positioning the researcher as the learner and the participant as the expert, is truly decolonising research (L. T. Smith, 2012, p. 179; Shayne Walker et al., 2006, p. 336).

## Co-management

> Real power lies with those who design the tools – it always has (L. T. Smith, 2012, p. 40)

Co-management or co-governance is combining state control with local, decentralised decision-making and accountability (Carlsson & Berkes, 2005, p. 66). It involves power-sharing and is generally paired with adaptive management (learning by doing). Co-management is collaborative, cooperative and research is participatory (e.g. kaupapa Māori approaches). Decision-making will be fair and democratic and accountability will be conferred in communities (Berkes, 2009, p. 1700). Co-management should not cherry-pick or appropriate the Indigenous knowledge that fits scientific concepts, knowledge, or procedures (Stevenson, 2006, p. 172). Resource managers would benefit from considering the effects of past and current human actions and the economic value of sustainable use (Gomez-Pompa & Kaus, 1992, p. 273; Torri & Herrmann, 2011, p. 169; S. Weaver, 1997, p. 385). Establishing an effective co-management environment involves active participation from each side and extensive and deliberate negotiation, collaboration, consensus, problem-solving and trust-building. This takes time and two-way communication and places people and relationships first (Berkes, 2009, p. 1694).

Genuine co-management and power-sharing should reduce transactional costs, improve efficiency, share risk-taking, enhance long-term planning and improve linkages within and between organisations. Conflict resolution is improved and any lag between monitoring and management is removed (Carlsson & Berkes, 2005, pp. 71-72; M. J. Christie, 1990, pp. 60-61; G Harmsworth, 2005, pp. 5-6; Garth Harmsworth & Shaun Awatere, 2013; Hart, 2010, p. 4; Walsh, Dobson, & Douglas, 2013, p. 1). Society could gain and access untapped natural resources (medicines and food), decentralise management and experience a truly adaptive, diverse and locally appropriate management regime involving the entire community. Co-management may increase capability and develop mutual respect between participants (Hoffmann et al., 2012). Ultimately, resources will be invested in the community so that they can actively undertake the management of their own (Maldonado et al., 2016, p. 122). Effective co-management will require the involvement of government (central and local), tangata whenua and the community (Towns, Bellingham, Mulder, & Lyver, 2012, p. 1).

The key to true co-management is managing key relationships (Berkes, 2009, p. 1692). Co-management should consider cultural beliefs and recognise the Indigenous peoples' intangible and non-material values. It also should occur beyond the conservation estate and needs to include all landscapes, habitat types and tenure, but most importantly it should include the Indigenous community. The largest effort to establish effective communication comes from the non-Indigenous partner who must invest more in learning about the Indigenous partner. The Indigenous partner is already very familiar with the other (Hoffmann et al., 2012, p. 46). The less powerful partner generally comes from a position of disadvantage and successful co-management must establish, legitimise, formalise and strengthen the position of the less powerful partner (Carlsson & Berkes, 2005, p. 67). Co-management requires the 'jurisdictional authority' to relinquish a degree of power and guarantee the other party's rights and responsibilities, building their capacity to participate (Carlsson & Berkes, 2005, p. 60; Jollands & Harmsworth, 2007, p. 721). This may include providing security of tenure, organisational rights, financial resources and access to facilitation and support. Alienation from the management process may reduce interest, participation and buy-in on the part of the community and if the authority dictates priorities, there is an ever-present danger that monitoring will be seen as an expensive luxury item (Garcia & Lescuyer, 2008, p. 1309).

Hoffmann et al. (2012) described the outcomes of successful co-management with the Dhimurru Aborigines of Australia. The key success factors they identified were strong governance and leadership structures, strategy that was embedded in organisational structures, strong communication and inclusive decision-making. The benefits of co-management were increased capability for all participants and the development of mutual respect. The lessons learned from the co-management process included allowing plenty of time for relationship building. Project ownership should sit with the community as this installs commitment and empowerment. Also, avoid overcommitting and implement an adaptive management framework. The success of co-managing varies due to geographic location, the extent and the overlap between Indigenous and colonial jurisdictions, resource availability, the differing objectives, the level of trust and the underlying desire to engage.

The New Zealand Department of Conservation is aware of the need to include ecological, economic and social benefits in conservation management and are investigating using te ao Māori methods to achieve this (Minsitry for the Environment & Department of Conservation, 2016, p. 1383). Territorial authorities are also increasingly seeing the value of mātauranga Māori and are working to build co-management relationships with iwi to enable knowledge exchange, support Māori aspirations, enhance natural resource management and build iwi capacity (R. Burton, 2013, p. 1; Fenemor et al., 2011, p. 317; Forster, 2012, pp. 217-218; Minsitry for the Environment & Department of Conservation, 2016, p. 13).

The Greater Wellington Regional Council, for example, has implemented the Whaitua Programme (Ruamahanga Whaitua Committee, 2018). The region has been divided into five super catchments and committees have been tasked with developing a management policy and strategic direction for each of them. The committees consist of iwi, politicians, scientists, private citizens and landowners (farmers). This programme puts iwi at the decision-making table and as participants in producing the documents that will define the future management direction. Phase two will involve putting work plans in place to meet the management objectives. For example, the Ruamāhanga Whaitua committee identified the following as the primary principles for managing resources in the region (Ruamahanga Whaitua Committee, 2018, p. 13):

- Mahitahi – partnership and work, community and purpose
- Wairua and mauri – intrinsic value and identity
- Ki uta ki tai – natural resource management (mountains to the sea)
- To matou whakapono – knowledge, wisdom and information

Another example of the co-management experience in practice was discussed with me by PH. PH is the environmental officer for the Rangitāne O Manawatū iwi authority Tanenuiarangi Manawatū Inc. The Te Ao Tūroa Environment Centre is responsible for the iwi's co-management and co-governance relationships of waterways, particularly focusing on the

Manawatū River. They are involved in research, provide cultural responses and impact statements and have a small education role. There is a MoP (Memorandum of Partnership) with Horizons Regional Council and a MoU (Memorandum of Understanding) with the Horowhenua District Council. The Palmerston North City Council has now undertaken partnership relationships with the iwi under statutory obligation. PH has also served in the capacity of his iwi's cultural responder on national issues at the ministry level, assisting in writing the fisheries management document.

PH described the iwi link with the Manawatū awa and how the river's declining mauri is impacting on the iwi. The wairua of the Manawatū awa is linked to the wairua of the iwi. Impacts on the awa quality include farming, sedimentation and storm water pollution. According to PH, the health of the awa is the elephant in the room. Palmerston North City and Fielding Township are the two major contributors of pollution in the awa. According to PH, the iwi consent that the council gained for discharge was signed off by members of an iwi who were not mana whenua. The signatories were from Foxton and Otaki iwi and because of this, the status of Rangitāne O Manawatū iwi was ignored. PH thinks this was deliberate but it has been remedied post-settlement. Many wāhi tapu lie within city boundaries, causing ongoing sources of conflict. PH suggested that often the authorities do not incorporate cultural values because iwi values don't fit with their own philosophy and may threaten their power (consents and control of information). The distribution of resources is also problematic. 5.2 million dollars (NZ) was given to the council to manage the Manawatū River clean up; the source of this funding was not disclosed. The council hired staff and purchased vehicles, built information kiosks and collected cultural stories. They made the iwi contest the remaining funding on a project by project basis. This was not co-management with equality of power or resource distribution and the result is that the water quality did not change.

Any framework developed to assess environmental health should allow resource managers like regional councils to meet their statutory obligations under Te Tiriti and form effective functional co-management partnerships with the local mana whenua. Co-management projects with Māori should treat Māori as equals and be more than a 'tick box' activity, going beyond consultation and putting Māori in meaningful advisory roles that meet Māori agendas (Hardy & Patterson, 2011, p. 76; Taiepa et al., 1997, p. 237). Co-management and participation at governance and operational levels can reinstate tino rangatiratanga and kaitiakitanga (Forster, 2012; Wright, Nugent, & Parata, 1995, p. 85). Effective co-management involves two equal partners adopting the best practices from both epistemologies and is more aligned with how Indigenous cultures implement natural resource management (Minsitry for the Environment & Department of Conservation, 2016, p. 13). If Indigenous knowledge is ignored, we may fail to preserve both the knowledge and the environment (Tripathi & Bhattarya, 2004, p. 1).

## Case Study – the co-management of Tītī (*Ardenna griesus*)

Tītī, muttonbird or sooty shearwater *(Ardenna grisea),* is one of the only species of terrestrial animal permitted to be harvested for cultural reasons in Aotearoa. It is actively co-managed by the local iwi and the Department of Conservation. Tītī are classified as near threatened on the IUCN threat scale and the population has declined dramatically in the last decade, probably due to marine habitat degradation. Tītī are keystone species because they are ecosystem-engineers, creating extensive burrow systems (Scott et al., 2009, pp. 291-292). Government agencies, using expert advice provided by ecological scientists, have historically made the decisions about which species can and cannot be collected, with only limited input from Māori. This has been a bone of contention for many Māori, who feel the inability to harvest customary food resources has caused damage to their economic and cultural wellbeing and resulted in inappropriate management and loss of ecological taonga. The case of the tītī has allowed Māori to work alongside mainstream scientists and resource managers to prove that customary harvesting can be sustainable.

The Tītī harvesting grounds are called manu. Each Rakiura Māori family manages their own manu and are responsible for it. Only that family can access their manu and harvest there. There are unharvested areas on the Tītī islands that act as refugia, effectively alleviating the impact of harvesting on the population (Bragg et al., 2009, pp. 275-277). There are two harvesting periods. The first is the 'nanao' from 1 April to .c 20 April, during which young chicks are extracted from their burrows. The second is the 'rama' from c. 21 April to 31 May, when fledging birds are taken. A lot of work has been done to assess the impact of the Tītī harvest on the overall population sustainability (Bragg et al., 2009). What Bragg et al. (2009)

and P. O. Lyver (2000) learned about Tītī harvesting was that harvesters generally harvested from areas in the manu that are easily accessed with sparse vegetation cover, with less harvesting in the more protected areas. Harvesters judged harvest size and population abundance based on burrow occupancy and the physical characteristics of the chicks. It appears that harvesters are very accurate when determining which burrows had chicks in them and which ones did not (Kitson, 2004, p. 322), and were able to do this better (more easily, cost-effectively and more accurately) than by using burrow-scopes. However, the scientific modelling suggested that the harvesters may be overestimating the population size. This is yet to be confirmed.

Clucas et al. (2012) assessed 67 years' worth of harvesting dairies kept by Rakiura Māori that tracked the variation in the rama start date. They reported that the harvest was coordinated with the phase of the moon as this affected chick emergence and the developmental stage of the chicks. Harvesting was not done on bright starry nights or during a full moon as fewer chicks emerged at these times. The time of the moon was not considered in the scientific studies and this may have significantly affected the study results. Rakiura Māori are particularly good at assessing the weight of chicks from the thickness of the neck, prominence of the sternum bone and their responsiveness to approach (P. O. Lyver, 2000). The fact that the most developmentally advanced chicks (largest and longest wingspan) were taken needs to be accounted for when scientists model population trends and demographics (Hunter, Moller, & Kitson, 2000, p. 395). The scientists commented that they came away with a better understanding of what it was they did not know about Tītī.

## Conclusion

> These knowledge systems can be complementary, and it seems naïve to think that thwarting interaction between them would be desirable (Becker & Ghimire, 2003, p. 10).

In the Māori world-view, a healthy environment is the foundation of a healthy society, family, person and economy (G Harmsworth & Shaun Awatere, 2013, p. 278). This thesis will investigate how Māori assess the health of their environment and explore mātauranga Māori ecological indicators and concepts. This thesis will hopefully facilitate the return of Māori ecological knowledge to ecological assessments. Since He Kete Hauora Taiao includes many social and cultural indicators, it can facilitate the return of tikanga, kaupapa and tangata (culture, values and community) to ecological management. Understanding how Māori ecological indicators relate to mainstream scientific ones will be the primary focus of this thesis. This will facilitate the construction of a framework featuring both MEK and ERM and define what such a framework would look like and how useful it will be for environmental co-management.

To achieve the goal of integrating science and mātauranga Māori (MM), it will be important that He Kete Hauora Taiao is useful and therefore used by iwi and scientists. It will also be important that He Kete Hauora Taiao privileges mātauranga Māori, allowing Māori values to be expressed in a way that is understandable to scientists. Placing Māori ecological knowledge at the centre of an assessment framework could ensure that anyone using it will have to consider Māori values in their ecological assessments. In so doing, I adhere to two of the strategic directions for kaupapa Māori research described by L. T. Smith (2012, p. 195); extending the boundaries of our knowledge and educating the wider research community from the perspective of Māori knowledge.

In this chapter, I have described the way that Indigenous knowledge can provide social context to ecological data while science can provide the technology to study ecological processes, functions and physical attributes. I have discussed how my heritage has flavoured how I see the natural world and how my position as a Māori and trained ecologist can expand our understanding of the natural world and benefit resource management. I have described how my whakapapa and education give me a way to see both worlds and I have described how this 'two-eyed seeing' can improve our understanding of the natural world. We can obtain ecological context, social meaning, ethics and values from traditional knowledge. This traditional knowledge can be added to the unbiased, rigorous and detailed data ecologists seek to provide. Under this paradigm, we may gain our knowledge from science and our understanding from Indigenous knowledge. To understand the knowledge system of an Indigenous people, their cosmological paradigm should be understood. In the next chapter, I will explore some of the key features and concepts of Indigenous cosmology.

# Ūpoko Rua – Mātai tuarangi

# Chapter Two – Cosmology

> The RarPmuri philosophy of humans interconnected with nature seemed to form the underlying principle of resource use. The worldview recognizes a kinship between humans and nature, such that natural resources are respected and cherished as providers of life and energy. As Salmón (2000b: 193) suggests, 'their knowledge of foods and medicinal plants embodies their relationship and, therefore, their model of self-identification with their place and their manner of using what nature has offered (Larochelle & Berkes, 2003, p. 366)

Our interactions with the natural world are shaped by our cosmology (philosophy and spiritual system), ontology (belief or understanding system) and epistemology (theory and practice) (Torri & Herrmann, 2011, p. 174). The Ancient Greeks had a similar framework, the kosmos (cosmology or world view) – corpus (body of knowledge) – praxis (practice) complex (N. Barrera-Bassols, A. Zinck, J., & E. Van Ranst, 2006, p. 118; Pauli, Barrios, Conacher, & Oberthür, 2012, p. 195). For Māori, cosmology, ontology and epistemology are symbolised by kete o te wānanga, the three baskets of knowledge; Te kete tauri, Te kete aronui and Te kete tuatea. These baskets contain all or our cosmological, ontological and epistemological knowledge. Kosmos – Te kete Tuatea (spiritual realities). Corpus - Te kete Tuauri (Perceptions and understandings – paradigm) and praxis - Te Kete Aronui (tangible knowledge) (Keelan, 2014). Another Indigenous philosophical framework is the Wisdom – Knowledge – Information – data paradigm described by Mercier, Stevens, and Toia (2012, p. 24) which also echoes the KCP complex. Wisdom equates to kosmos, knowledge to corpus and information and data to praxis.

To understand and interpret ecology and resource management (ERM) and Māori ecological knowledge (MEK), the worldview or cosmological origin of these knowledge systems should first be explored. Then we may begin to understand how we interpret the world, our ontology. Our worldviews often underpin our rituals, myths and beliefs and hence our interpretation of what we see in the world. Once we understand the worldview and the lens through which we interpret the world, we may then be able to comprehend and appreciate how and why we interact with the natural world and to implement appropriate management practices. Understanding the cosmology of Indigenous knowledge and in particular Māori cosmology, is the subject of this chapter.

People usually explain the world around them, understand how things work and shape their relationship with the environment through the lens of their cosmology. Cosmology creates a cultural identity including language, information dissemination systems, ethics, values and our links to the land, cultural survival mechanisms and technology. These things contribute to the land use patterns and the way the community adapts to and manages environmental change and often dictate day-to-day practices. Empirical observations of the changes in spatial and temporal behavioural patterns of species in the ecosystem guide and inform our decision-making processes. 'Monitoring' the response of the ecosystem often validates the established cultural systems and cosmology, completing the feedback loop. Understanding environmental processes therefore should not be done in isolation from cultural epistemology. For example, for Australian Aboriginals' learning about the cycad palm not only involves simple plant identification but more importantly 'stories and demonstrations of its use as food, the complex preparation process, its ceremonial uses, the traditional accounts of its use in purification rituals, its manifestation in sacred clan designs and songs and its kin affiliations' (M. J. Christie, 1990, p. 64).

## Mainstream Western science

> …science provides ever more information about less and less until we know everything about nothing (Provenza, 2000, p. 33)

Mainstream science is a way of thinking, doing and being (Ellen, 2004, p. 442). It has evolved from a reductionist hypothetico/deductive paradigm (Bussey, Davenport, Emery, & Carroll, 2016, p. 98; Ellen, 2004, p. 443; Orzecki, 2010; Provenza, 2000, p. 33; Weiss, Hamann, & Marsh, 2013, p. 287). It is a journey into the workings of nature (Provenza, 2000, p. 33). A version of 'Western' science history is that it originates in ancient Greece and the Mediterranean cultures and is the study of the natural world using a European philosophical lens. Science has evolved an ethos that science and culture should not collude because this adds subjectivity and cultural values. Scientific investigation focuses on answering specific questions with carefully prescribed methodologies and interpretations (Barbour & Schlesinger, 2012, p. 39). Science is rational, academic, reductionist, deductive, inductive, mechanistic and quantitative (Berkes & Berkes, 2009, p. 11). It is communicated in written (and graphic) form, has multi-scale functionality from local to global, has methodologies that may be transferred spatially and temporally, employing interchangeable elements and it seeks a universal truth (Tütüncü, Hedrén, & Storbjörk, 2013, p. 28). It is generally linear, discrete, theoretical and specific and tries to remain unbound by social or economic pressures (G. Brown & Raymond, 2007; Reynolds, 2004, p. 223).

Science is a methodology embedded in facts and processes, from which conclusions and theories are drawn, tested and validated (Beven, 2009, p. 19; Cobern & Loving, 2001, p. 59). The scientific method is to observe, hypothesise, predict, experiment, monitor, evaluate, interpret and finally to report (Armitage, 2003, p. 80; Gomez-Pompa & Kaus, 1992, p. 272). Science understands trends, minimum and maximum target levels and ecological averages and may generate models to predict the future. We use scientific language, structure, formalisation and abstraction to discover underlying mechanisms and principles (Young, Harmsworth, Walker, & James, 2008, p. 27). Scientific monitoring methods are precise, straightforward, teachable and repeatable. Scientific knowledge is transferred across time, space and culture (G. Brown et al., 2004, p. 163; Ellen, 2004, p. 442). Science often improves our technology, skills and knowledge. It may enable us to understand objectively more about natural phenomena and the consequences of modifying systems (Beattie, 1995, p. 110; Stockdale & Watson, 2009, p. 312).

Science can be expensive, requiring specialised and skilled practitioners, technology and analysis in situations where the resource being investigated is being actively extracted (Brodnig & Mayer-Schonberger, 2000, p. 2; Moller et al., 2004, p. 2). Science provides an array of snapshots in time from which trends are inferred. Testing these models against others validates them (Young et al., 2008, p. 21). Peer review is concerned with observational rigour and the quality of the data. Understanding the implications of the knowledge is often secondary (H. Huntington et al., 2004, p. 20).

The legacy of science is the removal of humans from nature, separating us from wild spaces and concentrating on biophysical mechanisms (P. O. B. Lyver, Jones, & Moller, 2009, p. 220; Weir, 2012, p. 4). The realisation of a heliocentric universe emerged from a pure science paradigm and unleashed a wave of technological innovation, free from social, cultural, spiritual, religious and environmental considerations and constraints (Cobern & Loving, 2001, pp. 58-59). Western natural world cosmology comes from the philosophies of Descartes, Bacon, Aristotle and Kant, who all place humans as autonomous from and in control of the natural world (Pierotti & Wildcat, 2000, p. 1334). Good science separates facts from judgments. However, this is the fifth of Rev Frederick Donaldson's Seven Social Sins: 'Science without humanity' (Seven Socal Sins, 1999). Donaldson first spoke of the seven social sins in a sermon he delivered at Westminster Abby on March 20, 1925. In October of the same year, Mohandas Gandhi published the same list in the newspaper Young India. The seven social sins are wealth without work, pleasure without conscience, knowledge without character, commerce without morality, science without humanity, religion without sacrifice and politics without principle.

## A short history of modern science

> Fill the earth, and subdue it: Genesis 1:28 (Gomez-Pompa & Kaus, 1992, p. 272)

In the most often told version of events, modern Western (European) epistemology started in Greece, nearly 500 years before Christ, with Socrates, Plato and Aristotle. Socrates defined Western ethical traditions. Plato founded the first academy of higher learning and taught political philosophy and Platonic realism and then Aristotle, the 'father of Western philosophy' devised the Cartesian logic 'laws of thought' on which modern Western epistemology is built. Cartesian logic states that everything is either true or false. Plato had previously argued more of a fuzzy logic paradigm with shades of grey (Berkes & Berkes, 2009, p. 9). The Age of Enlightenment during the renaissance in the $16^{th}$ and $17^{th}$ centuries saw the decoupling of nature and religion (Aikenhead & Ogawa, 2007, p. 557). Prior to this, nature was regarded as God's creation, to be nurtured and cared for both spiritually and physically (Tütüncü et al., 2013, p. 7). Then came a new breed of philosophers and scientists, including Galileo, Descartes and Newton. It was Descartes, famous for the maxim 'I think, therefore I am', who introduced the idea of knowledge dualism, separating the subject and the object, man from nature (L. T. Smith, 2012, p. 50; Tütüncü et al., 2013, p. 7). These men founded empirical evidence-based modern science and they came into direct opposition with the authority of the churches and royalty (Hatcher et al., 2009, p. 142).

From the Sumerians, we got symbolic written languages. The Babylonians created early mathematics and astronomy. We got centralised advanced astronomy, mathematics and technology from the ancient Greeks. The Roman Empire gave us engineering and our Western education system. The Islamic scholars of the Golden Age furthered our knowledge in mathematics, natural science, engineering and medicine (Cole, 2017, p. 131; Hardy & Patterson, 2011, pp. 76-78). The Age of Enlightenment brought a new understanding of how the natural world functioned and engendered humanity's mastery over it (Berkes, Kislalioglu, Folke, & Gadgil, 1998, p. 413). In the $18^{th}$ century, Newtonian mechanistic theory was applied to the environment. Ecosystem process and biochemical cycles became mechanical, clockwork processes with gears and tipping points (Berkes et al., 1998, p. 412). The nineteenth-century saw the next conceptual leaps in Western knowledge.

William Whewell coined the term ‘scientist’ in 1834, thereafter placing scientists in a new academic and value context (Aikenhead & Ogawa, 2007, p. 545; National Public Radio, 2019). Haeckel contrived the term ecology in 1869 from the Greek word oikos, meaning ‘a place to live’. Ecology integrates biodiversity and the physical environment (Mazzocchi, 2008, p. 1). In the Twenty-first-century, ecological science increasingly views ecosystems as alive, imbued with non-linear processes, multiple equilibria, thresholds and system flips that are often unpredictable and uncontrollable (Berkes et al., 1998, p. 412; Young et al., 2008, p. 21). Ecosystems are now seen as existing in equilibrium (steady-state) or non-equilibrium (maintenance within a biophysical range). The analytical view of the natural world is progressively being replaced with a more systemic, adaptive and humanistic approach (Funtowicz & Ravetz, 1993, p. 739; Hardy & Patterson, 2011, pp. 76-78).

Because of the complexity and interconnectivity of ecosystems, ecologists often find transferring scientific experimental protocols to the field difficult. Science permits us to compartmentalise, fragment and analyse the world in microscopic detail and to generate copious amounts of data (G. Brown et al., 2004, p. 163; Provenza, 2000, p. 33; Thrupp, 1989; Watkinson & Ormerod, 2001, p. 234). The more science learns about the microscopic workings of the natural world, the more we are revealing the interconnectedness of everything (Provenza, 2000, p. 33). The compartmentalisation of knowledge, socially and intellectually, may be an outcome of knowledge specialisation and not unique to science. However, it may serve to isolate knowledge, making it difficult for knowledge specialists like scientists to interact with each other, the wider community and other knowledge systems and thus impeding their ability to interpret knowledge (Nadasdy, 1999, p. 6; Thrupp, 1989, p. 19).

## Traditional ecological knowledge

> He [An experienced hunter in Burwash Landing said] said that biologists do not know as much about the environment as they think they do, because if you put them out in the bush alone they would not be able to survive (Nadasdy, 1999, p. 7)

Traditional knowledge is a living philosophy, with elements of the sacred and the spiritual connecting people to the land and contributing to societal wellbeing (Cobern & Loving, 2001, p. 54; Hardy & Patterson, 2011, pp. 78-79; G Harmsworth, 2002, p. 5; Hatcher et al., 2009, p. 145; Hobson, 1992; Tsosie, 2012, pp. 1140-1141; K. Whyte, 2013, p. 5). Traditional ecological knowledge (TEK) is structured around the unseen powers in nature that connect all things (Hatcher et al., 2009, pp. 143, 145; H. Huntington et al., 2004, p. 19; K. P. Whyte, Brewer II, & Johnson, 2016, p. 6). The Indigenous world is often holistic and metaphysical and it has social constraints integrated into daily life and driven from a need to survive. The TEK cosmology has five facets: factual observations, management systems, culture and identity, ethics and values and knowledge systems (history, past and current use, oral traditions and teachings) (Agrawal, 1995, p. 8; Barnhardt, 2005, p. 16; Corsiglia & Sniveky, 1997, p. 2; Hatcher et al., 2009, p. 143; Houde, 2007, p. 5; Usher, 2000, pp. 186-187). Along with these five facets TEK has four tenets: we must respect non-human entities, we have a bond with the natural world, we are connected to place and that connection comes with ethical and behavioural responsibilities (Pierotti & Wildcat, 2000, p. 1335).

Traditional ecological knowledge consists of a varying array of the following characteristics. It may be subjective, qualitative, observational, longitudinal, intuitive, practical, egalitarian, incremental (cumulative), adaptive and locally detailed and verified (Aikenhead & Ogawa, 2007, p. 583; Berkes & Berkes, 2009, p. 8; Ellen, 2004, p. 443; Tütüncü et al., 2013, p. 28; Young et al., 2008, pp. 18-19). It is the knowledge of Indigenous peoples, local communities, farmers, growers and hunters. It links traditions, community values and environmental knowledge (Arowolo, 2011, pp. 8, 10; Tripathi & Bhattarya, 2004, p. 1; Wehi, 2009, p. 268). It is ostensibly a way of knowing and of doing that provides a conceptual framework for classifying the natural world from a social, cultural, spiritual, economic and technological context (Appiah-Opoku, 2007, p. 83; Cobern & Loving, 2001, p. 59; Howes & Chambers, 1979, p. 6; H. P. Huntington, 1998, pp. 237-238; Weiss et al., 2013, p. 287). It may span generations spent observing ecological patterns in animal and plant behaviour, distributions and health in response to environmental changes. It is obtained through observation and also extensive, utilitarian, continual and pervasive interaction with the environment on a daily basis (Berkes & Berkes, 2009, p. 10).

Traditional ecological knowledge generally relies on real-time observations and a deep understanding of how environmental changes affect biodiversity. It is essentially a spatial data system and people are its data nodes (Brodnig & Mayer-Schonberger, 2000, p. 3). Therefore it is extremely compatible with spatial databases such as geographic information systems (GIS) and the two can support one another. Indigenous knowledge broadens and deepens the community's understanding of the local environment on a fine geographic scale (Forster, 2012, p. 112; Usher, 2000, p. 187). Because it operates at a patch rather than an ecosystem level, Indigenous knowledge may reveal slow, coarse changes (Chalmers & Fabricius, 2007, p. 2; G. Oba & Kotile, 2001, p. 426). Indigenous monitoring is mostly done by harvesting, hunting and collecting plants and animals and paying attention to the timing of biological events (Cobern & Loving, 2001, p. 55; Ford & Martinez, 2000, p. 1249). If the harvesting ceases, the knowledge of the biology, abundance and habitat of the plants and animals also ceases (Larochelle & Berkes, 2003). Indigenous scientists generally have their own protocols that involve genealogical relationships and reciprocal responsibilities. Traditional ecological knowledge data collection is often relatively rapid, low cost and easily implemented by the users of the data collected and it is relevant to the community and the local environment (Moller et al., 2004, p. 2).

Traditional ecological knowledge is usually validated by experts in the community and does not require the same level of data accuracy, objectivity or reliability that satisfies scientific quantitative analysis. Traditional knowledge practitioners are often baffled by a scientist’s need to ‘count and measure everything’ because they instead read and interpret signs and signals from the environment in the context of ecological interactions (Berkes & Berkes, 2009,

p. 8). Traditional knowledge practitioners may not trust data produced by scientists because it is seen as taken out of context and conversely, scientists may find TEK observations too context-dependent to be useful at broader scales (H. Huntington et al., 2004, p. 19). Language is key to comprehending traditional knowledge and its significant cultural and ecological influences (Dei, 1994, p. 28; L. T. Smith, 2012, p. 160). The Amazon Indians have over 20 words to describe green and the Australian Aboriginal people have 12 names for waves (Verschuuren, 2006, p. 319). TEK is often perceived to be archaic or the preserve of the old, the rural, or the uneducated. Rather it is dynamic, adaptable, evolving and contemporary (Arowolo, 2011, p. 13; M. S. Reed et al., 2007, p. 264).

Berkes and Berkes (2009, p. 8) noted that in North America, traditional knowledge practitioners do not make simple linear or cause and effect models, as these are viewed as crude and unsophisticated and this may also be true for other cultures. Indigenous knowledge utilises a large number of less specific and multi-causal indicators, simultaneously providing a flexible cumulative mode using fuzzy logic (Berkes & Berkes, 2009). Fuzzy logic is a mathematical approach to complex systems that deals with approximations and missing, unreliable, uncertain and non-binary data and data connections. Fuzzy logic, like the human mind, categorises data in closely related, loosely defined groups, reducing its complexity (Berkes & Berkes, 2009, p. 9).

The Māori relationship with the natural world is generally adaptive and holistic and we aim to preserve the harmony, interconnectedness and the sacredness of nature (G Harmsworth & Shaun Awatere, 2013, p. 274). Indigenous resource management often includes humans and comes from the experience of kaitiaki and kaumātua (caretakers and elders), tikanga (practiced method), whakapapa (genealogy) and our bond to the land (Hardy & Patterson, 2011, p. 77). Mātauranga Māori (MM) involves many aspects of te ao Māori including reo, karakia, waiata, whakataukī and pepeha (language, prayer, proverbs and tribal sayings) as well as the cultural practices involved with rongoā, raranga, whakairo, kaimoana, mahinga kai, wānanga and tohunga (medicine, weaving, carving, seafood collection, gardening, teaching and becoming an expert) (G Harmsworth, 2002, p. 5). Mātauranga Māori is generally dynamic and evolving, adaptive and vibrant and remains highly valued and relevant to Māori, the nation and the world (Forster, 2012, pp. 103-104; G Harmsworth & Shaun Awatere, 2013,

p. 275; Keiha & Moon, 2008, p. 15). Mātauranga Māori can inspire creativity, honour and treasure the past, respond appropriately to new opportunities and shape the future and it should continue to adapt to modernity (Hardy & Patterson, 2011, p. 80; Stephenson & Moller, 2009, p. 145).

## Māori cosmology

> In Māori consciousness, land was part of themselves, in the same way that [a] hand or eye was part of them. Land was mother and their ancestor, it was viewed as integral part of their personal and group identity. At the same time, it was the prime economic resource in their subsistence economy….land is seen as the source of tribal and individual identity. Without land and a place to express that identification, a person is cut adrift. He / she has no past, no present and no future. Land is referred to as the cohesive force of the tribe…..If we want to survive as Māori's we can only do so as a group, unified by our land (Douglas, 1984, pp. 41, 73, 75)

Māori cosmology links the spiritual and material realms. Ecological processes are personified as the children of the sky father, Ranginui and earth mother, Papa-tūā-nuku. These children have names and personalities and all are connected with the environment. All life comes from Rangi and Papa. Their offspring produce natural resources. These gods/ecological elements are instilled with sentience and our relationship with them should be managed. Māori live in a world where the gods are also human and ancestors. Many Indigenous cultures anthropomorphise the natural world and represent deities physically in this world. Tibetans see their mountains as Gods and personify them (Xu et al., 2005, p. 3). In the Yukon, glaciers listen, have moods and can be angered by humans (Cruikshank, 2012).

For Māori, as with many other Indigenous nations, the environment is conceptualised as a set of integrated and interconnected systems and the universe is all interconnected (G Harmsworth & Shaun Awatere, 2013, p. 274; D. King, Skipper, & Tawhai, 2008). Anything done to the environment changes the mauri of the environment and the quality of the resources that the environment provides. As articulated by Michelle Thompson-Fawcett, to gain a sound appreciation for such an Indigenous environmental ethic, one should begin with a general understanding of the spiritual connections that Māori have with the natural landscape, as creation plays a fundamental role in Māori culture (Kawharu, 2002, p. 260). All interactions Māori have with the environment are governed by mythology, spirituality and values, with the sole purpose of sustaining the wellbeing of the environment and the natural resources on which the people rely (G Harmsworth & Tipa, 2006, p. 3).

Māori have generally had a deep understanding and awareness of ecological processes, albeit in a different way than ecologists. For example, Māori understood that water coming from Ranginui is eventually returned to Tangaroa in a cycle of generation, degradation and rejuvenation. This regeneration instils a living essence into the water. This view of water having a living essence is not easily comprehended or evaluated by ecologists. For Māori, freshwater is a taonga and essential to life. The mauri of the awa is instilled by the inorganic and organic elements that constitute it (Ruamahanga Whaitua Committee, 2018, p. 5).

## Ngā kete e toru - The baskets of knowledge

Tāne-nui-a-rangi collected three baskets of knowledge from the 12$^{th}$ heaven (R. Smith, 2014, p. 3). Te kete tuauri may be interpreted as the basket of knowledge, containing the spiritual and the doings of the atua. It is the knowledge of creation and energy patterns that frame our perception of the world (Moorfield, 2020). Te kete tuauri is defined by our worldview, our values and beliefs and the information we teach. It is our cultural knowledge. Te kete aronui contains the knowledge of the physical world – the knowledge before us (Marsden, 2003, p. 61). This basket represents the knowledge of ritual, literature and philosophy and is how we understand, interact with and interpret the world. Traditionally, Te kete aronui is the basket of peace, aroha, ritual, literature and the arts and relates to knowledge acquired through careful observation of the environment. To me, this kete represents the understanding mankind has gained through monitoring. Finally, Te kete tuatea holds the knowledge of agriculture, resource management and industry, along with the knowledge of evil and war. To me, this kete represents the doings of man embodied in the methodologies, tools and technology we use in our daily interactions with the natural world. It represents our assessment and interpretation of the world and how we model and predict outcomes of management practices. It is philosophically interesting to note that in the Māori worldview, resource use sits alongside evil knowledge that is harmful to man. Does this ontology show that Māori perceived the danger resource management poses to the biome? The necessity of using natural resources is generally not argued, despite the association with danger, evil and negative things.

There are many narratives around the baskets of knowledge. Cole (2017, p. 140) discussed the baskets of knowledge using the paradigm of energy flows. Te Tuauri represents the energy that exists beyond the world of darkness, Te Aronui is the inception of perception and Te tuatea is the world beyond space and time. This was expressed in terms of energy coming from nothing into a state of transformation and then existence. Knowledge can also follow this path, starting as the unknown and unknowable, then moving to a state of discernment, observation and perception, then finally understanding. The koru is used to symbolise Io's (Io is the great creator) latent and potential energy, the life principle, light and enlightenment. Io's energy flows from the heart of the koru through Rangi and Papa, to the atua and then to us (Henry & Pene, 2001, p. 235). Mauri is what we name that latent energy and it is what connects all life, instilling tapu and whanaungatanga (Forster, 2012, p. 24). Both the KCP Complex and the baskets of knowledge reflect the way our worldview influences our actions, through the way we understand the natural world. I have used these frameworks to interpret both worldviews, translating them into cosmology, epistemology and ontology.

### Kaitiakitanga and Whakapapa

> As minders, kaitiaki must ensure that the mauri or life force of their taonga is healthy and strong… Should they fail to carry out their

> kaitiakitanga duties adequately, not only will mana be removed, but harm will come to the members of the whanau and hapū... Thus a whānau or hapū who still hold mana in a particular area take their kaitiaki responsibilities very seriously. The penalties for not doing so can be particularly harsh. Apart from depriving the whānau or hapū of the life sustaining capacities of the land and sea, failure to carry out kaitiakitanga roles adequately also frequently involves the untimely death of members of the whanau or hapū (Selby, Moore, & Mulholland, 2010, p. 15)

According to G Harmsworth and Shaun Awatere (2013, p. 274), to acquire a deeper understanding of Māori cosmology and epistemology, you need to understand te reo and whakapapa. I would add kaitiakitanga to this list. Kaitiakitanga and whakapapa describe our relationship with the natural world and are best understood through the lens of te reo. For Māori, the connection to the land is literal. The question 'ko/nō wai koe, who are you?' translates to, 'from what river do you belong?' (Forster, 2012, p. 26). The word wai means water or river and koe means you. In Fijian, vanua describes a social group (family) and the land they occupy. This word may very well be the root word for the Māori words whanau and whenua (family and land) (Berkes et al., 1998, p. 412). For Māori, being a kaitiaki for the whenua involves being part of a living landscape, nurturing it and constructing an intimate understanding of the environment and an extensive set of environmental indicators.

The word whenua means both placenta and land, reminding us of our celestial ancestry, our connection to the land and that we are infused with the divine essence of Tāne (Forster, 2012, p. 25; G Harmsworth & Shaun Awatere, 2013, p. 276). The whenua and its health and productivity provide a person with identity and mana (Douglas, 1984, p. 73; Kawharu, 2002, p. 203). Hōhepa Kereopa of Waimana explained, 'So in the end we need to think of the land as ourselves and treat it like how we would want to treat ourselves' (Selby et al., 2010, p. 99). The day-to-day lives of Māori are often linked to the environment and we may feel bound to it. This spiritual, cultural and physical connection with the land may affirm a persons' identity and prosperity. Nurturing mother Papa-tūā-nuku is often viewed as a responsibility that connects you to your tūrangawaewae.

We all come from nothingness and our whakapapa is what locates people in time and space and is the expression of our genealogy (Te Rire, 2012, p. 60). Whakapapa begins with nothingness before Io-matua-kore created the tangible world. First to be created were the primeval parents, Rangi and Papa, who birthed the atua, who in turn created all the living creatures and ourselves (G Harmsworth & Shaun Awatere, 2013, p. 274). The departmental atua are the gods that have dominion over aspects of the natural world, such as the fish, the rains, volcanoes etc. Humans and non-humans share a common origin and to know your whakapapa is to know yourself (Whitt, Roberts, Norman, & Grieves, 2001, p. 3).

Because of the importance of whakapapa connections, iwi may have to consider how they will engage with organisms introduced for biocontrol or altered with biotechnology for pest control purposes. According to PH, a Rangitāne O Manawatū kaitiaki, his iwi is the only iwi to have recognised the huge potential of dung beetles. PH was responsible for introducing dung beetles into the Manawatū. He said that some members of the iwi were not happy with the idea of dung beetles on the wāhi tapu and this is an issue still being resolved. PH discussed the work he did while with Landcare Research Ltd. There, they worked on a biotechnology solution for the control of possums where possums would contract a gut parasite from infected faeces and become infected with an immune-contraception that is 99.99% effective. It was not used for fear that it might be introduced into Australia and destroy their possums.

Selby et al. (2010, p. 1) describe kaitiakitanga as an inherent, irrefutable obligation to our tupuna and our mokopuna. It links us to the past and the future, anchoring us in the natural world. Failure to kaitiaki reflects poorly on the whanau, iwi and hapū. We all have a kaitiaki responsibility, even if it is only for our small suburban section. We are all part of a society that collectively has a responsibility to bequeath our whenua to future generations in better condition than we received it. Ngāti Kahungunu refers to kaitiaki as the seeking of balance and the attainment of wellbeing through sustainable natural resource management (Selby et al., 2010, p. vii). JM, a Tūhoe kaitiaki and one of my interviewees, describes the link between whakapapa and kaitiaki. He explained that because he is Tūhoe, he can access Te Urewera and only people from Tūhoe, as mana whenua, have this access. He revealed that various hapū have specific areas of Te Urewera they are able to access and each hapū has areas of the ngahere designated for hunting and areas strategically planted with food tree crops.

TM is a kaitiaki of Taranaki iwi in the Wellington region and describes what being kaitiaki actually means. Her iwi are the mana whenua for Matiu/Some's Island and TM is a practicing kaitiaki for the island. She explains that being a kaitiaki is a privilege achieved by intimacy with the land and involves knowing the substance of the land. Being kaitiaki and putting their house in order is a matter of mana for her iwi. She and her single, childless sisters put in more hours on the island than other iwi members because they have the time to do so. They do everything from maintenance, cleaning, cooking and publicity right through to ecological management (including removing dead possums that wash down the Hutt River and onto the island following a 1080 operation). An important aspect of being kaitiaki is connecting people to the land. TM describes how she can feel the energy of the land changing when there are people and communities involved. She says 'the island pulsates differently when you connect people to the place'. TM contends that highly-keyed and stressed visitors affect the behaviour of the animals and maintains that the animals don't like the high energy people. TM asserts that kaitiaki have to protect the energy of the plants and animals that live there. Because of this, TM doesn't use perfumed toiletries when visiting the island because perfume is 'sickly' to the animals.

TM argues that the animals are her bosses and as a kaitiaki, she must do what they require. She has noticed that bird activity on the island has declined in recent years and suggests that some of the birds may have migrated to the mainland. She also says that the number of Cook Strait Giant Weta (*Deinacrida rugosa*) appears to have declined. She thinks that the weta have moved away from where they were released and initially reported. She doesn't know the details of any weta monitoring done by DoC or other researchers, as she doesn't receive any of these reports and results. She does hand searches to find weta to show to visitors and used to readily find them. Now they are nearly impossible to find and the ones they find are smaller than they once were.

Kaitiaki and whakapapa may provide us with a sense of place and this sense of place provides spatial value associations. The greater the knowledge of a place a person has, the more values they may assign to that place (C. Raymond & Brown, 2011, p. 655). A study by G. Brown and Raymond (2007) used regression analysis to show that 'special places' are correlated with aesthetic, recreation, economic, spiritual and therapeutic values, creating place attachment. People may value places because these places are associated with relationships, valued objects, or experiences (C. Raymond & Brown, 2011, p. 656). Place attachment and the values that are important to people may vary depending on the culture of the people involved (G. Brown & Raymond, 2007, pp. 89-90; G. Brown & Weber, 2012, p. 318). The association of the observer to the place and their attachment to and understanding of a place drives their perceptions of risk to the environment and their willingness to accept damage (C. Raymond & Brown, 2011, p. 653).

Those that stay on the whenua and keep the home fires burning, the ahi kā, have become responsible for maintaining the hapū connection to the whenua and generally are more involved kaitiaki (Bargh, 2017, p. 16; Forster, 2012, p. 12). According to TM, a kaitiaki for Wellington-based Taranaki iwi, urban Māori trying to reconnect to their ancestral whenua have a hard time. As an individual, you are alone; it may be hard to find allies and 'the iwi check you out' and scrutinise you when you go back to the marae and try to reconnect. Can non- Māori become kaitiaki if iwi and hapū members retain the mandate, if not the practice, of kaitiaki? My feeling is that non-Māori can become kaitiaki but may not have the authority that whakapapa to the whenua affords iwi and hapū.

## Indigenous ecological knowledge and mainstream science

> Because even the 'purest' science is laden with values ... (Beattie, 1995, p. 111)

Both ecology and resource management and traditional ecological knowledge (TEK) employ habits of the mind, such as curiosity, honesty and trust. Both use empirical observations, pattern recognition and inference and both are adaptable and repeatable (Barnhardt, 2005, p. 16; Corsiglia & Sniveky, 1997, p. 2; Gagnon & Berteaux, 2009, p. 1; H. Huntington et al., 2004, pp. 18-19). We all note important variables and patterns and we create an extensive database of knowledge (Cobern & Loving, 2001, p. 55). As a community, we constantly test the reliability of our observations and our observers and over time hone our understanding (H. Huntington et al., 2004, p. 19). Both ecology and resource management and traditional ecological knowledge recognise successional dynamics, fluctuating ecosystem services, species interactions, taxonomy, sustainability, adaptive management and disturbance regimes in the environment (K. Whyte, 2013, p. 6). From traditional ecological knowledge, we get an understanding of animal migrations, catch per unit effort and body condition. Using ecology, we may infer prey/population dynamics and generate population models (Moller et al., 2004, p. 1). Scientific trend analysis can detect small changes in overall trends, while traditional ecological knowledge is particularly adept at assessing the impact of adverse events because data is not averaged, which removes the influence of outlier observations (Moller et al., 2004, pp. 4, 9-11).

Traditional ecological knowledge and ecological science and resource management may complement one another and improve management outcomes (Mark S. Reed, Dougill, & Baker, 2008, p. 1253). However, traditional knowledge and ecological science are different and should be kept distinct to preserve the mana of each. They each require their practitioners to possess distinctive knowledge, values, skills, etc. (K. Whyte, 2013, p. 6). There is no blanket approach to the scientific discipline of ecology, no standard epistemology and no absolute knowledge set (Barbour & Schlesinger, 2012, p. 37).

### Sacred ecology - When ecology becomes spiritual and sacred

> The sacred ecology refers to the interactions between humans and nature in a particular landscape in this life and the next. Sacred ecology emphasizes that human beings are part of the ecosystem and that all life is equal in terms of power, skill and moral responsibility (Xu et al., 2005, p. 9)

For many Indigenous people, the environment has its own spirit. Humans are a part of the natural environment and their management of the environment must be holistic, respectful and harmonious. The environment is often seen as a living system instilled with its own spirit that humans are a constituent part of (Berkes et al., 1998, p. 410; Gomez-Pompa & Kaus, 1992, pp. 271-273; Whitt et al., 2001, p. 4; Xu et al., 2005, p. 11). Humans fill their own ecological niche and influence ecological integrity, functions, processes and services (C. M. Raymond et al., 2013, p. 539; Salmón, 2000, p. 1329). We may see ourselves as located firmly as part of the ecosystem and not separated from it. The environment may sustain social and cultural health (Bakhtiar, Choy, Mohd. Noor, & Salleh, 2010; Weir, 2012, p. 3). We are not external observers or mere beneficiaries of ecosystem services (Hermann, Schleifer, & Wrbka, 2011, p. 18).

The Indigenous peoples of Australia describe the living environment as occupying the centre of a network consisting of culture, society and the land (Walsh et al., 2013, p. 3). There is no wilderness because it is always someone's home. Humanity may be considered part of the natural world and members of an 'extended ecological family' with common ancestral origins. Indigenous people may learn from their encounters with the natural world and value animals as teachers and equals (Watson & Huntington, 2008, p. 272). Interacting with the environment means belonging to that environment (S. Weaver, 1997, p. 389). This ontology is even reflected in the architecture and building design. An example is roofing tiles styled like fish scales in India (Gupta, 2007, p. 338). Indigenous people often nurture their place through traditional management and knowledge systems.

If we do not practice self-discipline and live in harmony with nature, cherishing it, protecting its diversity and not taking more than is needed, we may risk harming it, just as a storm or fire does (Holling & Meffe, 1996, p. 334; Larochelle & Berkes, 2003, pp. 367-368; Xu et al., 2005, p. 10). This means acknowledging and accepting human impacts and weighing management actions against ecological and societal outcomes (Pierotti & Wildcat, 2000, p. 1336; Xu et al., 2005, p. 10). Removing humanity from the environment endangers biodiversity, commodifies the natural world and removes ethical and moral obligations to the biota, our ancestors and our descendants (Houde, 2007, p. 9; Salmón, 2000, p. 1327). For many Indigenous people, ecological domains are interconnected, include people and are not managed in isolation. Integrating them improves natural resource management and the wellbeing of the people (Walsh et al., 2013, p. 1).

Many Indigenous cultures treat facets of nature as deities and ascribe them anthropocentric attributes. Ecological processes and features may be instilled with the qualities of living beings with familial relationships with the people living on the land. Rivers become 'mothers' and antelope become 'brothers'. The Arrernte Aboriginal peoples talk to the birds and let them know things (Walsh et al., 2013, p. 13). This does not mean that resources such as antelope cannot be used, only that it must be done with respect and in the proper way. These metaphysical links to physical elements are what connect us to the natural world (Salmón, 2000, p. 1331).

Identifying the land that nurtures us as female is common to many cultures. For Māori, she is Papa-tūā-nuku, the earth mother. The Indonesian Banawa-Marawola people say Tanaku Indoku, Umaku Langi - the land is my mother my father the sky (Armitage, 2003, p. 85). For Europeans, she is Gaia, the sacred feminine symbol of the holism of ecosystems and ecology. For others, she is/was 'the monstrous feminine' that will absorb and smother the virile masculine who is/was obligated to tame, possess and render her fertile through force if necessary. Hamer (1992, p. 45) said 'the masculine has unquestioned God-given right to subdue or cultivate the feminine'. The rape of the land is still spoken of by environmentalists and not by accident (Hamer, 1992, p. 44).

Hames (2007, p. 184) examines whether the sacred ecology ethos prescribed to TEK practitioners arises from a true preservationist conservation ethos or if it is a form of savvy resource management and can be attributed to low population pressure. Both views are probably correct. While some aspects of TEK cosmology and epistemology are directly pertinent to resource management and conservation ideals, others are not. TEK is neither infallible nor is it valueless and irrelevant when it comes to sustainable resource management (Johannes, 1993, p. 37). Tierney et al. (2014) argue that most hunted or harvested species are generally the least threatened, the most abundant, productive and easy to obtain. These resources may be utilised because they are already the most abundant and productive species, but good management contributes to keeping them this way. The exploitation of a resource (animal or bird) is based on how hard it is to catch (effort), how abundant it is (encounter rate) and the 'return on investment' or how nutritious or large the resource was (gain/benefit). This is the harvest per unit time maximisation in the Optimal Foraging theory

(Adamowicz et al., 2004, p. 150; Alvard, 1993, pp. 356-357). Optimal foraging theory assumes that hunters act to maximise short-term resource gain rather than for conservation (Alvard, 1993, p. 368)

Indigenous people are not immune to mismanaging natural resources and have depleted resources in the past. However, in general, they have been able to maintain and preserve biodiversity and resources. Low population density and their values and beliefs around environmental respect and resource use constraint may have facilitated this outcome (Torri & Herrmann, 2011, p. 170). This is possibly also in response to the immediate loss of megafauna that appears inevitable following human contact. I do not want to over-romanticise Indigenous peoples' relationship with the environment. Anyone can destroy their environment, particularly when also coping with low socioeconomic status, poverty and social disorder (Thrupp, 1989, p. 15; Torri & Herrmann, 2011, p. 175). Idealising Indigenous science and consigning it to pre-modernity may separate and stereotype it, ascribing the dominant culture's attributes and epistemology to it and defining it as an 'other' (Satterfield et al., 2013, p. 105).

## Cultural landscapes

> Cultural landscapes are the interface between nature and culture…and are the essence of culture and identity (Schaich, Bieling, & Plieninger, 2010, p. 271)

Landscapes are socio-ecological systems reflecting human perceptions, values, needs and agendas (Hermann et al., 2011, p. 18; Stevenson, 2006, p. 173; Tripathi & Bhattarya, 2004, p. 4). This is a society's cultural landscape and Indigenous people live in a cultural landscape of their own construction. A cultural landscape is a physical representation of human society and culture and the community's interaction with the environment (Bakhtiar et al., 2010; Stephenson, Bauchop, & Petchey, 2004, p. 119). Cultural landscapes differentiate the areas people live in, where they interact with the environment (hunt, fish, farm, harvest, etc.), where their valued sites are and how they interact with landscape features (Willemen, Verburg, Hein, & van Mensvoort, 2008, pp. 34-35). The disappearance of mahinga kai sources and the lack of access to customary harvesting sites may sever the bonds to our knowledge base, customary practices and communities and diminishes the value of the cultural landscape (G. Tipa, 2009, p. 108; G. T. Tipa, 2013, p. 56). The capacity of the land to sustain the people diminishes and new relationships with the land may need to be forged (Forster, 2012, p. 41). Māori once relied solely on the food they harvested from the forest or gathered from the sea, apart from small scale kumara cultivation.

## Conclusion

> ….we need to recognize that human populations are an integral part of ecosystems and must be included in studies just like other key species. The prevailing view of Homo sapiens as somehow detached and insulated from ecosystem processes is outdated and dangerous (Armsworth et al., 2007, p. 1384)

The essence of the Indigenous worldview, including that of Māori, is that nature is sacred, humans are part of nature, humans should live in harmony with nature, the entire planet is alive and technology should be low-impact (Cobern & Loving, 2001, p. 56). This means we become a part of a living landscape (Gomez-Pompa & Kaus, 1992, p. 277). Through centuries of interacting with the environment, Māori have gained a wealth of ecological knowledge. The basis of Māori ecological cosmology is whakapapa and kaitiakitanga. Whakapapa describes how individuals are connected to the land and may define how we perceive environmental elements. Kaitiakitanga defines Māori responsibilities and obligations to the land commuted by our whakapapa and defines our management of natural resources. Indigenous cosmology helps construct the ecological indicators we use to assess the state of the environment which informs management decisions. In this chapter, I have described Indigenous cosmology, from which a well-tested set of environmental indicators originates. Indigenous environmental indicators are very much related to the relationship that the people have with the land and draw on spiritual, cultural and social values (D. King et al., 2008, p. 385).

The next chapter will translate cosmology into a natural resource management paradigm. I will explore how these respective cosmologies translate into resource management practice. This means exploring the two epistemologies and ontologies. For ERM this means examining integrated and adaptive resource management, restoration ecology and conservation management. For TEK this means exploring hunting, agricultural and forest management practices, rules of thumb and taboos, among other things. Understanding the respective ontologies is the basis from which we may understand and explain the epistemologies and the ecological indicators used to assess our interactions with the natural world. These indicators are an important aspect of He Kete Hauora Taiao because they are what quantifies our interactions with the natural world, providing a way to define the impact of what we do. Understanding the origin of the MEK and ERM indicators may enable the linking of the two and the construction of a bridge between MEK and ERM that will support He Kete Hauora Taiao.

# Ūpoko Toru – Āhuatanga taiao
# Chapter Three – Ecological monitoring and resource management

What gets measured gets managed (P. J. Burton, 2014, p. 153)

Resource and ecological management and monitoring are generally triggered by some change in the state of an ecological system. The triggers that cause people to want to monitor or manage an aspect of the natural world can be changes to species, communities, ecosystems, or landscape-level patterns (Brownstein et al., 2015, p. 106). Once a trigger stimulates the implementation of a management programme, the management regime should be identified. This usually involves a cost/benefit analysis and an assessment of the value of the ecosystem or biodiversity that is being affected. Management actions can range from passive monitoring (i.e. the *status quo*) and protection to allow passive restoration (natural recovery), to active afforestation and rehabilitation (rebuilding of biodiversity and community structure and composition)(P. J. Burton, 2014, pp. 149, 151).

According to Binoy and Radhakrishna (2013, p. 757), many resource managers make decisions on management goals and programmes based on stakeholder preference (typically by majority rule), cost/benefit analysis, risk assessments and scientific monitoring and modelling. Barrows et al. (2005, p. 1335) suggests ecosystem management should focus on ecosystem threats and preserving ecological integrity (Barrows et al., 2005, p. 1335). Holling and Meffe (1996, p. 334); Potschin and Haines-Young (2013, p. 1054) suggest that we should do this using an integrated management approach with a minimal intervention rather than command and control style management that is focused on management effectiveness.

In this chapter, I will explore mainstream resource management and ecological assessment epistemologies and probe their underlying cosmology. This chapter describes how mainstream resource managers value ecosystems and the valuation frameworks that are employed to prioritise cost and resource management programmes. Monitoring strategies, tools and techniques are also reviewed. The first step in implementing a resource management programme is to define the management objective. Once the management goals have been decided upon, measures of success may be identified. Subsequently, the monitoring programme required to ascertain success may be developed. The monitoring program will define the sample unit type (plot or point), quantity required and the monitoring frequency and if plots are used, their size and shape. The monitoring programme will require data storage, data analysis, programme evaluation and report progress relative to milestones and targets set out in the management plan (B. J. Biggs & Kilroy, 2000, p. 4; Block, Franklin, Ward, Ganey, & White, 2001, p. 295).

## Resource management in mainstream science

Resource management programmes usually involve manipulating some aspect of the natural world. Some resource management programmes become formal experiments with proper controls, replicates and randomised application of treatments and sample points. The experimental control can simply be the unmanaged initial state prior to intervention, or it could be another ecologically similar habitat that remains in an unmodified state, although these can be difficult to find (Block et al., 2001, p. 297; P. J. Burton, 2014, p. 149). Four ecological tasks are the underlying goals of mainstream natural resource management (Towns et al., 2012, p. 1). The first is the preservation of ecological representation (preserving biodiversity and habitat diversity), the second is building resilience (imparting resilience to perturbation), thirdly, installing redundancy (providing ecological capacity), and lastly, restoration (restoring ecological function) (Tear et al., 2005, p. 847). These are the four R's of ecological management: representation, resilience, redundancy and restoration. To achieve these goals, resource management programmes focus on ecosystems (protected areas), populations (focal species), or outcomes (with distinct operational targets) (Barrows et al., 2005, p. 1334).

How we decide on management strategies for our natural resources is often defined by our cultural cosmology and valuation framework. According to C. M. Raymond et al. (2013, p. 539), five resource management models define our resource management epistemology and sit on a continuum from command and control to ecological reciprocity. The first resource management model is Ecosystem Production. The ecosystem is viewed purely as a provider of services for us and the management goal is to maximise these benefits. The second model is The Closed Loop, where the ecosystem is viewed as a set of stocks flowing between humans and the environment. The third model is Stewardship, where we manage the ecosystem from the position of a legal and moral obligation. The fourth model is the Web of Life. In this model, we are part of a vast web of life and management involves managing all these interconnections. The fifth and final model is the Ecocultural Community, which places humans at the centre of a network that includes the ecosystem and the social and spiritual realm.

Four of the most commonly used natural resource management paradigms - Integrated Catchment Management, Adaptive Management, Restoration Ecology and Conservation Management - all fit the stewardship model best. Integrated Catchment Management attempts to manage all the connected ecosystems in a water catchment, from the mountains to the sea. Adaptive Management operates on feedback loops, continually adjusting management as the environment responds. Restoration Ecology is the ecology of restoring the damaged ecosystem connections that form the web of life. Conservation Ecology is the preservation of threatened ecosystems or species using our legal levers and guardianship obligations. These management paradigms are not mutually exclusive and more than one management approach may be applied simultaneously.

## Integrated Catchment Management

Integrated Catchment Management involves the management of the watershed as a distinct spatial unit, from its origin in the mountains to where it joins the sea. Generally, a catchment is the watershed of a river but may be as small as the watershed of a single waterway, such as a stream. Integrated Catchment Management is intended to provide ecosystem and community resilience at a catchment scale and improve decision-making. Such management integrates all the social, economic and ecological needs of the communities living in the catchment (Fenemor et al., 2011, p. 313). Many territorial authorities in Aotearoa are now moving more towards whole catchment management because it is one of the most effective management units for the preservation of biodiversity. First Nations have been practicing catchment management for centuries. The ancient Greeks, Turks, Swiss, Japanese and 16$^{th}$ century Chinese all practiced catchment management. Their management areas often extended to include the adjoining sea. The Fijians call these catchment management areas Vanua; the Japanese have Iworu; the Mali have Dina and the Indonesians have Tambak (Gadgil & Berkes, 1991). Catchments can become associated with the family groups or tribes living there and these familial associations become embedded in the communities' identities and culture (Berkes et al., 1998, pp. 410-411).

Integrated Catchment Management involves managing for the retention of endemic diversity and the natural hydrology of a watershed. It involves strategic land use and has a strong social and political component (Holling & Meffe, 1996, p. 334 ). Catchment management often requires managing the impacts of agriculture. Agricultural intensification frequently results in poor water quality because the typically increased input of nitrogen, phosphates, faecal contaminants and suspended solids to waterways. Integrated Catchment Management plans may require farm practices to change, for example, reducing stock numbers, moving away from monocultures and reducing the application of stock effluent and fertilisers to land. In addition, using feeding pads to keep cattle off soils during wet periods and riparian plantings may both significantly improve catchment water quality (Houlbrooke et al., 2009, p. 324; Wilcock et al., 2009, p. 803).

### Adaptive management

A primary goal of resource management is resilience and sustainability. Adaptive resource management models are based on feedback loops, thresholds and maintaining structural processes and diversity (C. Allen, Cumming, Garmestani, Taylor, & Walker, 2011, p. 337). Adaptive management involves observing, establishing goals and objectives and defining management policies. These plans are then embedded into flexible institutions and organisations to monitor, review and re-evaluate management outcomes and strategies (Armitage, 2003, p. 80; Duru et al., 2015, pp. 1270-1271; Jones, Allen, & Cowen, 2012, p. 36). Adaptive management relies on feedback, both positive and negative, from continually adapting system components moving towards homeostasis (C. Allen et al., 2011, p. 344). Adaptive management is considered to be dynamic, systemic (operates at a system level), and 'intelligent' as it allows for continual learning and it is outcome-focused (Scarlett, 2013, p. 2). One of the greatest strengths of adaptive management is that it evolves (Berkes & Berkes, 2009, p. 7).

Using adaptive management enables us to acquire a wider range of perceptual and cognitive skills and knowledge and provides transparency in decision tools. It is robust and permits multiple objectives and pressures (Folke, Hahn, Olsson, & Norberg, 2005, pp. 348, 356; Larson, Belote, Williamson, & Aplet, 2013). The observational, empirical and modelled data it generates provides a deep understanding of populations, communities and ecosystem functions and services (Barrows et al., 2005, p. 1334). Policies and goals are treated as testable hypotheses, have management programmes and are approached like experiments to find the best solution to ecological uncertainty (Carlsson & Berkes, 2005, p. 67). Adaptive management is ‘learning to manage by managing to learn’ (Beven, 2009, p. 240). The benefits of adaptive management have been realised by Western resource managers since the 1970s and it is now widely advocated (Brownstein et al., 2015, p. 106). Many management ontologies, including that of Māori, may be classified as adaptive management. Indigenous people seek to identify the outcomes of their actions and adapt management to their traditional practices and beliefs.

## Restoration Ecology

Habitat restoration is a goal often undertaken by resource managers, who may even attempt to return ecosystems to a pre-human state (Victoria A Froude, Rennie, & Bornman, 2010, p. 337). Often, restoration management aims to restore stability to a forest, assisting with regeneration and accelerating ecological succession. The initial primary plant colonisers and subsequent successional phases culminate in a complex assortment of emergent canopy and shade-tolerant species resilient to perturbation. Planting late-successional or nurse species and excluding animal stock are often primary tools used to achieve restoration (Aerts & Honnay, 2011, p. 2). The Bora also utilise natural succession and mimic it by planting annuals, root crops and later bananas, before finally planting forest tree species. They utilise the resources produced in all phases. This method does not deplete soil fertility and limits erosion, causing little damage to the landscape (Berkes & Davidson-Hunt, 2006, p. 37).

Restoration should be done from a biodiversity/ecosystem function point of view, rather than being focused on a single species. Habitat restoration using species-led programmes might only be effective if multiple species are involved and ecosystem restoration values are maximised (Cullen, Moran, & Hughey, 2005, p. 311). Restoring ecosystem function requires the presence of multiple species (Aerts & Honnay, 2011, p. 3). Restoration management is a countermeasure to replace what is lost but can often only partially mitigate the damage (Gomez-Pompa & Kaus, 1992, p. 271). Restoration management is a long-term strategy. It takes an average of 400 years for mature forests to replace bare land (Carswell et al., 2013, p. 530). Given the long-timescale of forest restoration, management planning should consider the role of disturbance events and natural renewal. Restoration management plans may apply natural or anthropogenic disturbances and including fire, floods, landslides, pest infestations, windfall trees or clearcutting.

Forest succession is not unidirectional and the more stages concurrently present, the more biodiversity and ecosystem functionality supported. Ecological management now considers the importance of managing community assemblages to allow species to re-establish following management intervention. Monitoring of restoration plantings of pohutukawa (*Metrosideros excelsa*) on Tiritiri Matangi Island found that they suppressed native plant and bird diversity (Forbes & Craig, 2013, p. 346). Studies have shown that it takes three years before restoration plantings were colonised by some frugivorous forest bird species (Jansen, 2005, p. 280). Highly mobile generalist species are the first to utilise restoration plantings, taking two years (Jansen, 2005, p. 280). Specialised insectivorous bird species may not use restoration plantings until there is a well-developed leaf litter and trees become mature enough to support a good supply of food insects. These conditions took 8-17 years to develop in the Australian Northern Queensland rainforests (Jansen, 2005, p. 281). Plants that are planted in a restoration programme should be eco-sourced genetic stock endemic to the local area. This means species should be planted within their natural range or habitats. This is because local plants are adapted to local conditions and may retain genetic diversity that underpins unique phenotypes or phenologies that are adaptive to local conditions (e.g. resistant to disease) (Porteous, 1993, p. 12).

## Conservation management

> In the real world, conservation of forests and justice for biodiversity cannot be achieved until conservationists incorporate other peoples into their own moral universe and share Indigenous peoples' goals of justice and recognition of human rights. (Alcorn, 1993, p. 426)

There are two types of conservation programmes; site and species led. Site led programmes involve conserving/protecting high-quality habitat subjected to minimal human impacts. Species led programmes concentrate on reversing the decline of a particular species. Terrestrial conservation management programmes in Aotearoa usually involve restoration planting and multispecies pest management (Cullen et al., 2005, p. 315). Species led management programmes often revolve around charismatic rare species with high conservation status and may not address ecosystem loss (R. J. Holdaway, Wiser, & Williams, 2012, p. 620). Despite this, common species often play a much larger role in ecosystem services, functions and processes, even in production farming contexts (Herzog et al., 2013, p. 53). Site led programmes involve setting up conservation areas that are managed to exclude or control human activity in the area. These sites are often physically contained with fences or natural geographical barriers such as mountains or rivers. The common philosophy is that preserving the most threatened ecosystems will preserve threatened species and the most threatened ecosystems should be prioritised (R. J. Holdaway et al., 2012, p. 627). The ring-fencing of conservation areas or individual species may mean other sites or specie are abandoned (S. Weaver, 1997, p. 390). In Aotearoa, some of the most significant biodiversity gains may be achieved by restoring biodiversity on privately owned lands, such as in the 'halos' of biodiversity surrounding urban sanctuaries and on the alluvial plains. Most of our conservation estate is in the highlands and is already well protected and managed (Carswell et al., 2015, p. 206).

Conservation is often an expression of human values, attitudes and actions (Gomez-Pompa & Kaus, 1992, p. 271; Kareiva & Marvier, 2012, p. 963). Wilderness areas are seen as areas that humans can only visit and they remain pristine free from human interference. Preservationist ecology involves locking a selected area away from human interference to conserve it and is often included in legislative frameworks (Berkes et al., 1998, p. 413). 'Conservation is often viewed as alternative to productive land use' and is generally deemed suitable for unproductive land otherwise of little value (Speden, 2008, p. 11). Conservation science seeks to understand the requisite size, shape, area, carrying capacity, connectivity, etc. required to effectively protect an ecosystem or species (Torri & Herrmann, 2011, p. 174). Conservation science draws from various fields, including social science, genetics, ecophysiology, hazard evaluation, natural resource management, historical biogeography, population and physiological biology, agriculture, anthropology, climate science, ethics and public health and policy, to name a few (Kareiva & Marvier, 2012, p. 963).

Conservation managers are now often the gatekeepers to land that used to belong to Indigenous communities (Alcorn, 1993, p. 426). Excluding Indigenous people from sequestered forests and parks and banning harvest is generally foreign to most Indigenous people and contradicts well established and effective management techniques (C. D. Becker & K. Ghimire, 2003, p. 44; Duffield, Gardner, Berkes, & Singh, 1998). Conservation that ring-fences and locks away parts of the natural world may alienate Indigenous people, including Māori, from ancestral lands and our kaitiaki responsibilities (Berkes et al., 1998, p. 413). This type of management clashes with the Māori ecological epistemology of connectedness and erodes our whenua relationship (Funk & Kerr, 2007, p. 205). Many Māori feel we are not trusted to be environmental managers and that our customary use is viewed as plunder if conceded to (Ellison, 2006, pp. 88-89). Conservation using both cultural perspectives together would enrich our lives and our ecology (Gomez-Pompa & Kaus, 1992, p. 277; S. Weaver, 1997, p. 384). One of my kaitiaki interviewees, PH, a member of Rangitāne O Manawatū iwi, spoke about the locking up of ngahere resources in DoC estate removed access by his iwi to important food and medicinal resources.

OM, another of my interviewees, raised some interesting observations about modern scientific conservation management, particularly in an urban landscape. Urbanisation, fragmentation and privatisation of the land poses novel management problems She commented on how the establishment of Zealandia (formally Karore Sanctuary) protects and reinstates many endangered species to the mainland but it has also sequestered land, curtailing historic access rights and uses. She says Zealandia has been good for the diversity of manu in the region and tui (*Prosthemadera novaeseelandiae*) are now more common than they were in her childhood, but it has also changed access to the land. The increase in tui is probably due more to the intensive baiting regime to control rats and possums implemented by the Greater Wellington Regional Council and Wellington City Council within the Wellington City green spaces, rather than the sanctuary. The success of the manu at Zealandia has also created new issues. People now have to co-habit with kaka, which damage trees in their gardens. The birds get sick from eating lead roofing nails and can be boisterous and create a nuisance. The regional council has also received noise complaints about tui. The population of kaka (*Nestor meridionalis*) has outgrown the sanctuary and they are now nesting outside of its protection. This also has to be managed. Many of the more susceptible species such as hihi (*Notiomystis cincta*) and tieke (saddleback *Philesturnus rufusater*) will probably never be able to nest outside the sanctuary fence and so their populations will be limited and genetically isolated.

## Economic valuation of ecosystem services

When resource managers apply environmental valuation, we often ascribe moral, cultural and fiscal values to the outputs of natural, built, human and social capital. This is usually done to aid the prioritisation of management, define management objectives or to quantify the impacts of development. Valuation is often done through environmental economics, cost-benefit analysis, optimisation models and the market valuation of ecosystem services and natural capital (Boumans et al., 2002, p. 532; Dempsey & Robertson, 2012, pp. 764-765; Hermann et al., 2011, p. 18; Minsitry for the Environment & Department of Conservation, 2016, p. 14). Including ecosystem services (see chapter 7) in valuation frameworks broadens the conventional market-based economic approach. Considering provisioning, regulating and cultural services (culturally important landscapes and intellectual and experiential benefits) attempts to correct the common undervaluation of ecological commodities and makes them more understandable and relevant for the public, policymakers and politicians, etc. Valuing ecosystem services (ES) may help to illustrate where ecosystem benefits are being distributed and to understand trade-offs, identify gaps in understanding and define potential areas for innovation and sustainable management (Chee, 2004, p. 550). Scientists often resort to economic definitions of ecosystem services to provoke a policy response. We may not choose to protect the environment until we value ecosystems in their natural state over their modified state (Kadykalo, 2013, p. 102)

The neoliberal market is one current resource valuation system, but the market is manufactured and therefore so are the constituent limits and targets derived from it (Bateman, Mace, Fezzi, Atkinson, & Turner, 2011, p. 207). For example, the Neoliberal market value of a tree may be accounted for solely by its timber. However, the oxygen it produces, the soil it stabilises, the carbon it sequesters and the soil biodiversity it nourishes are left unaccounted for (S. Farber et al., 2006, pp. 124-125; Spangenberg & Settele, 2010, p. 327). Many ecological services, non-human organisms and ecosystems, particularly remote ones, have no market value, not even a manufactured one. These are deemed to have little economic value and possess only intrinsic value. This invites overexploitation and environmental harm (Beder, 2000, p. 229; S. C. Farber, Costanza, & Wilson, 2002, p. 387). Neoliberal economics allows for the removal of natural resources so long as there is reinvestment in other forms of capital such as housing, stocks, or gold. The human capital that is valuable on the economic market is valueless to the ecology that supports us (Beder, 2000, p. 238).

Economic valuation based only on biophysical models may neglect human needs and desires and neglects ecological limits (Spangenberg & Settele, 2010, pp. 327-328). All members of society, including future generations, share the same ES. Therefore, using market valuations generates conflict between societal, individual and intergenerational priorities and perpetuates inequality (Lienhoop, Bartkowski, & Hansjurgens, 2015, p. 523). According to S. Awatere (2005, p. 11), despite having a lower income, Māori are prepared to pay more for environmental improvements than non-Māori and statistically have a higher level of concern for the environment.

## Cost-Benefit Analysis

Consumption of ES has both costs and benefits to society. It is important for resource managers to identify these economically (Hermann et al., 2011, p. 21). Cost-Benefit Analysis (CBA) is a common method for integrating environmental and economic elements (Beder, 2000, p. 234). CBA is the only legally tested risk management process in the Biosecurity Act section 72. It is utilised in the RMA as a consultation tool and it underpins site led management programmes. If applied inappropriately, it may miss non-market valuations and social costs (referred to as welfare losses) which could result in inappropriate outputs and poor implementation (Giera & Bell, 2012, p. 34). To undertake a robust and meaningful CBA, a full understanding of the environmental values, timescales, future discount rates, appropriate spatial resolution and market price impacts is important. Future discounting is the net present value in any given future year adjusted by a discount rate with appropriate appreciation or deprecation applied (Chee, 2004, p. 557). A well-done CBA also includes an analysis of various technical management options, an outline of the technical and economic assumptions and a sensitivity analysis of key variables (Giera & Bell, 2012, p. 59). A sensitivity analysis proposes optimistic or pessimistic scenarios to define probabilities and produce weighted average outcomes (Chee, 2004, p. 558).

Invasive species control is one of the big expenses for resource management in New Zealand and local and central government routinely conduct CBA's to define and assess management options. Pest control has three types of costs: defensive costs (monitoring, enforcement, maintaining, research and control), output losses (lost productivity, welfare costs), and environmental costs (hard to measure) (Giera & Bell, 2012, pp. 1-3). The total cost of defensive monitoring in New Zealand is $836 million (NZD 2012) annually with $407 million of that paid by the private sector (Giera & Bell, 2012, p. 3). Total output losses from invasive species in New Zealand are $1,292 million (NZD 2012) with $885 million due to pest animals and invertebrates and $303 million due to plant pests. The Agricultural sector wears most of this cost, $885 million (both plant and animal). This equated to 2% GDP in 2008 (Giera & Bell, 2012, p. 3).

Annual expenditure on controlling pest species:

- $41 million ($NZ 2008) by regional councils
- $337 million by the central government
- $458 million by the private sector (L. Roberts et al., 2015, pp. 91-92)

Statistics NZ is the official data agency responsible for ES valuation in Aotearoa. Stats NZ gets the physical data required for ecosystem service accounting from the LCDB (Land Class Data Base), LINZ (Land Information New Zealand), and LUCASs (Land Use and Carbon Accounting) databases (Barry, Yao, Harrison, Paragahawewa, & Pannell, 2014, p. 137). New Zealand's economic indicators are derived from New Zealand Census data, various Ministries' and local body databases and from organisations such as Quotable Value, who provide Residential Land Value data (Batstone, Elmetir, Tayor, Sinner, & Clark, 2009). Patterson and Cole (2013, p. 496) calculated the value to the New Zealand economy of each ecosystem service category. Supporting services produce $33billion (NZ dollar 2013), regulating services $15b, provisioning services $30b and cultural services $1b. For example, forestry provides $7.3 billion and we receive $921 million in energy production (NZ$ 2012). $250 million of this is from carbon sequestration. We receive $94 million (NZ$ 2012) from recreation in three of our plantation forests (Dymond, 2013, p. 75). The cost of erosion is estimated to be between $1 per tonne to $6.60 per tonne equating to $127 million annually (NZ $ 2012) (Barry et al., 2014, p. 137). If a more recent analysis of these figures has been done I have not discovered it.

## Mainstream scientific ecological monitoring

> A major influence on the effectiveness of any monitoring programme is whether a question is being asked in the first place, and if it is, is it the right question? (Byrd, 2008, p. 93)

Environmental assessments may enable us to better understand the environment, ecosystem services, focal species and the outcome of management activities. We know comparatively little about the status of most plants, nearly all invertebrates and all microbes. Geographically, two-thirds of the world's biomes, including wetland, grassland and marine habitats have very little monitoring systems in place (Balmford & Bond, 2005, p. 1221). Monitoring supports management plans by providing information on the outcomes and outputs of management regimes (Byrd, 2008, pp. 3-4). Monitoring programmes measure the effectiveness of management strategies, should be linked to well defined and measurable management objectives and should have established monitoring targets and reference conditions (Barrett & Gray, 2011, p. 1286; Block et al., 2001, p. 295; Critchley, 2000, p. 87; Gibbs, Snell, & Causton, 1999, p. 1055; Jones et al., 2012, p. 4).

Good monitoring designs should have adequate spatial and temporal coverage, avoid bias and they should have precise ranges, targets and operational protocols. Monitoring programmes should have appropriate replication and randomisation to ensure statistical power and robustness (Block et al., 2001, p. 297). Monitoring should be able to accurately, repeatedly and comprehensively detect long and short term changes, identify the most important stressors and predict the response to these pressures (Archaux, Bergès, & Chevalier, 2007, p. 179; Griffith, 1997, p. 330; Sweetapple & Nugent, 2011, p. 159). Monitoring programmes that use a small number of indicators may not generate enough data to evaluate the entire complex system adequately and with rigour (Dale & Beyeler, 2001, p. 3; Danielsen et al., 2003, p. 407). To be able to interpret the monitoring outputs and detect changes, we may need to understand the accuracy and confidence intervals the data generates (Barrett & Gray, 2011, p. 1289). For example, it is difficult to accurately scale and extrapolate monitoring done on small pieces of land to larger habitats (Barrett & Gray, 2011, p. 1292). Reliance on a small number of indicators can be misleading and the greater the number of indicators over a variety of system components the more reliable and expensive the analysis will be (Mark S. Reed et al., 2008, p. 1267).

Monitoring operations are categorised as either Output or Outcome. Output monitoring, also known as performance monitoring, measures the efficiency of management programmes. It measures the direct outputs of management practices, such as the number of pest animals killed or the area of a pest plant infestation treated. Output monitoring is often easier to monitor than outcome monitoring since the variables are fewer and clearer. Output monitoring has one of four objectives: Monitoring the results of management goals, monitoring the efficiency of management processes, monitoring the financial performance of management programmes and monitoring the management goal compliance achieved (Jones et al., 2012, p. 3). Outcome monitoring can assess the impact of the management on the ecology. Outcome monitoring is concerned with management effectiveness and moves away from a service delivery mode. It involves monitoring ecological changes resulting from management inputs. Outcome monitoring is generally biodiversity or ecological state monitoring and is focused on biodiversity changes, ecosystem functions, ecological sustainability and even agricultural production. Indicators include things like native bird abundance, or the recovery of understory vegetation in a forest fragment (Jones et al., 2012, pp. 1-2).

Output or outcome monitoring can be done as either species led or site led programmes. The latter focusses on habits and management areas, while the former concentrates on specific focal species, populations, guilds, taxonomic assemblages, or communities (Block et al., 2001, p. 295). Species focused monitoring is used when the goal is to protect endangered species or threatened populations. It is often expensive and unless the target species is ecologically significant, it may not protect important ecological functions and may miss important ecological relationships among non-target species. Monitoring communities of species can link species occurrences to environmental parameters over multiple spatial and temporal scales and assess conservation outcomes (Barrows et al., 2005, p. 1333). Community monitoring involves measuring species occupancy, relative abundance and stressors (Barrows et al., 2005, p. 1343). Habitat monitoring may be cheaper and easier, but we may not know enough about the interspecies relationships and the links between habitat and population status to make it viable (Block et al., 2001, p. 295).

## Sampling strategies

This section will briefly discuss sampling strategies for scientific studies. The choice of sampling strategy will depend on the study goals, the site, the species being monitored and time and resource availability (Alves, Da Silva, Soares, & Fonseca, 2013, p. 135). Ecology and resource management quantitative assessment is done in the field at selected sampling points, plots or along transects. It is expedient that monitoring locations should be well defined, permanently marked and relocatable so that repeat sampling of the exact same area is assured (Anderson, Laake, Crain, & Burnham, 1979, p. 576; Dodd, 2011). Regardless of the sampling strategy, ideally sampling units should be statistically independent of one another, with respect to the target species. The use of permanent transects allows for temporal trend analysis. The locations for the sampling may be determined in an *ad hoc* fashion, randomly, or systematically. Sampling locations may be stratified by different habitats (e.g. forest or habitat types) or may be clustered around focal points (e.g. habitat features) (S. Buckland et al., 2012, pp. 618-619). Stratified and clustered points improve the encounter rate (sampling power) while maintaining some randomisation, which in theory reduces observer bias. Large numbers of replicated plots may improve the accuracy of an estimate because the plot to plot differences will have minimal effect on the mean value (D T Booth, Cox, Fifield, Phillips, & Williamson, 2005, p. 97).

Point sampling is when the observer goes to a specific geographic point and samples at that point only. For example, bird counts are done as point samples and can include a distance component. The perpendicular distance is triangulated from the observer to the target. Plot sampling involves sampling an area of known size as a representative subset of the larger ecosystem. Plots can be quadrats, circles of a known diameter, transects and strips or any geometric shape. Non-geometric shapes can also be used as long as the exact area can be determined, which is possible using GIS. Transect or strip sampling involves sampling the content of a long narrow plot. Quadrats can also be used to measure the density of a target species by calculating its occurrence in the known area of each quadrat in the network. The advantage of transects is that more area can be sampled than with quadrat sampling. Transects may be less effective for small management areas, when the target species is sparsely distributed, has a strongly clumped distribution or when it is cryptic or rare because the encounter rate will be too low (S. T. Buckland, Borchers, Johnston, Henrys, & Marques, 2007, pp. 989, 997).

Monitoring studies should carefully consider how data is to be used. For example, the placement of sampling plots in an *ad hoc* fashion may compromise the independence of the sample units, so that data may not conform to the assumptions of the statistical models that are used to identify patterns. Poorly executed studies may, in some cases, still be useful to identify the presence or absence of a plant or animal. Using lures can improve the sampling sensitivity, which may be beneficial for monitoring rare, cryptic, or highly mobile species. Lures can be visual (luminescent strips and flour blazes for possums), edible (bait), audible (call recordings), or chemical (e.g. pheromones), but these can compromise measurements of activity and abundance (Stephen T. Buckland, Summers, Borchers, & Thomas, 2006, p. 378).

Often sampling is based on rules-of-thumb (e.g. if you don't know how many samples to take, take 30), funding and convenience, rather than statistical rigour and sound ecological principles (Brownstein et al., 2015, p. 106). For example, the Department of Conservation protocol for vegetation monitoring states that the transect area should be half as wide as the tallest vegetation in the plot and twice as long as it is wide to ensure all the desired vegetation is captured, but these are relatively arbitrary specifications (S. T. Buckland et al., 2007, p. 990). This will give a forest with 20m high emergent canopy trees a 20m (10m on each side of the centreline) by 40m transect, which could miss rare species unless a sufficient number are done.

## Ecological indicators

Since it is not practical to measure every aspect of an ecosystem, we use indicators (P. J. Burton, 2014, p. 149; Lee, McGlone, & Wright, 2005, p. 79). Indicators are numerical values that simplify complex information or phenomena (Victoria Ann Froude, 2011, p. 114; Parisi, Menta, Gardi, Jacomini, & Mozzanica, 2005, p. 331; Rosenstock, Anderson, Giesen, & Carter, 2002, p. 48). Indicators quantify information, revealing trends and enabling statistical analysis, which makes ecological information accessible to policymakers and managers (Certain et al., 2011, p. 1; Dobbs, Escobedo, & Zipperer, 2011, p. 197). Ecological indicators are aspects of ecological features that may provide insight and indicate ecological function. They can be the biotic (community composition, richness, evenness and abundance) or abiotic (hydrology, topography, geology, climate) components of the system or the pressures acting on them (Barry J Biggs, Kilroy, Mulcock, Scarsbrook, & Ogilvie, 2002, p. 7.1). Ecosystem indicators can become proxies to represent an entire ecological process (e.g. carbon sequestration rates) (Anastasiadis et al., 2013, p. 6). Indices are useful for tracking the performance of management targets. (Dobbs et al., 2011, p. 197). There are three different types of indicators. Environmental indicators detect and monitor environmental state changes, such as the amount of phosphate or nitrate in the water or the amount of dry matter in a sample of leaf litter. Ecological indicators monitor stressor induced changes in the biota. Biological indicators identify and monitor changes in biodiversity and include measurements of indigenous dominance, species occupancy and habitat representativeness (Dodd et al., 2011, p. 91; McGeogh, 1998, p. 185)

The ecological indicator types mentioned above were described further by Hernández-Morcillo, Plieninger, and Bieling (2013, p. 438) (see **Figure 1**). The first category are condition indicators. These are the physical, chemical and biological properties of an ecosystem. The second type are function indicators, which describe ecological processes. The third type are intermediate service indicators, which relate to the quantity and quality of the ecological products we obtain. The fourth type are benefit indicators and these deal with the consumption of ecosystem products. The final type are impact indicators, which relate to the state of wellbeing for people.

Ideally, indicators are able to be scaled spatially from plots throughout the site, from watershed to landscape and are ecologically scalable from genes through to individuals, communities, populations, species and functional groups (Brooks, Connell, Wardrop, & Jackson, 1998, p. 137). Indicators should be clearly linked to the parameter(s) that they indicate (e.g. changes in vegetation cover, land use, predation pressure, etc.) (Block et al., 2001, p. 296; Landres, Verner, & Thomas, 1988). They should be interpretable, able to be indexed and standardisable, to remain relevant if data collection techniques change (Robert B. Allen, Bellingham, & Wiser, 2003, p. 209; Andrews, Karlen, & Cambardella, 2004, p. 1945; Rutters et al., 1992, pp. 23-24). To be informative, an ecological indicator should be reliable and predictable, robust (validated, cross-checked and well understood with known baselines), spatiotemporally transferable and repeatable. To be functional, indicators should be relevant, realistic, precise, responsive, sensitive (able to detect the appropriate change), specific and appropriate. This means they should be correlated with land-use changes and related to assessment goals. To be valuable, they should be predictive, interpretable, communicable and anticipatory. To be feasible, they should be, quick, easy and cost-efficient (Belnap, 1998, p. 638; Bibby, 1999, p. 82; Carignan & Villard, 2002, pp. 48-49; Dale & Beyeler, 2001, p. 3; Dale & Polasky, 2007, pp. 289-209; Griffith, 1997, p. 343; Hernández-Morcillo et al., 2013, p. 436; Lobry de Bruyn, 1999, p. 427). Assessing several similar indicators together, such as the survival rate of planted trees, canopy density and indigenous dominance generates a multivariate analysis improving effectiveness (P. J. Burton, 2014, p. 153).

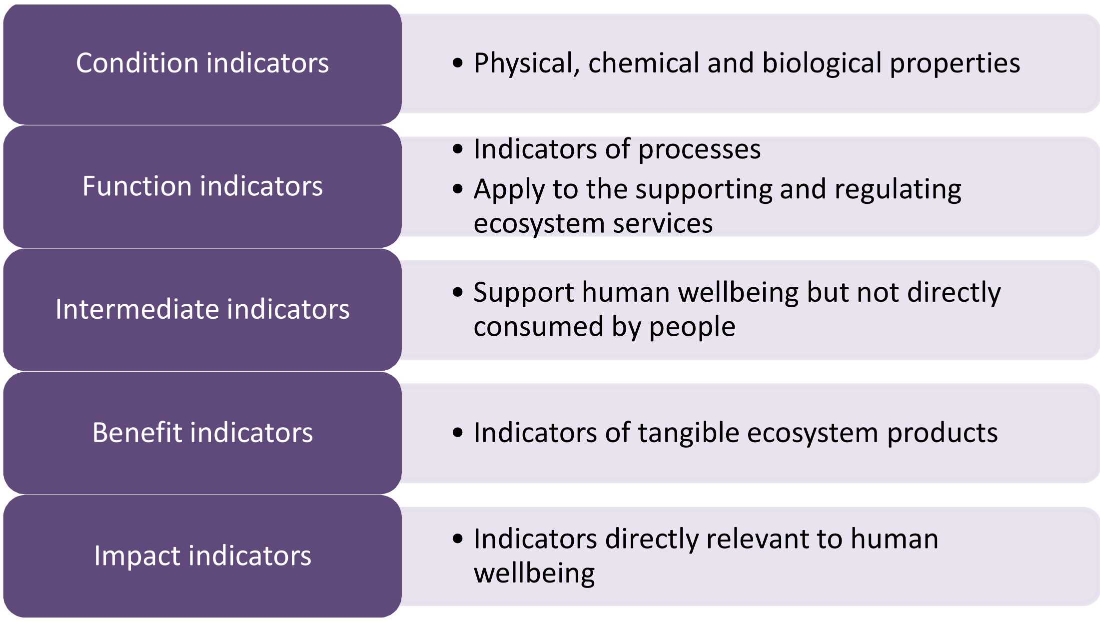



**Figure 1**. Ecosystem indicators framework developed with respect to cultural ecosystem services (Hernández-Morcillo et al., 2013, p. 438).

## Monitoring tools and technology

In this section, I will briefly introduce some of the technologies and platforms available to land managers for ecological monitoring in Aotearoa. These include remote sensing, graphic information systems and databases, digital image analysis and environmental DNA.

### Remote sensing

Remote sensing is the generation or sampling of data remotely. This data can be in the form of digital images from aerial photography, camera traps or environmental DNA. Remote sensing is a rapid, cheap way of inferring changes over large areas and can reach more locations (Robert B. Allen et al., 2003, p. 212). Remote tracking has been widely used in endangered species management using radio transponders or GPS tagging. Chatham Island tāiko (*Pterodroma magenta*) have been monitored using transponders. GPS tracking devices have been employed for species that travel large distances such as albatross, elephant and shark species (Taylor, Cockburn, Palmer, & Liddy, 2012). Data such as flight altitude or cetacean dive depth and behaviour can be collected with satellite-monitored sensors. Given its versatility and power, remote sensing is considered the future of ecological monitoring, but it should be paired with *in situ* monitoring and modelling to achieve its full utility.

### *eDNA*

Environmental DNA (eDNA) is DNA that exists in the environment. It is the DNA that organisms (including fungi, animals, protists, microbes and viruses) leave in the environment. Environmental samples are taken and recombinant DNA analysis is done to find specific markers. Genomic, plastid and mitochondrial eDNA can be obtained from a variety of sources including faeces, hair, scales, feathers and soil. Some of the analysis from eDNA includes population size and relatedness, sex ratio and paternity studies, species distributions and the verification of the presence of rare and cryptic species or a pest incursion (Kohn et al., 1999).

### *Acoustic monitoring*

Acoustic monitoring is a form of remote sensing commonly used for bird and bat monitoring in New Zealand. A recording device is deployed and population density is estimated from cue (call) density (bursts per ha per minute). Observers should be able to identify individual calls (vocal identity). Currently, data analysis is not automated, making data collection extremely time-consuming. This method is best applied to species with individuals that have the same call rates and are all equally detectable (D. K. Dawson & Efford, 2009, p. 1202).

### *Electronic databases*

eBird and iNaturalist are internet-based, citizen science databases. Their power is in the facility to collect large numbers of observations which can reveal population movements and migration in real-time across large spatiotemporal scales. Suspected erroneous observations are vetted by specialists (Scofield, Christie, Sagar, & Sullivan, 2012, p. 5).

### *Camera traps*

A camera trap is a motion-activated camera that is used to capture images of animals as they come into range of it. The technology is constantly improving and images have increasingly good definition and can be calibrated with other monitoring techniques (Mills, Godley, & Hodgson, 2016, p. 1). Images can be infrared or camera traps can capture high definition images of animals as they interact with other monitoring devices so that individual animals may be identified (Rendall, Sutherland, Cooke, & White, 2014). Camera traps may be more useful in abundance studies when populations of target species are high (rats, mice, possum, hedgehog, goat, pig, deer, cat, etc. in New Zealand) because they have no saturation point.

### *Image analysis*

Image analysis can also be done without GIS. An example of this is the use of software to analyse photographs to determine the exact spatial cover of a particular species. SamplePoint from Landcare Research Ltd. New Zealand is one such software package. The user defines the area of the image requiring analysis and the number of sample points required. Photos can be taken in a vertical or horizontal plane. The computer then places the prescribed number of points randomly within the defined area and the user assigns a value to each point. For example, these values could represent the species of plant at that point or the presence of leaves that are healthy or damaged by disease. I have used this software to determine the percentage cover of buddleia (*Buddleja davidii*) that had been damaged by the buddleia leaf weevil (*Cleopus japonicas*). SamplePoint has also been used to assess the impact of stocking rates on shortgrass prairie. Automated analysis is currently less accurate than manual analysis, but this will improve over time (D. Booth, Cox, & Berryman, 2006, p. 98). This type of remote sensing is both effective and cheap (D. Terrance Booth & Cox, 2008, p. 185).

## Geographic Information Systems

Remote imaging describes images taken from satellites or aerial photography by manned or unmanned aircraft. These images are analysed using Geographic Information System (GIS) software packages that analyse spectral signatures and convert pixels to information classes.

GIS is becoming the default method used by local and central government to manage their spatial information and is now very much entrenched in resource management. The technology is becoming faster and more accurate and providing higher resolution over time. GIS can be used as a decision support tool to help model land use, ecological sustainability and environmental impacts. It is an aid for land management implementation, monitoring and resource management policy and planning (Pacey, 2005). GIS is a living database and the data is constantly updated, added to and manipulated. GIS plots information and data as independent layers on a map which can be manipulated to explore relationships.

GIS is a powerful data analysis tool and has a utility function beyond being a repository for data (T. R. Allen, Wang, & Crawford, 2013, p. 81; Brodnig & Mayer-Schonberger, 2000, pp. 1, 8-9). A repository for data is only the first function of GIS. The second function is the analysis and manipulation of data for thermal, biophysical, temporal and spatial changes. It can assess the changes in land quality, land use and vegetation cover using spatial metrics (patch shape, size, composition, connectivity, etc.) (Cohen & Goward, 2004, p. 541). GIS generated maps are now routinely used for land cover, biophysical feature mapping and geomorphological studies (T. R. Allen et al., 2013, p. 81). The third function is retrieval and reporting of spatial data. The fourth and final function is the display and visualisation of spatial data (Brodnig & Mayer-Schonberger, 2000, p. 6; Coppin, Jonckheere, Nackaerts, Muys, & Lambin, 2004, p. 1567).

GIS can map forest complexity using image brightness, radiance and three-dimensional spatial structures to gain an understanding of plant lifeforms and traits (crown structure, tree height and spacing), species distributions and habitats (Ferrier, 2011, p. 96; Torontow & King, 2012, p. 388). Remote cameras with advanced optics and spectrometers (up to 244 wavelengths into the UV and radar spectrums) can analyse variation in reflectance caused by different leaf properties, such as pigment composition, water content and leaf and canopy architecture.

Satellite imagery, with a resolution down to 1m, may differentiate individual trees by using their multispectral signatures. Spectral analysis is usually done using what is known as a ‘supervised classification’ where the user ‘trains’ the system to identify specific spectral signatures and attributes them to a specified category (Huang & Klemas, 2012, p. 931). This data can also be used for hydrological studies to define the boundaries of streams, lakes, wetlands, seepage areas, aquifer extents, recharge zones, evapotranspiration zones and precipitation. Thermal imaging may detect thermal anomalies that can indicate the presence of water (Becker, 2006, p. 316). Spectral analysis can be combined with Light Detection and Ranging (LiDAR) canopy height models to further differentiate scrub, grass and forests.

GIS data enables us to classify ecosystems, delineate habitats and identify ecosystem sources and their sinks, (Andrew, Wulder, & Nelson, 2014, pp. 331, 328; Cabello et al., 2012, p. 3289). Sources are where ecosystem services are generated and sinks are where they are consumed. Spatial population analysis may help define biogeographical linkages and dispersal history and has been used to define ecoregions using differences in stonefly, caddisfly and freshwater fish assemblages and diversity (Leathwick, Moilanen, Ferrier, & Julian, 2007, pp. 7, 12). With GIS data, we may build physiological models, conduct habitat assessments, undertake landscape characterisations, investigate interactions between humans and biodiversity, perform socioeconomic studies, model how land use impacts biodiversity, generate accounting models and visualise ecology for planning and policy purposes (Aspinall, 2009, p. 209; Cohen & Goward, 2004, p. 541). Understanding ecosystem functional characteristics and spatial distributions is essential for assessing conservation status and management, population modelling and monitoring environmental change (Cabello et al., 2012, p. 3292).

### *LiDAR*

LiDAR (Light detection and ranging), works a bit like sonar but uses lasers bounced off the substrate to generate a picture. LiDAR can be used to generate a canopy height model (CHM) that produces a vegetation map of the canopy structure by height and can identify different ecotones and define ecosystems and species distributions (D. G. Brown, 1994, pp. 643, 654). CHM models can be used to identify emergent trees and assist in assessing forest extent, type, age and successional stage. The canopy can be stripped off to generate a digital terrain model

(DTM), mapping the underlying terrain. A DTM model can reveal streambeds, floodplains, channels, seeps, flood risk zones and earthworks such as building platforms, dams, tracks, roads and even hidden archaeological sites of cultural significance (T. R. Allen et al., 2013, p. 83).

*LCDB*

LCDB (Land Cover Database) is a multispectral imagery database that holds all our current land cover and land use data in New Zealand. It reveals the changes in cover and land use that have happened since the last database version. The LCDB has 33 different land cover classifications, including five indigenous vegetation cover categories (Cieraad, Walker, Price, & Barringer, 2015, p. 309; Dymond, Shepherd, Newsome, & Belliss, 2017, p. 1; Singers & Rogers, 2014, p. 3).

*LENZ*

The LENZ (Land Environments New Zealand) database is the nation's physical environment database and provides an analysis of land environs (11 climatic, landform and soil variables). It may be used as a proxy biodiversity layer. The LENZ database contains the threatened ecosystems and protected areas layers. Spatial analysis of LENZ and LCDB revealed the ecosystems experiencing the greatest loss of biodiversity and showed that more than 70% of indigenous vegetation cover is lost from 57% of land environments. In addition, the majority of loss of the most threatened ecosystems (47%) happened between 1996 and 2002 (Cieraad et al., 2015, pp. 309-310; Singers & Rogers, 2014, p. 3; Susan Walker, Price, Rutledge, Stephens, & Lee, 2006, p. 169).

## Conclusion

Ecological science and resource management involves conserving areas and practicing restoration ecology. Ecological assessment of environmental change is therefore generally retrospective. The damage done or the change achieved by management practices is appraised after the fact using a single or very small number of specific biological, physical or functional responses. However, ecological science is now moving towards adaptive management, integrated catchment management and the inclusion of social attributes. Comparison of the mainstream and Indigenous management epistemologies may reveal that both share operational similarities and aim to achieve the same ecological outcomes. They just come from different cosmological starting points and employ their knowledge sets differently. Indigenous resource management epistemology is the subject of the next chapter.

Sustainable resource management adapts to changing economic, political and environmental variables. It is flexible and innovative, maximises land-use spatiotemporally, maximises biodiversity (wild and domestic), maximises productivity and minimises external inputs (Barrera-Bassols & Zinck, 2003b, p. 228). As well as exploring the resource management ontologies, this chapter explored the economic valuation system commonly employed as a prioritisation framework. The economic value of land and the ecosystem services we consume are often used to assess the benefits and gains from the environment.

This chapter explored the epistemology and ontology of ecological science and resource management. The next chapter will explore the epistemologies and ontologies of traditional ecological knowledge. Chapter Four will investigate traditional resource management practices for rangelands, food production, soil management and the various methods employed to interact with the environment, including cultural calendars. The last section in the next chapter explores various Māori environmental assessment models as a staging point for the one I will create.

# Ūpoko Whā - Ritenga and tikanga

# Chapter Four – Indigenous and Māori resource management and environmental assessment

> Local knowledge on ecosystem dynamics and consequences of peoples' interactions with the environment is often embedded in informal institutions such as taboos and management practices which are embedded in social and cultural contexts (Tengö et al., 2007, p. 289)

Traditional ecological knowledge (TEK) and resource management are often driven from Indigenous cosmology and employ decision support tools and strategies that are different from those of ecological science and resource management (Larochelle & Berkes, 2003, p. 364). Traditional resource management practices are derived from local observations and consist of rituals, ceremonies and informal sanctions, all of which are maintained by traditional social institutions (Ruiz-Mallen & Corbera, 2013, p. 3). TEK has a socio-religious foundation and the holders of knowledge and authority are rangatira, chiefs or respected elders who sanction resource use (Gupta, 2007, p. 337; Ulluwishewa, Roskruge, Harmsworth, & Antaran, 2008, p. 279). TEK is generally place-bound and deals with particular physical, temporal and contextual observations and conclusions, rather than with rules. A management framework derived from knowledge of specific places may clarify, operationalise and conceptualise ecological and resource management outcomes. Doing this provides adaptive, sustainable management outcomes. It provides the necessary context for communicating management objectives resolves conflict and evokes a sense of the cultural landscape (Potschin & Haines-Young, 2013, p. 1054). Place-based resource management is effective but often undervalued by non-Indigenous resource managers and scientists. TEK includes a social context often excluded by non-Indigenous scientists including ecologists (Potschin & Haines-Young, 2013, p. 1054).

For Indigenous people, resource management practices are often tied to culture and are concerned with quantifying our impact on the environment. Indigenous ecological monitoring may involve not only monitoring the ecological impact of resource use but also the cultural, social and economic wellbeing of the whanau. In this chapter, I will discuss Indigenous resource management practices, tools and techniques to provide insight into Indigenous ecological assessment indicators. I will also outline the leading mātauranga Māori ecological assessment frameworks.

## Traditional resource management practices: Tiaki whenua and tiaki taiao (caring for the land and environment)

> Local knowledge was more holistic than many published indicator lists for monitoring rangelands, encompassing vegetation, soil, livestock, wild animal and socioeconomic indicators (Mark S. Reed et al., 2008, p. 1267)

Indigenous resource management paradigms apply to the management of soil, forests and rangelands, hunting and gathering of wild foods and even biosecurity. The tools used by Indigenous people to achieve sustainable resource management include rules of thumb, taboos, fire, sacred groves and cultural calendars. These tools consist of detailed traditional knowledge embedded in belief systems. Societal experts generally hold this knowledge and they govern its application and its dissemination, usually orally. TEK practitioners understand local microclimates and important local environmental variables such as the risks of flooding, frost, hail, storm, fire and drought. TEK resource managers employ techniques such as multiple cropping, natural pest control methods, manure application, tilling methods, animal husbandry, seed and cultivar selection and cultivation methods to achieve their goals. They may draw on a vast knowledge of the taxonomy and curation, cultivation and husbandry of important plant species (Thrupp, 1989, p. 15).

TEK practices often involve small-scale disturbances. These improve overall biodiversity by producing diverse environments and by creating patchiness and habitat mosaics. In contrast, the large scale disturbances that are typically associated with industrial resource extraction, tend to destroy ecosystems and promote the local dominance of a few species (W. H. Thomas, 2003, p. 991). In general, agricultural intensification is associated with declining biodiversity, ecological function, resilience and ecosystem service stability (M. B. Thomas, 1999, p. 5950). In contrast, landscapes under TEK resource management may support high levels of biodiversity and ecosystem function. For example, the Rara'muri homeland in the Chihuahua region of Mexico has been managed for over 2000 years, yet it retains a diverse biota that includes over 300 plant species (Salmón, 2000, p. 1328).

### TEK rangeland management – herding/farming

> As soon as you set the plough in the ground, you are working against nature.... Then you have to start managing and start thinking ahead (Romig, Garlynd, Harris, & McSweeney, 1995, p. 233)

Agricultural habitats are often important for our cultural and economic wellbeing and are an important component of the natural landscape. Agricultural habitats are now integral and vital to many ecosystem functions and processes. A significant ecological pressure is the presence of large herbivores, which are central to pastoral agriculture. The key ecological indicators for all agriculture include the impact of pests (insects, diseases, weeds), the cost of pest control, soil fertility (erosion, yield, depth and organic carbon component), and profit and productivity (or lack thereof) (Rigby, Woodhouse, Young, & Burton, 2001, p. 466). Traditional pastoral and herding management practices are generally labour intensive, have low capital and are dynamic and multi-faceted. They are steeped in history, are locally appropriate and diverse, are geared for survival and risk avoidance and they integrate social institutions.

Rangeland assessment looks at the land's physical characteristics, carrying capacity, suitability and the result of management decisions e.g. the type of livestock run (H. Roba & Oba, 2008, p. 603). Monitoring key forage species and the health, fecundity and productivity of the animals grazing them is a reliable method of overall landscape assessment and to assess biodiversity dynamics (Dewalt, 1994, pp. 124-125; H. G. Roba & Oba, 2009, pp. 603, 608). Farmers know which species of plants draw water to the surface, require a lot of water, provide shade, improve soil fertility, decompose rapidly or slowly and host pest organisms (Dawoe et al., 2012, p. 99).

Herders are generally concerned with the properties of the forage plants, such as the timing of forage sprouting, drought resistance, abundance, yield and nutritional value, especially at critical times of the year. Rangeland management may focus on ensuring the removal of grazing pressure from the grasses at critical times. These practices maintain pasture productivity and are adapted to the rainfall patterns in the area (Bollig & Schulte, 1999, p. 509). To avoid habitat degradation, ideally stock are moved communally so that pasture is not overused and trampled, disease prevalence is reduced and water depletion avoided (Fernandez - Gimenez, 2000, p. 1321). Habitat degradation and loss of rangeland biodiversity may not be of interest to pastoralists but the overall productivity created by biodiversity is important (Bollig & Schulte, 1999, p. 511).

Livestock are arguably the most important environmental barometer for herders employing TEK-based resource management. Livestock yield often determines the utilitarian value and health of the land. Pastoralists understandably have a detailed knowledge of what vegetation their stock prefer to eat, where to find these species and how abundant they are (Fernandez - Gimenez, 2000). Kakinuma and Takatsuki (2012) discussed how pastoralists know that narrow-leaved plants recovered from grazing pressure better than broad-leaved herbaceous species and adjusted stocking rates accordingly. Mongolian herders divide grazing lands into 'hot' or 'cool' territories. Mountain-steppe, river floodplain and north-facing pastures are 'cool' whereas 'hot' pastures occur on the desert-steep, waterless areas and south-facing aspects. Cool territories are best suited to 'cool muzzled' animals, camels and goats, 'while hot muzzled' animals, yaks and horses, did better on hot territories (Fernandez - Gimenez, 2000, p. 1320). Northern Kenyan herders also categorized their land into 'Badhaa', cool sub-humid uplands characterised by red volcanic soil and high tree canopy cover and 'Gamoji', warm lowlands with dark to grey soils covered mainly with lower scrub vegetation (Dabasso, Oba, & Roba, 2012, p. 4). Interestingly, the division into hot and cool muzzled animals correlates to the ecological science nomenclature categorisation of herbivores as either grazers or browsers. Watkinson and Ormerod (2001) argued that these TEK assessment strategies, including assessing the relationship of the livestock health to their diet, were better than scientific ex-closure experiments. Small ex-closures may only measure one treatment and are often too small to be representative and therefore do not reflect grazing pressure or seasonality and provided little information on the ecological community (Watkinson & Ormerod, 2001, p. 234). **Table 1,** shows an amalgamation of the TEK indicators used to assess rangeland quality from multiple different cultures.

TEK practices have value in providing ecological health, sustainability and resilience, particularly in soils (Barrios et al., 2006, p. 249; Stockdale & Watson, 2009, p. 309; M. B. Thomas, 1999, p. 5944). In Asia and Africa, the sustainable livestock grazing management emulated the migrations of wild ungulates (Bedunah & Angerer, 2012, p. 609). These management practices prevented the invasion of grasslands by woody species, which is one of the most important threats to grassland productivity (Watkinson & Ormerod, 2001, p. 233). Overgrazing may remove all the palatable grass species and opens the land to the invasion of woody species that the stock will not eat. A study in Mali showed grazing pressure was positively correlated with tree cover and negatively correlated with shrub/herb cover (Angassa, Oba, & Stenseth, 2012, p. 74). Woody weed invasion of grazing land costs an estimated 13 million per hectare per year in South Africa (Watkinson & Ormerod, 2001, p. 233). Barrera-Bassols and Zinck (2003a, p. 180) claim that TEK is sophisticated at a micro-environmental level and 'in general, land use decisions made by local people are more accurate and better adapted than the technical recommendations forwarded by extensionists'. Extensionists promote agricultural agendas. There is a risk of losing TEK as the elders, the holders of this knowledge, pass away without having had the opportunity to pass it on to the now urbanised younger generation (Birmingham, 2003, p. 489).

## Animal

- Yield of meat and milk
- Stock fecundity
- The texture of the animals' dung, and coat condition
- Freedom from disease and bloating
- Animal behaviour, e.g. animals refuse to graze on poor forage, bunch up and are restless  or difficulty to move
- Competition with or predation by wildlife

## Social

- Economic and social security
- Risk of floods and fires
- Continuity of available water

## Vegetation

- Location of specific trees to locate water
- Colour (greenness) of vegetation
- Appearance of weeds and abundance of unpalatable species
- Plant vigour (nutritional value, height, and dry mass yield)
- Amount of soil retained by vegetation
- Change in species composition and diversity
- Availability of grasses and abundance of woody species
- Suitability of the vegetation for different livestock grazing needs or human needs such as roof thatching or medicinal plants
- Percent cover: >75% herb good, 50-75% herb fair, 25-50% herb poor
- Reduction in grass layer
- Invasion by poisonous plants that cause bloating in livestock etc.

## Invertebrate

- Earthworm abundance and diveristy
- The appearance of beetles feeding on dry leaves; the invasion of grasshoppers and parasitic worms indicate environmental instability

Soil

- Presence of litter
- Organic matter, depth of humus layer
- Colour
- Texture and consistency
- Pugging or surface compaction
- Change in depth
- Moisture content
- Surface water and infiltration
- Chemistry (salinity, pH., N and P etc.)
- Erosion

**Table 1.** An amalgamated list of many of the rangeland health indicators that various Indigenous herders and farmers use to inform management (Abate, Ebro, & Nigatu, 2010; Chokor & Odemerho, 1994, p. 148; Fernández-Giménez & Fillat Estaque, 2012, p. 10; Mark S. Reed et al., 2008; H. Roba & Oba, 2008; Trung, Verdoodt, Dusar, Van, & Van Ranst, 2008, p. 27).

### Cropping and wild food harvesting

> 'Why don't we stay in the same place all the time? Because if we stay in the same place, the livestock stops getting fat. And also there are many flies in the summer and the water is too salty and not suitable for livestock. If the water is too salty the animals will get [diarrhoea] and lose weight. Warm water also causes an increase in worms in animals. Every disease is abetted by warm water. That's why I'm . . . looking for clear water and good grass' - Sangiseree, Jinst Sum 1994 (Fernandez - Gimenez, 2000, p. 1322)

In TEK based resource management, the collection of wild foods is often governed by precise and detailed knowledge of the natural history of the species concerned. Some TEK based practices are designed to enhance the sustainability of the resource and may involve the restrained or incomplete use of a resource. For example, the Huna Tlingit peoples of Alaska have managed local gull populations for 'millennia' in a healthy state (Hunn, Johnson, Russell,

& Thornton, 2003, p. 6). They employed practices that ensured the continued abundance of the resource. They did not harvest eggs from nests that held three eggs as these eggs had been in the nest long enough to have developed into embryos. They only removed freshly laid eggs, which would induce the birds to lay again. This harvesting practice was based on closely observing gull-nesting behaviour and a profound understanding of gull breeding biology. Despite this success Hunn et al. (2003) describe how the creation of a federally controlled national park in the Huna Tlingit ancestral lands and the subsequent ban on traditional gull egg harvesting both deprived the local people of access to their cultural practice and ultimately led to a reduction in the state of health of the gull colonies.

From the perspective of the maintenance and continuity of TEK resource management, harvesting is often integral to monitoring and knowledge transference. Harvesting is often about stewardship of the land and maintaining trails and cabin sites that would otherwise become overgrown and unusable. It is important to use the resources, or the knowledge of their husbandry will be lost (Parlee, Berkes, & Gwich'in, 2005, p. 133). The Rarámuri people in the Sirerra Tarahumara region of Mexico know when and where the *Okowi sawarodme* mushroom will appear and be at maximum size, how long it will survive and when it is best consumed (Larochelle & Berkes, 2003). The Rarámuri consider it logical to eat wild plants and they know which plants are easy to collect, where to collect them, their nutritional value and the cooking fuels required. Raramuri cultivate wild plants in milpas or corrals, where they also grow maize and beans (Larochelle & Berkes, 2003). They keep sheep and goats in these milpas overnight for about two weeks then move the entire structure, working the manure into the soil to fertilise it. Brassicas are then planted during the rainy season and the rain helps force the seeds into the soil. The soil remains fertile for two to five years and the cultivated Brassica sp. cross-fertilize with wild varieties, providing both genetic and biological diversity which strengthens the species and the ecosystem. The locally produced hybrids are better adapted to local conditions and are more resistant to local diseases (Larochelle & Berkes, 2003, pp. 368-369). The Mayan planted corn in excess to accommodate loss to insects and birds and in that way the loss is absorbed and the ecosystem is also supplied 'One seed is for the bird, one for the ant, one for me and one for my neighbour' (Morales & Perfecto, 2000, p. 56). Farmers experiment with seeds and crop yield in much the same way that scientists do, but just not in a formal (laboratory and experimental field trials) setting.

Kawharu (2002, p. 24) discussed some plant management practices that Māori implement. One such practice is to strip the excess leaves of the kiekie (*Freycinetia banksii*) and harakeke (flax *Phormium spp.*) and leave them at the harvest site to promote further growth and to protect the plant from insect infestation. This practice was called 'hei whāngai anō', which means to nurture or cultivate again. Cutting the leaves on an angle diverts rain away from the 'heart' of the plant, while planting it with its 'back' to the rising sun protects it from rot and promotes growth. Not using the vivid green new shoots is important as this 'is the next generation'. Māori also monitor the health of harakeke. Yellow leaves or black spots may indicate inadequate nutrition or the need for management intervention.

One of my interviewees, JM, a kaitiaki who grew up in Tūhoe, said he and his koroua, kuia and tipuna became the holders, experts and practitioners of the tribe's mahinga kai knowledge. This hard-earned knowledge was gained over generations through practical experience and it was JM's whanau who were trained as mahinga kai specialists and bore the hapū responsibility to provide food for the iwi and visiting manuhiri. His iwi held the knowledge of hunting, foraging, growing, storing and preparing the food. When he was young, his whanau lived off the land and trips to the store were big events that occurred sporadically over the year and would end up as entourage processions that could grow to 300 people and required proper respects be paid at each marae on the way. According to TM, Taranaki iwi eat crackers made of karaka flour. This and other knowledge of how to harvest and prepare kai is emancipating and economically beneficial.

## Soils

> The pedosphere is the thin semi-permeable membrane at the Earth's surface that serves as an interface between the solid and fluid envelopes. These envelopes are the atmosphere, the hydrosphere, the biosphere and the lithosphere. It is at this juncture between the spheres that soil forms (Jónsson & Davíðsdóttir, 2016, p. 26)

Soil is the basis for all terrestrial biodiversity and contains more biomass than all above ground biota combined (Jónsson & Davíðsdóttir, 2016, p. 26). A square meter of organic temperate agricultural soil may contain over 100,000 different species per cubic centimetre and soil biomass can exceed 45 tonnes per hectare. Soils provided many ecosystem services. Soil provides habitats for biodiversity within and above the ground, nutrient and pollutant filtering, organo-chemical cycling, carbon storage and gas exchange regulation, climate control and water flow regulation, among other processes. Soil biota is responsible for 30-40% of biologically available nitrogen released and is important in the mineralisation process. Even cultural benefits can be derived from soil; for example, it is a place to bury our dead and provides clays for pottery, henna and other dyes (Dominati, Patterson, & Mackay, 2010, pp. 1861-1866; Dymond, 2013, p. 144; McAlpine & Wotton, 2009, p. 20).

The Picháitaro Mexicans of the Patzcuaro Basin have an expression that means that the 'land moves and behaves' (Barrera-Bassols & Zinck, 2003b). They understand that land changes throughout the year and according to the season, climatic variability and land management practices. They equate the land behaviour to that of a living organism. It can be old, tired, sick, hungry and thirsty. Soil 'breaths', 'sweats' and 'swells' and requires air infiltration to regulate its temperature (N. Barrera-Bassols, J. A. Zinck, & E. Van Ranst, 2006, p. 149). Considering the amount of macro and microscopic life in soils, this position may be very accurate.

Soil that is loose, soft, crumbly, flexible, loamy, has abundant biodiversity, a sweet earthy smell and active decomposition with no compaction, generally produces the largest biomass yield. Whereas soils that are less suitable for cropping are lumpy or powdery, greasy, rough, dense, light in colour, have a sour or chemical smell, are compacted and may have a hardpan. Plants growing in fertile soils generally have large spreading roots with numerous feeder roots, thick and tall stems and larger, darker leaves. They germinate better, grow more vigorously, take longer to mature and have more nutritional value. Soil pugging often occurs when the water content renders the soil incapable of supporting heavy animals and the soil is deformed and compressed. Healthy plants grow in dense uniform stands and are often better able to withstand droughts and pest infestations and support more and healthier animals. Soils under old-growth native forest, with a thick humus layer, or well-husbanded productive agriculture/horticulture land will generally support abundant faunal diversity, have good porosity, water drainage and aeration, established decomposition processes and effectively filter contaminants.

Over generations, TEK practitioners have developed a range of cost-effective local fertility maintenance strategies (Briggs & Moyo, 2012, p. 73). Farmers and herders are familiar with the use of manure as an organic fertiliser and the various properties of manure produced by different animals. Cattle produce a 'hot' strong manure, whereas poultry produce a 'cold' manure good for balancing 'hot' clayey soils (N. Barrera-Bassols et al., 2006, p. 149). Malawian farmers preferred organic fertiliser (animal, crop and household waste) over industrial fertiliser, as it was cheaper and increased productivity and because less was required (Briggs & Moyo, 2012, pp. 73-74). The uptake of industrial fertiliser was not only an economic choice. They carefully weigh and evaluate what is best for the land, noting that chemical fertiliser burned the soil, produced mixed results and disrupted natural processes. They noted that the application of synthetic fertilisers resulted in signification decreases in yield (Briggs & Moyo, 2012, pp. 73-74, 76). This was interpreted as a disruption to the soil's microbiome, fauna and flora, which are critical to soil health.

Crop types and varieties are carefully matched to soil 'potential' (Corbeels, Shiferaw, & Haile, 2000). Farmers in Tigray, Ethiopia demonstrate detailed knowledge of soil and crop relationships. 'Rekik' or poor fertility soils are used for housing or forestry while the fertile 'reguid' soils are cultivated. The amount of seed sown in reguid soil varied according to the fertility of the soil (Corbeels et al., 2000, pp. 15-20). Many African people manage soil fertility by matching crops with the soil type and fertility, rotating crops and changing fallow times (Briggs & Moyo, 2012, p. 75; Habarurema & Steiner, 1997, p. 81; Kundiri, Jarvis, & Bullock, 1997; Mairura et al., 2008; Talawar & Rhoades, 1998, p. 11). Borana herders in Ethiopia categorise grazing units based on dominant soil type, dominant landform, drainage properties, woody cover, dominant grass species and the prevalence of parasite infestation. They assess the quality of the grazing unit based on the quality of forage for cattle (Wario, Roba, & Kaufmann, 2015, p. 721). TEK practitioners assess the impact of cultivation on nutrient depletion to determine what must be replaced (Talawar & Rhoades, 1998, p. 10).

Erosion control and management is another important undertaking. Purhépecha people of the Pátzcuaro Basin, Mexico, accept erosion as a normal soil process providing fertility to lower slopes. Erosion is managed by 'land trapping, bunds [embankments], living fences, deviation of intermittent waterways, terrain levelling and intensive manuring (Barrera-Bassols & Zinck, 2003b, p. 240)'. Slope management includes planting trees to counteract erosion and increase organic matter. Ploughing perpendicular to the slope controls overland water runoff and increases crop moisture. Planting fruit trees at the foot of cultivated fields provides food for wildlife, preventing them from feeding on crops and provides wind protection (Barrera-Bassols & Zinck, 2003b, p. 241). The people of Kampar, plant the Indonesia plant sago (*Metroxylon sagu*) on the edges of fields to conserve water and provide a water reserve in the dry season. They also prohibit planting the land with perennials and the cutting down of trees along the river, which they consider to be unethical activities (Bakhtiar et al., 2010). These policies may remove the temptation to slash and burn the forest to grow perennial crops, preserves the water table and prevents bank erosion.

### Soil categorisation

> Farmers and scientists appraise soil in different ways. While farmers are interested in soil productivity and appropriate management practices, they take only the topsoil or the arable layer into account. Soil scientists, on the other hand, are also interested in the deeper-lying soil horizons and soil genesis. In addition, farmers' classification is based on local soils and farmers' objectives (Habarurema & Steiner, 1997, pp. 75-76)

Indigenous farmers use physiochemical, agro-ecological and sociocultural qualities to classify, assess and manage soil (Talawar & Rhoades, 1998). They concentrate on the topsoil primarily, rather than the subsoil, which is harder to access and has less influence on the vegetation quality and therefore stock health (Hutchings, Smith, & Harmsworth, 2018; Romig et al., 1995, p. 230). They favour assessing biophysical components such as organic matter, earthworms, decomposition, erosion, compaction, colour, texture and hydrology. Farmers understand important plant attributes such as root and leaf morphology, growth rate, drought resistance, biomass, seed germination rate, ease of tillage and how these relate to soil health and crop yield. Ecologists may monitor habitat health and assess a narrow range of physical factors. TEK practitioners may assess the health and diversity of the animals on the land (Johnston, Sibly, Hodson, Alvarez, & Thorbek, 2015; Gufu Oba, Post, Syvertsen, & Stenseth, 2000, p. 606). They view the field as a whole ecosystem, involving all the biotic and abiotic factors that influence crop health (Jónsson & Davíðsdóttir, 2016, p. 26). Soil health and fertility are managed for resilience and the enhancement of biological processes (Barrios et al., 2006, p. 249; Desbiez, Matthews, Tripathi, & Ellis-Jones, 2004, p. 204).

For Indigenous herders and farmers, soil taxonomy is dynamic and is framed in the community's social, cultural, economic and political contexts (Niemeijer & Mazzucato, 2003). TEK practitioners tend to assess and categorise soil quality based on morphology, functionality and the highly visible physical qualities of the soil that supports the vegetation. The Borana herders of Ethiopia identify soils based on colour, sandiness and presence of volcanic stones or pebbles (Wario et al., 2015, p. 729). The Bête of equatorial West Africa's Ivory Coast assess soil quality for each crop type based on the hydrological characteristics and they adapt their farming practices to suit the land. The Senufo people use vegetation cover as well and they have a detailed understanding of where plant species naturally occur (Birmingham, 2003, p. 494). The Nsit farmers of south-eastern Nigeria assess soil colour and the greenness of the fallow vegetation is an indicator of soil health (Chokor & Odemerho, 1994, p. 145). This is also true of people in Ethiopia and northern Nigeria who also include, texture, structure and hydrology in their classification of soils (Breuning-madsen, Bruun, & Elberling, 2010; Corbeels et al., 2000; Habarurema & Steiner, 1997; Kundiri et al., 1997). Rwandan herder classification is based on fertility, depth, structure, colour, indicator plants, texture, consistency and parent material (Habarurema & Steiner, 1997). They have nine categories and numerous sub-categories.

The Bellona Island people of the Solomon Islands have identified four soil types useful for cultivation, while the Baruya of New-Guinea distinguish six agricultural soils by colour and up to nine with ceremonial uses (Breuning-madsen et al., 2010, p. 86). Farmers in the Burkina Faso use soil depth, drainage, fertility and crop response (Niemeijer & Mazzucato, 2003). In central Kenya, they use the chemical composition of the soils, acidity, salinity, organic matter, smell, the presence of earthworm and beetle larva, plant species diversity, plant growth characteristics and the land's weed susceptibility (Mairura et al., 2007, p. 202). Nepalese people have a complex and extensive set of 62 indicators, divided into five categories based on soil characteristics (colour, fertility, manure demand, erosion proneness and hydrology), crop performance, agricultural management, environmental factors and biology (Desbiez et al., 2004). For Vietnamese TEK practitioners, earthworm biodiversity and gross soil characteristics determine what crops will be planted where. For example, black soil is best for maize cultivation (Trung et al., 2008, p. 27). The Baruya people of Wonenera, New Guinea, also use a combination of gross soil characteristics, vegetation growth traits and the abundance and presence of poisonous plants (Behmanesh, Barani, Abedi Sarvestani, Reza Shahraki, & Sharafatmandrad, 2016).

Trung et al. (2008), investigated the similarities and differences between how Indigenous people around the world and ecological scientists categorise soil. They found general agreement at a coarse level but generally only for the top plough layer. Differences emerge when deeper horizons are included in the analysis (Habarurema & Steiner, 1997). This is understandable as traditional herders and farmers are generally concerned with soil as it relates to farming and focus on these horizons, while ecological scientists try to implement universal criteria and apply diagnostic properties to horizontal strata, incorporating soil origin and a range of chemical and physical attributes (Habarurema & Steiner, 1997, p. 84; Niemeijer & Mazzucato, 2003, pp. 411-412, 500). Scientists are often interested in the soil profile and develop complex soil taxonomies. Indigenous farmers may understand some of the processes and actions that influence soil properties, such as erosion, topography and fertility, but have limited understanding of the pedogenetic factors and soil process interactions. TEK practitioners instead understand how these things impact the biological processes and functions in relation to crop or forage production, suitability for stock and biodiversity (Habarurema & Steiner, 1997). Often the ecological scientists' and TEK analyses of soil quality are in close agreement (Trung et al., 2008). However, TEK practitioners do not need production models or soil maps to help them mitigate adverse events or manage difficult terrain successfully (Parrotta, 2011, pp. 13.12,14 ).

**Generalised soil quality indicators employed by Indigenous herders and farmers**

- Presence of earthworms (and casts), beetles and other invertebrate biota
- Crop productivity
- Topsoil characteristics (workability, stoniness, colour, odour, consistency, and composition (sandiness etc.)
- Depth of humus layer
- Surface compaction
- Erosion
- Slope/gradient
- Surface water
- Soil moisture
- Vegetation yield, colour, and vigour
- Plant distributions and resistance to diseases
- Weed abundance

**Table 2**. Indigenous soil quality indicators (Dawoe et al., 2012, p. 98; Trung et al., 2008, p. 27).

## The soil biome

> Soil is the very source of civilisation: 'Culture begins with cultivation'. It is the beginning and end place for land-borne life, a vital link in the cycles of life: the digester of the dead and the birthplace of the new. Life should be a covenant between people and the land. Just as soil gives us life, we should be custodians of the life of the soil. Let us value and conserve soil, 'the place of our nativity' (Buchan, 2010, p. 10)

Soil biota diversity is arguably the most reliable indicator of soil fertility independent of artificially ascribed targets or ranges and is sensitive to the ecological process and the physical characteristics of the location (Nyamapfene, 1983, p. 55). The soil biota consists of both fauna and flora. The fauna includes nematodes, annelids and arthropods (arachnids, diplopodia, crustacea and insecta). These fauna are important physical engineers of soil structure, creating macro-pores and promoting horizon mixing. Soil flora is primarily composed of microorganisms, bacteria, fungi and algae, which are the primary biochemical engineers of the soil environment (Lavelle et al., 2006, p. 3). Decomposers are particularly important as they feed on litter, breaking down dead plant material and creating new soil. Grazers in the litter and soil itself feed on the living roots and mycorrhizal hypha associated with plants, influencing nutrient cycling, soil structure, cation exchange, leaching capacity and pH and increasing bulk density, porosity and soil carbon content (Golubiewski, 2012, pp. 21-23; Knoepp, Coleman, Crossley Jr, & Clark, 2000, pp. 308, 358). Fungiviorous grazers tend to dominate in low intensification farming and herbo-fungivorous species dominate in high intensity farmed pasture, where there is more root biomass to feed on (Schon, Mackay, Minor, Yeates, & Hedley, 2008, p. 218).

The microbiome is vital to the functioning of the biosphere. It responds rapidly and is sensitive to change. One gram of soil may contain over a thousand fungal hyphae and a million bacterial cells, all driving decomposition and the cycling of energy, carbon, phosphorus, nitrogen and other nutrients (Altieri, 1999, p. 26; Dymond, 2013, p. 146; Romig et al., 1995, p. 230). The microbiome is arguably highly dependent on the physical, climatic, pedogenic (genesis, morphology and classification) and edaphogenic (interaction with living things) characteristics of the soil. The microbiome may be the most important aspect of forest biodiversity and restoration and our understanding of microbial biomass, activity/productivity and diversity is growing all the time (Aerts & Honnay, 2011, p. 7). Molecular tools developed by ecological science in recent years have contributed vastly to our knowledge of the spatial distribution, drivers and the response to land-use changes of soil microbial communities.

Mainstream agrosystems have oversimplified soil food webs compared to less modified systems and have different below-ground ecological interactions (Stockdale & Watson, 2009, p. 309). Organic farming practices may increase soil biodiversity and can be economically profitable. For example, the cost of sacrificing some farmland to provide a ‘beetle bank’ was more than offset by the savings in reduced pesticide usage and improved yields (Lin, 2011, p. 186). Farming alters the invertebrate fauna of soils, particularly the earthworm community. Schon et al. (2008, p. 218), studied New Zealand farms and found earthworm fauna under intensive farming lived deeper in the strata, probably in response to tillage frequency. Low-intensity farming situations had more large invertebrates (over 2mm) and oribatide mites (moss or beetle mites from the Acariformes clade). Oribatide mites are a particular good invertebrate indicator because they have a high degree of species dominance (are relatively common) and are widely distributed. The biological activity of the soil determines the rate of processes such as nitrogen mineralisation and the decomposition rate. The nitrogen mineralisation rate and the microbial respiration rate can be measured in the laboratory.

Earthworm biomass can be a valuable tool to assess management and for environmental monitoring and these are a key indicator species (Paoletti, 1999, p. 137; Romig et al., 1995, p. 230). Earthworms are bio-engineers and play a large role in aggregate stabilisation. Sandhu suggested that 1 tonne of earthworms produce 1000kg of soil per hectare per year (Dymond, 2013, p. 88). Disposing of cow manure to pasture decreases earthworm biomass. Heavy metals, insecticides, herbicides, fungicides, fertilisers, mulches, tilling, vegetation cover and litter can all influence the worm community, sometimes negatively (Paoletti, 1999, p. 144). In NZ agricultural settings, earthworm fauna is poor a relative to native forests, with generally only two or three species from only three of the five earthworm guilds (no coprophagic- dung living or arbprocolous – tree-living species are found in New Zealand fauna) (Dymond, 2013, pp. 88,116; Paoletti, 1999, p. 141).

### Forest management

> The trees are flowering much earlier now and they don't tell us what they used to. This might be a result of climate change - G Kermara 2005 (D. King et al., 2008, p. 398)

TEK forest management objectives are generally designed to manage human activities and resource extraction (Wiersum, 1997, p. 9). Resource gathering and collecting are controlled and systematic. Trees are deliberately tended, purposefully cultivated and some species are domesticated (Wiersum, 1997, p. 11). Pruning of wild trees is often done to promote the edible vegetative growth and prolong the life of the plant. The slow cycling of nutrients in forests is often fundamentally different from horticultural and agricultural systems. The cycling of nutrients in forest systems allows a build-up of organic matter and the formation of soil. Forests can generate large quantities of organic litter and recycle nutrients. Trees may have slower growth rates and different nutrient cycling than crops or grasslands and this allows forests to grow in areas that would not support crops (Knoepp et al., 2000, p. 308). Removing the trees to take advantage of the rich humus and nutrients for farming or cropping may not be sustainable. The removal of trees removes a vast store of nutrients from the system, natural nutrient replenishment ceases and the land may quickly become less fertile. In young tree stands, dominated by pioneer species with few mature emergent canopy species, species richness may be limited by environmental (mean annual temperature, moisture, etc.) and seed dispersal constraints. In ancient woodlands, species richness may be constrained by the biological history (colonisation), the existing genetic diversity of the population (species pool), and the forest's physical size, age and structure (Nordén & Appelqvist, 2001, p. 780).

The ngahere was interpreted and managed according to the status of important taonga trees within it. PH, a Rangitāne O Manawatū kaitiaki, described the primary Māori philosophy of forestry management is the maintenance or improvement of the forest's physical, philosophical and cultural function. Tawa, for example, according to JM, a Tūhoe kaitiaki-and one of my interviewees, is a dominant, brutal and hardy species, with deep roots that can take over native forests. Trees like kahikatea are whanau trees that need others of the same species around them in order to survive. Māhoe puts the mauri back into the soil and is a nursery species for other native trees, attracting birds. It is also used as a flavouring for food. Karamu and kanono fruit three times a year and the berries are an important food source for manu and a good flavour for the meat in hāngi.

According to JM, there is a growth table that is about 30 feet deep, about the limit that worms will go. Trees need to reach this depth to thrive. Tawa are a species that get their feet below this level. JM can tell from the look of the worms how deep they are going and he can tell a lot about the state and health of the soils from the worms and other bugs. A worm with grey insides has come from depth. The abundance and behaviour of birds and insects may tell us when the trees are in flower, if the fruit is ripe or when new shoots are developing and thus can track seasonal changes in the forest. The activity of the insects and birds often dictates what management activities the people may be required to undertake. The forest is ultimately managed in order to manage the birds.

JM described how Tūhoe management of their ngahere included thinning of the wild-growing food trees, weed management, etc. Gardens were never kept in the same place for more than three years at a time. They even burnt the ngahere to promote the growth of rarauwhe (bracken fern *Pteridium esculentum*), a staple food source. The fires also returned nitrogen to the forest. According to JM, Tūhoe have a cultural land use map prescribed 700yrs ago and passed on through the generations. JM is the latest to learn this knowledge and is now a kaumātua, but now there is no one to pass the knowledge on to, the management of the ngahere has ceased. It has regressed and is not as productive or healthy as it once was. JM says that Māori want to participate in pest control governance. JM pointed out that when management ceased, the quality of the ecosystem for mahinga kai declined.

### Hunting

The intention of hunting and fishing in TEK cosmology is sustainability and respect for the animals. The tenet of respect is believed to ensure continued abundance and availability of the resource. Acting inappropriately may jeopardise hunting success. The game won't make themselves available to the hunter if proper protocols are not followed and due respect not paid (D. Fraser et al., 2006, p. 7; Gupta, 2007, p. 337; Ziembicki, Woinarski, & Mackey, 2013, p. 78). The enactment of traditional ceremonies may be required, anything from apologising to the deceased animal to supplying offerings to deities. 'Often, Aborigines blamed themselves for the disappearance of a species because they ceased to perform the relevant ceremonies after they had left their traditional lands for European missions or settlements (Burbidge, Johnson, Fuller, & Southgate, 1988, p. 36)'.

The Inupiat and the Inuit believe animals such as the caribou (*Rangifer tarandus*), beaver (genus *Castor*) and beluga whale (*Delphinapterus leucas*) exist in unlimited supply and hunting them will allow the animals to be reborn in a cycle of reciprocity (Krech, 2005, pp. 81-82). The Koyukon in the Yukon say that they do not take anything. Animals choose to give themselves to hunters as a gift that must be respected. Respecting the animal requires awareness of your behaviour and actions toward living and non-living things. You can be banished if you break these customs and disrespect nature. You only become a successful hunter when you truly understand, respect and honour the animal. Then they will respect you and allow you to take them (Watson & Huntington, 2008, p. 261). Customary hunting traditions manifest in cultural conventions. Tūhoe Māori harvested juvenile as well as adult tītī to reduce the impact on harvested populations. Adult breeding birds were left to breed again (Philip Lyver, Jones, & Doherty, 2009, p. 9). Present population numbers of birds and people may make harvesting native birds currently unsustainable, but this may not always be so. Including Māori in this conversation could make us more likely to participate in it.

Māori fishing tikanga also dictates that large breeding fish were to be left, preserving the capital stock (Ulluwishewa et al., 2008, p. 279). The large mature Dall rams (*Ovis dalli*) in the Yukon are not taken by the Kluane nation. The mature animals are the teachers of the younger ones and if they are lost information on behaviour, survival, etc. is lost in the same way the loss of an elder impacts human communities. The targeting of the large rams as desirable trophies has less impact on Dall numbers and is therefore permitted under mainstream management. However, this went in direct opposition to Indigenous management practices, where large mature males were not removed because this damages the flocks' social knowledge. It also removes prime genetic stock, lowering the genetic fitness of the entire population (Nadasdy, 1999, p. 9).

### Biosecurity practices

Integrated pest management could minimise pesticide resistance and may be cheaper, more effective and less time-consuming. This technology includes host plant resistance breeding, biological control and various management practices such as companion planting and crop rotation (M. B. Thomas, 1999, p. 5944). An understanding of the pest and natural predator interactions may be necessary to maintain the integrity of the system. Modifying the system has consequences, including trophic level interactions, pest population dynamics and host-pathogen interactions. Having a truly integrated approach to pest management on agricultural land may require moving away from pesticides and towards a better understanding of pest and host population biology (M. B. Thomas, 1999, p. 5944). A healthy plant may be better able to resist pest attacks.

The strategies employed are many and varied. Farmers in Patzún Guatemala attribute the control of pests to weather, soil conditions, the 'strength' of their site, their own tolerance to insect damage, their religious practices and their agricultural methods (Morales & Perfecto, 2000, p. 53). They also bury crop residue (stalks) to prevent pest infestations, because the grubs then eat the stalks and not the crop roots (this is against scientific advice) (Morales & Perfecto, 2000, p. 57). Intercropping is a key tool for TEK biocontrol. Intercropping maize with peanuts creates food web complexity that keeps the maize steam borer (*Busseola fusca*) in check and grass strips in cereal fields improve the survival of pest predator populations (M. B. Thomas, 1999, p. 5950). Farmers in Patzún deliberately intercrop species that repel insect pests and don't grow monocultures, although few were consciously cognisant of the biocontrol benefits of their practices (Morales & Perfecto, 2000, p. 56). Farmers also plant trees at the edges of fields to attract birds that control insects (Morales & Perfecto, 2000, p. 57).

Māori believe that you should not mix the water from different catchments. Mixing the water mixes and disrupts the mauri. It is also an effective biosecurity practice. Not mixing the waters prevents the spread of pathogens and pests. I am not suggesting that this custom was a deliberate biosecurity practice, only that it illustrates the importance of protecting the integrity of habitats and ecosystems. Introducing biocontrol agents is one option available to mainstream resource managers. The cost to benefit ratio of a biocontrol agent depends on the likelihood that the target infestation will spread, the ability to detect it, the probability of eradication, the efficacy of the agent and what is known about the biology and ecology of the agent (Turner, Bulman, Richardson, & Moore, 2004, p. 324).

## Rules of thumb

> Tūhoe saying: 'find the bug, you'll find the tree. Find the tree you'll find the bird. JM

Traditional management practices include rules of thumb. Rules of thumb are 'precise prescriptions for prudent use of living resources…' (Gadgil & Berkes, 1991, p. 9). Rules of thumb characterise resource management practices that ensure the long-term sustainability of the resource and evolve from trial and error. They have generally stood the test of time and become accepted and practised by the community (Gadgil & Berkes, 1991, p. 9). A community may not even be aware of, or are only vaguely aware of, the decision-making processes behind their rules of thumb, which may have originated generations ago (Gadgil & Berkes, 1991).

Rules of thumb function to protect ecological diversity and maintain threshold levels, protect selected species, populations, or ecosystems and define and legitimise political management and responsibility (Gadgil & Berkes, 1991; Gadgil, Berkes, & Folke, 1993, p. 154). An example of a rule of thumb is Jewish people not eating animals that have died from natural causes, or animals not killed quickly or humanely. They will not slaughter animals and their young on the same day and will not eat pork. These rules are good conservation practice, promoting the humane treatment of animals, ensuring the quality of the meat (meat from an animal that suffered is full of adrenaline and is tougher and not as nice tasting), and preventing illness from eating diseased meat or secondarily ingesting harmful substances. Another example is in Amazonian fishers who will not eat carnivorous fish, which are known to accumulate toxins and parasites (Meyer-Rochow, 2009, pp. 5,7).

### Taboos

> When mistakes were made or resources came under stress, appropriate ritual and remedy including the invocation of tapu and rāhui, were set in place (Pacey, 2005, p. 17)

Often taboos are management levers that become integral to the belief system of the community and part of the social fabric at a philosophical level. Colding and Folke (2001, p. 586) argue that taboos are foremost ‘resource conservation’ tools employed as a ‘strategic response to avoid game depletion (p. 586)’ rather than coming from a preservationist ethos. However, taboos do have a spiritual and preservation conservation function (Torri & Herrmann, 2011, p. 180). Taboos work because they are crafted and enforced by the users. Taboos can be flexible and adaptable in their application, enforced and released as the need arises or changes. Taboos use local knowledge and may be more efficacious than legally enshrined harvest restrictions, imposed nationally irrespective of local populations and conditions (Monson, 2004, pp. 8-11). The inclusion of the community in the development and implementation of taboos/rāhui results in better acceptance and observance of the restrictions and better ecological outcomes (Wright et al., 1995, p. 85).

Traditional resource managers use taboos to control which species are harvested, the condition of individuals harvested, or the amount harvested. There are many types of taboos (Wiersum, 1997, p. 10). Segment taboos are imposed on certain parts of the consumer community. For example, only kaumātua or rangatira can consume certain foods. Temporal taboos are imposed at certain times of the year, such as a harvest season, beyond which harvest is prohibited. Tītī have two strictly adhered to harvest seasons. Method taboos dictate how the harvesting or hunting should be done, what rituals need to be performed and the methodologies used. Life history taboos dictate the appropriateness of harvesting based on the age or life stage of the organism. For example, hunting may be prohibited during mating or nesting. Rules pertaining to the size, weight, or sex of the animals that are allowed to be taken fall into this category. Species-specific taboos ban the harvest of a species altogether and may be temporary or permanent. Habitat taboos restrict the harvesting or hunting from certain locations such as spawning grounds, sacred groves, distance limits from habitation, etc. (Monson, 2004, pp. 8-11).

Some examples of resource taboos are practiced by the people of Kampar, Indonesia, who prohibit fishing in the slow-flowing part of the river, thereby protecting the spawning sites and fish nurseries (Bakhtiar et al., 2010). The Cree of Canada divide hunting grounds into smaller areas and one section per year is hunted on a four-yearly rotation to increase the net overall harvest (Gadgil et al., 1993, p. 153). Chisasibi people in James Bay hunt goose in areas rotated on a seven-day cycle, reducing the amount of overall disturbance to the geese population and ensuring the birds return to the site to make hunting easier (Gadgil et al., 1993, p. 153). For some iwi, kererū were tapu 'the hidden bird of Tane Mahuta'. It was a violation to disturb a kererū nest; they were deemed food of the chiefs in some tribes and it was an offence to harvest them during times of prohibition (P. Lyver et al., 2009, p. 10).

Māori have the concept of rāhui, which is a temporary ritual prohibition closing an area for harvest or visitation. This was a political measure designed to protect a resource for conservation reasons, to keep people safely away from dangerous places, or as a sign of respect following a death (Forster, 2012, p. 20). JM described the way Tūhoe used rāhui in Te Urewera. Rāhui were placed on areas of the ngahere used for specific purposes and stretches of the river that could be fished at certain times of the year. Rāhui controlled the locations of gardens and were used to manage plant and animal populations and to prevent disturbance of secondary growth.

In the Western world, we often impose a type of taboo in the form of catch limits and exclusion zones. These are often based on minimum viable population modelling. Unfortunately, often there is not enough data to ensure these models are accurate for all geographical and temporal variations. These models can be complex, difficult to validate and even if their predictions lead to legislative regulation, enforcement may be impractical. This is particularly true for marine species and species that migrate over large distances and species for which we have incomplete data on population dynamics. The main issue with modelling maximum sustainable yield is dealing with ecological stochasticity and we often end up with populations in decline and a loss of ecosystem resilience, which further increases stochasticity (Monson, 2004, pp. 8-11). Modelling population dynamics is challenging because ecosystems are complex and have multiple variables that are difficult to resolve at large spatial scales. Many population dynamics models only account for one variable and are derived from a poorly resolved population base-line and are therefore of limited value.

### Fire

Fire has long been a management tool for TEK practitioners. Selective burning produces nutrient-rich soil and increases insolation. It produces a mosaic of different age classes in a forest, favouring plant diversity by promoting understory plant growth and wild food abundance (Larochelle & Berkes, 2003, p. 369). Fire management by Native Americans was noted to open up clearings and corridors that provided habitat for ungulates and wildfowl. Australian aborigines also used fire to improve feeding habitat for game (bandicoots and wallabies) and improve hunting access (Gadgil et al., 1993, p. 153; Ziembicki et al., 2013, p.

85). They also understood that their fires produced smoke particles that seeded clouds and brought rain (Holmes & Jampijinpa, 2013, p. 5). In Ethiopia, burning removes moribund grass and kills trees and saplings, increasing the abundance of palatable grasses and the fertility of the land. A change in management in recent years with a lack of burning has resulted in the thickening of the woody vegetation and herbaceous species (Angassa & Oba, 2008, pp. 211-212). Māori burned area's to promote the growth of bracken fern and then harvested and ate the root rhizomes and fire was also used to drive moa out of the forest when hunting.

### Sacred groves

Sacred groves represent the intersection of the human world, the natural world and the spiritual world (Verschuuren, 2006, p. 308). Sacred groves are protected forest fragments that provide habitat mosaics that contribute to important ecosystem services. Sacred groves may provide a source of native plant seed, wildlife refuges and animal source populations. In India, sacred groves were often set aside for spiritual and religious purposes as well as for protecting biodiversity. Sacred groves can provide habitats for species that perform biocontrol or pollination functions in the neighbouring farmland. Monocultures, which are more susceptible to disease, are limited and the uncultivated areas can provide medicinal plants that would not be found in farmland (Colding & Folke, 2001). There are sacred groves in Zambia and Kenya where digging roots, cutting wood and burning are forbidden because they hold the power to control the rains. These were removed by the government and now locals and scientists are indeed recording dramatic changes in local rainfall, infiltration and erosion (Ceperley, Montagnini, & Natta, 2010, p. 18). Gadgil et al. (1993, p. 154), suggest that refugia such as sacred ponds and groves initially established as resource management mechanisms have now become instilled with spiritual values because of the extensive time and effort invested in them. In any case, sacred groves are a valuable management practice that should be preserved (Tengö et al., 2007).

## Cultural calendars

> Basic biological information about plants transmitted through ecological calendars most commonly included their regional presence and the seasons of their flowering, fruit ripening, tuber maturity, greening and/or senescence (Prober, Connor, & Walsh, 2011, p. 6)

Cultural calendars are often constructed around cultural knowledge and document important spatiotemporal ecological events. This knowledge is intergenerational and is often passed on ritualistically. Cultural calendars are cued from animal behaviour, environmental changes, or by astronomical events. These calendars are arguably more accurate than the Gregorian calendar in predicting biological events because they are defined by the change in physical conditions at a local level and not an artificially constructed time structure. Cultural calendars may have cycles spanning many years and can reveal inter-annual climate variation (Prober et al., 2011, pp. 2, 6-7). For subsistence farmers, the ability to predict weather patterns, phenological events and animal behaviour may be of vital importance and many TEK practitioners are very good at doing this. Mongolian pastoralists count the number of joints on the stem of the bagluur plant (*Anabasis spp*). When the stems have two or three joints they will move on to new pastures (Fernandez - Gimenez, 2000, p. 1321).

Australian aborigines are able to predict the arrival of fruit bats, rainbow parakeets (*Trichoglossus haematodus rubritorquis*) and Torres Strait pigeons (*Ducula bicolor Scopoli*) by the presence of 'morning glory' clouds over the Gulf of Carpentaria. According to the Nyangumarta people, cold southeast winds in northwest Australia herald the running of bluenose salmon (*Eleutheronema tetradactylu*) and the threadfin (*Polydactylus* sp.) (Prober et al., 2011, p. 6). In southeast Queensland, string-like processions of hairy caterpillars predicted the clustering of breeding mullet in the waterways. The arrival of a species of March fly signalled the crocodile was laying and the presence of a different March fly species signalled that the plums were ripe (M. J. Christie, 1990). The prolific flowering of tea-trees (*Melaleuca alternifolia* and *Leptospermum scoparium*) on the Yorke Peninsula in southern Australia indicates the arrival of large numbers of fish, prompting Narangga people to plan initiation ceremonies while food is abundant (Prober et al., 2011, p. 6). The Warlipiri people of the Northern Territory knew that when the acacia flowers fall the snakes are mating and extra care should be taken in the bush. In British Columbia, the call of the Swainson's thrush (*Catharis ustulatus*) indicates that salmonberries (*Rubus spectabilis*) would soon be ripe and ready to harvest (Prober et al., 2011, p. 6).

TEK practitioners were/are often expert astronomers, linking many astronomical and ecological events. The night sky is not only an important part of Indigenous peoples' cosmology, as discussed in chapter two, but is also an important timekeeper. The position of Orion in the sky indicates the nectar production of (*Banksia dentata L.f.*) in northern Queensland. Those in northern Queensland, South Eastern and South Western Australia know the emu (*Dromaius novaehollandia*) is laying her eggs when the Pleiades (Seven Sisters) are in the northwest sky after sundown. The appearance of the Pleiades also signals the whelping of dingo pups in Western Australia, while the appearance of the constellation Lyra in March signals mallee fowl (*Leipoa ocellata*) have begun nesting. Sighting Arcturus on the northwest horizon after sunset signals the beginning of the koala (*Phascolarctos cinereus*) mating season. To the Brambuk of Western Victoria, the appearance of the Emu constellation in the Milky Way Galaxy marked the spring abundance of birds' eggs and other foods, indicating the time to hold large gatherings and trade, seek marriage partners, settle legal conflicts and hold corroborees (Prober et al., 2011).

The lunar cycle is of particular importance to Indigenous cultures as it 'controls the rhythm of farming activities, forest exploitation and gathering of fruits and mushrooms (Barrera-Bassols & Zinck, 2003b, p. 233). Barrera-Bassols and Zinck (2003b, p. 233) suggest that among the Pichātaro's farmers, it is commonly believed that 'the moon controls the amount quality and flow of water in the land, plants and animals'. Lunar cycles also regulate rainfall and diseases associated with frost. Full moon (Nana kutsi huiniri uiripiti), is considered an appropriate time to harvest maize and extract wood, which is dry by then. In contrast, planting fruit trees and castrating animals takes place during the new moon (Sapichu kutsi huiniri), because the body of living organisms is well provided with water at that time. Sowing is discouraged during a waxing moon (Andarani shatia) because of excessive moisture, which favours pests and diseases (Barrera-Bassols & Zinck, 2003b, p. 233)'. The effect of the moon on the flow of water through living creatures and the environment is generally not a part of ecological science assessments and management, yet can be critical to Indigenous ontology.

### Maramataka

> He would be taught the names of the various stars and comets and the different signs appearing in the sky or mountain, showing them when not to go to war, when not to go to sea, or when not to go to a certain place (Makereti, 1986 [1938], p. 10)

Māori were experienced and expert astronomers and meteorologists. They understood how the cycles of the moon and stars mark the seasons and influence climate and ecological events. This is maramataka. Huhana Bubbles Mihinui explained that maramataka refers to the lunar calendar but it is even more than that. It is the knowledge of weather, tide patterns and environmental rhythms (Kawharu, 2002, p. 28). The moon was an extremely important timekeeper for Māori and our calendar was based on its monthly cycles through the seasons (M. Roberts, 2006, p. 15). Maramataka guided Māori in all things from planting, weeding, fishing, to maintenance tasks and ensured that all activities were done at the optimum time (P. Harris, Matamua, Smith, Kerr, & Waaka, 2013, p. 330; Kawharu, 2002, p. 66).

Maramataka is at the foundation of all traditional and modern agricultural, fishing, medicinal, educational and conservation practices (D. King et al., 2008, p. 1). Each day of the month has a different name, describing the phases of the moon and each moon night is identified as being good or poor for fishing and planting (M. Roberts, 2006; Ropiha, 2000). The year begins for Māori with the rise of Matariki (other culture's names for Matariki include the seven sisters, the Pleiades and Subaru), or Puanga (Rigel) (P. Harris et al., 2013, p. 330). Matariki rising occurs not long before the shortest day in winter in early June and signals the beginning of the season of celebration for the anticipated fertility of the coming spring. It is a celebration of rebirth and of negotiating the previous years' perturbations.

Māori had extensive meteorological knowledge and recognised and named many cloud formations (D. King et al., 2008, p. 394). Māori knew which particular cloud formations predicted fair or foul weather. According to the Ngāi Tūhoe people, Te Tautau o Te Kahu, or horizontal cloudbanks in the east illuminated by the setting sun, meant bad weather and if Tuputuputu is behind Taioreore (Bigger and lesser Magellan Clouds) it will be fine weather (D. King et al., 2008). According to JM, Tūhoe know that the pōhutukawa (*Metrosideros excelsa*) flowering from the bottom up indicates a wet season with fat seafood ahead. The way the waves sounded as they broke against the shore could tell the Te Rōroa people (NW North Island) that bad weather was on the way. Knowing the winds influenced sailing, fishing spot selection and ensured safety on the water.

Māori were also accomplished astronomical navigators and could track the celestial bodies through the sky over the course of a year (P. Harris et al., 2013, p. 334). Māori used the position of the moon, planets, stars, oceanic currents and wave patterns and the behaviour of marine animals and birds to navigate back and forth across the Pacific Ocean at will (P. Harris et al., 2013). The Pacific Ocean may have been a familiar water continent to the Polynesians. Evidence suggests Māori were routinely trading with South Americans in pre-history. For example the kumara comes from South America (Field, 2013). **Table 3** below describes some examples of astronomical and meteorological indicators used by iwi. This list below is far from comprehensive and only gives examples of the type of maramataka held by Māori. As well as extensive meteorological and astronomical maramataka, Māori had an extensive breadth of phenology and animal behavioural knowledge to draw upon. Māori were acutely aware of the flowering cycles of the trees in the environment and the behaviour of the birds' that fed on them. **Table 4** below is a sample of this considerable wisdom. These indicators were keyed to local observations, varying region to region, iwi to iwi, as different geographic and climatic conditions influenced the timing of ecological events (M. Roberts, 2006). The practical benefits of understanding the ebb and flow of bird populations in your rohe and predicting upcoming seasonal trends are important for managing resources sustainably.

## Astronomical and Meteorological

- **Marama, the Moon**:
  - Visible rings indicate a heavy fog
  - Appearing on its back indicates rainy weather - *Kai Tahu: E South Island*
- **Ra, the sun**
  - Visible rings around it indicates a coming storm - *Kai Tahu: E South Island*
- **Matariki or Pleiades star constellation**
  - The observed distance between the stars (near of far) indicates fair or foul weather
  - The stars appearing to quiver indicates fair or foul weather - *Ngai Tuhoe: NE Central North Island*
- **Tu-mata-kokiri (Meteors)**
  - Meteors falling horizontally or vertically indicates the prevailing winds for the coming season - *Ngai Tuhoe: NE Central North Island*
- **Whānui or Vega**
  - Moving fast or slowly across the sky indicates a lean or fruitful season - *Ngai Tuhoe: NE Central North Island*
- **Atutahi or Canopus**
  - Standing apart from the milky way in October indicates a dry summer ahead
  - Twinkling brightly from one side indicates strong winds will blow from that direction - *Kai Tahu: E South Island*
- **Mangaroa or the milky way**
  - Appearing curved indicates bad weather
  - Appearing straight indicates fine weather - *Kai Tahu: E South Island*
- **Puaka or Rigel**
  - Appearing south of the rising sun indicates bad weather
  - Rising north of rising sun indicates fine weather
  - Rising in line with the rising sun indicates drought - *Ngai Tuhoe: NE Central North Island*

**Table 3.** Some examples of astronomical and meteorological maramataka adapted from (D. King et al., 2008, pp. 403-407).

## Marine

- **Rāwaru of blue cod (*Parapercis colias*)**
  - Stones in the belly indicates bad weather on the way - *Ngāti Koata: N South Island*
- **Kelp**
  - Hanging kelp furling a certain way indicates the approaching rain - *Ngati Wai: NE North Island*

## Bird behaviour

- **Pukeko (*Porphyrio melanotus*)**
  - Heading for higher ground indicates a storm approaching - *Ngāti Wai: NE North Island*
- **Kaka (*Nestor meridionalis*)**
  - Becoming boisterous indicates a storm - *Ngāti Pare: NE North Island*
- **Koekoeā or long tailed cuckoo (*Urodynamis taitensis*)**
  - Their return indicates the return of good weather
  - If they stop singing the wind will turn southerly - *Ngāti Pare: NE North Island*
- **Ruru or morepork (*Ninox novaeseelandiae*)**
  - Calling shrilly to one another indicates bad weather approaches - *Ngāti Pare: NE North Island*
- **Pīpīwharauroa or shining cuckoo (*Chrysococcyx lucidus*)**
  - Their return indicates spring - *Ngāti Pare: NE North Island*
- **Kuaka or bar tailed godwit (*Limosa lapponica*)**
  - Their return indicates spring - *Ngai Tuhoe: NE Central North Island*
- **Riroriro or grey warbler (*Gerygone igata*)**
  - Build their nests with the entrances on the opposite to the upcoming seasons prevailing winds - Ngai Tuhoe: NE Central North Island
  - Building nests high in the canopy indicates the coming season will be mild with warm westerlies
  - Building nests low down indicates a poor season - *Kai Tahu: E South Island*
- **Torea or variable oystercatcher (*Haematopus unicolor*)**
  - Changing their call indicates an approaching storm - *Ngai Tuhoe: NE Central North Island*
- **Matuku or bittern (*Botaurus poiciloptilus*)**
  - Crying continually indicates imminent floods - *Ngāti Ruanui: SW North Island*
- **Mohua or yellow head (*Mohoua ochrocephala*)**
  - Flocking in the tree tops and retreating back amongst the leaves indicates bad weather is imminent - *Kai Tahu: E South Island*
- **Kōtuku of white heron (*Ardea modesta*)**
  - If plentiful in summer indicates gales and a poor winter - *Ngāti Apa: N South Island*

**Phenology**

- **Kowhai (*Sophora microphylla*)**
  - Flowering indicates the kina are now fat and juicy - *Ngāti Pare (NE North Island). Ngai Tuhoe: NE Central North Island*
- **Puahou or five finger (*Pseudopanax arboreus*)**
  - lower branches blossoming first indicates a warm bountiful season - *Ngāti Awa: Central North Island*
- **Karaka (*Corynocarpus laevigatus*)**
  - F*lowering heavily indicates a drought* - Ngai Tuhoe: NE Central North Island
- **Pohutukawa (*Metrosideros excels*)**
  - Flowering from the bottom of the tree up indicates warm pleasant season ahead
  - Flowering from the top down indicates a cold wet season will follow
  - Early flowering indicates drought - *Te Arawa: Central North Island*
- **Grass**
  - Dew on the grass indicates a nor-east wind
  - Dry grass indicates a southerly - *Kai Tahu: E South Island*

**Table 4.** Some examples of maramataka around bird behaviour, phenology and marine. (D. King et al., 2008, pp. 403-407)

Maramataka, whakapapa, kaitiakitanga, tikanga and the occurrence of major environmental events such as volcanic eruptions, hurricanes, tsunami, floods and drought were recorded and passed on as mōteatea (laments), pepeha (quotations), whakataukī (proverbs) and waiata (songs) (P. Harris et al., 2013, p. 330). These orations capture and retain local environmental information and experience. The relevance of the moon to the tides is reflected in one such related pakiwaitara. Te Marama (the moon) took two sisters as wives; one named Rona represents the person seen in the moon and her sister Tangaroa-a-roto symbolised the connection of the moon to the tides (M. Roberts, 2006, p. 15). Māori were also fully aware that the time for the Earth to travel once around the sun is 365 and one-quarter days and either added lunar nights every few months or added a month every few years to maintain lunar synchronicity (P. Harris et al., 2013, p. 330).

Maramataka can augment our modern responses to ecological variability and adapt to climate change (D. N. T. King, Goff, & Skipper, 2007, p. 387). Linking the timing of ecological events to management practices allows adaptability and improves the predictions of adverse climate events and resource management decisions. Since maramataka has been gathered and passed on inter-generationally, it involves long-term trends and can reveal climate change. The kaumātua of the Ngāti Kahu in the far north have been noticing changes in the Maunganui harbour over decades. Tidal flows have changed where land reclamation has occurred (Selby et al., 2010, p. 30). They felt that because of their extensive knowledge and experience of the area, they knew more about the ecological changes than the scientists did. They felt that the scientists were only guessing. Elders in the Manawatū have observed changes in the number of tuna (*Anguilla spp*) migrating in the Hōkio stream. They noted that up until the mid-twentieth century, tuna migrated in such numbers that neighbouring whanau and iwi shared in the abundance and that this can no longer happen (Selby et al., 2010, p. 42).

## Māori environmental assessment models

> Monitoring provides Māori with tools to articulate perceptions of environmental change, environmental health and Māori wellbeing. The tools can be used to give a statement about the state of the environment in time through a Māori lens and provide a vital reservoir of knowledge for all New Zealanders to improve their understanding of New Zealand's unique and fragile cultural and physical environment (G Harmsworth & Tipa, 2006, p. 22)

Mātauranga Māori indicators are derived from tikanga and use knowledge that is still available and obtainable (Ti Kipa Kepa Brian Morgan, 2010, p. 247). Mātauranga Māori indicators include spiritual - atua and wairua, social – hapū and iwi, cultural – manaaki, kaupapa and tikanga and economic - tangata domains. For Māori, these domains are inseparable from the physical (Ti Kipa Kepa Brian Morgan, 2010, p. 247). Mātauranga based indicators are sympathetic to the iwi's historical knowledge and current resources (people, money, skills) (G Harmsworth & Gadgil, 2002, pp. 13-14). They support Māori classification systems, organisational frameworks and methodologies and protect Māori intellectual property rights. Like science indicators, Māori ecological indicators should have clear goals pertinent to management and be relevant at both local and national levels, (see **Table 5**).

| Māori ecological indicators need to... |
| --- |
| • Foster wairua - cultivate the spiritual essence of the whenua<br>• Enhance mauri - enrich the life giving properties and the life-force of the whenua<br>• Respect whakapapa - promote the genealogical links to the land of the flora, fauna, and the people<br>• Emphasise Te Ao Māori - support indigenous biodiversity<br>• Reinforce mana auta - support the quality of ecological domains<br>• Focus on taonga and mahinga kai species - concentrate on management of culturally important species<br>• Integrate whakawhanaungatanga and tangata - be relevant to the community to support management done by the community for the community and be practical and tangible<br>• Be conducted using tikanga, kaupapa and maramataka - be underpinned by Māori customary practices, knowledge, goals, values and principles<br>• Sustain toiora - ensure the ecological, social, economic and cultural welling of the whenua and those that live on it<br>• Be able to reveal both positive and negative changes<br>• Be able to reveal gradual, incremental change<br>• Use both qualitative and quantitative data |

**Table 5**. Lists the features required by Māori ecological indicators (G Harmsworth & Gadgil, 2002, p. 14).

## Mauri model

The Mauri model was developed in 2002 by Kepa Morgan using the concept of mauri and integrates economic, social and spiritual dimensions into environmental assessments (Dymond, 2013, p. 277; Ti Kipa Kepa Brian Morgan, 2010). These attributes are viewed in relation to mauri and ranked from -2 to +2 (see **Figure 2**). The rankings can then be tabulated and weighted and then trend comparisons done (Ti Kipa Kepa Brian Morgan, 2006). The mauri model can be used to compare two sites or the same site at two different points in time. The Mauri-o-meter can be used alongside the Resource Management Act and the Local

Government Act to provide a way of assessing management decisions from a Māori perspective. It is a decision support matrix that can assess institutional performance (Ti Kipa Kepa Brian Morgan, 2006, p. 6). It is easy to understand, inclusive of the community, requires acceptance but not necessarily understanding of the value system by the resource manager/s and provides a comparable index for trend analysis. It does not require specific or specialised monitoring tools, techniques, or training. The Mauri model does not directly compare or connect mātauranga with science and although it effectively quantifies mauri, allowing resource managers a tangible measure of it, it does not enable the concept of mauri to be cogitated by scientists in a way that values it equally alongside scientific ecological concepts.

The Mauri model indexes ecological features in relation to mauri, providing a way to quantify this esoteric concept and in this way include this Māori value in mainstream resource management. The output of this model tends to be set alongside the scientific assessments. This, however, does not ensure that the outputs of the Mauri Model are given equal consideration or relevance by non-Māori resource managers. Since there is a lack of interaction between the Mauri Model outputs and mainstream ecological science, the results could easily be overlooked by mainstream resource managers. Mainstream resource managers may value scientific data that they understand and trust more than a simple index of a Māori concept that they do not understand as well. There is also a danger that the Mauri Model may be used by unqualified or inappropriate (both Māori and non-Māori) practitioners as an easy way to claim that there has been engagement with Māori. This would make this tool open to being used inappropriately as a way to tick box interacting with Māori. He Kete Hauora Taiao removes these problems by coupling Māori values, such as mauri, directly to mainstream scientific metrics, therefore ensuring that the data has been viewed through a Māori lens that weights the value of both equally.

The trustees of Rotoiti paku near Matata used the Mauri model to measure the outcomes of restoration efforts on their lakes and geothermal pools (Dan Hikuroa, Slade, Morgan, & Gravley, 2010, p. 154). The trustees were dissatisfied with the scientific report produced by the consultant and felt the report did not meet their needs. The scientists used parts per million and parts per billion of contaminants to describe the contaminant load of the lake. The iwi felt that this measure was not well understood or relevant to the iwi and did not reflect the wellbeing of the roto. The trustees understood that the science was necessary but wanted more and different indicators, such as kaitiakitanga, to be included. They applied the Mauri model, discovering that many of the indicators they selected showed degradation had occurred since the 1900s. Some of the indicators they used were pollution, biodiversity, wāhi tapu, healing properties, mahinga kai, ability to swim, legal loss of the lake and land ownership, cost of restoration, loss of income and loss of kaitiakitanga. The Mauri model may also be used as a forecasting tool. The Mauri model was applied to hypothetical geothermal development using three of each of the environmental, economic, cultural and social indicators and the current state was compared to a hypothetical sate in 2040. The study predicted positive changes in mauri over that time (Dan Hikuroa, Morgan, Gravley, & Henare, 2010).

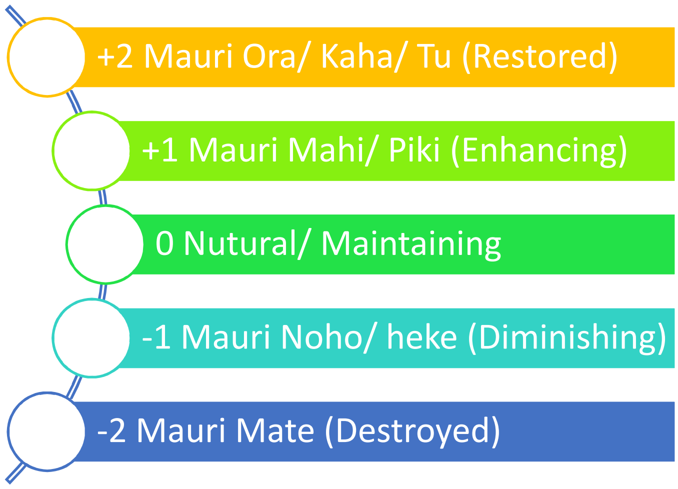



**Figure 2.** The Mauri-o-meter adapted from (Dymond, 2013, p. 277; Daniel Hikuroa, Slade, & Gravley, 2011, p. 6; Te Kipa Kepa Brian Morgan & Fa`Aui, 2018, p. 988)**.**

## The Korowai Framework

Baker (2012) developed the Korowai framework in response to problems she saw with the way genetically modified organism assessments are done by the ERMA (Environmental Risk Management Authority) using HSNO (Hazardous Substances and New Organisms 1996 Act). She felt that the needs of her iwi were not being met and believed a kaupapa Māori approach was required to protect the mauri of the whenua. The Korowai framework has three components: worldview (understanding and perceptions), values (how things should be), and ethics (what we do). The korowai represents the weaving of values, ethics and epistemology together to create a protective 'cloak' of wisdom and integrity. The woven structure signifies that if just one thread is pulled out the integrity of the decision-making process is undermined (Baker, 2012, p. 91). The tikanga aspects signify the warp and the indicators denote the weft of the fabric. The korowai framework measures the indicators of mauri, whakapapa, tohu and tapu through the tikanga (Māori lens) of kaitiakitanga, sustainability, relationships, wairua, respect and reciprocity to define the outcomes of genetically engineered organisms in Aotearoa.

This framework was applied to the impact of genetically modified organisms on ngāngara (lizards and creeping things). Māori recognise ngāngara as important bio-indicators of the quality and health of the environment and consider them bearers of ecological messages, warnings and omens (Baker, 2012, pp. 87-89). Baker (2012) demonstrated that GE undermined whakapapa relationships, resulting in a disconnect between the land, the people and the GE modified organism and did not support mauri (Baker, 2012, pp. 91-92). These implications could include the unwanted flow of genetic material through organisms and into the environment and the impact on the wairua of unrelated organisms resulting from gene mixing. She stated, and I paraphrase, GE undermines the genealogical and evolutionarily relationships that are held within the genetic material and is done in ignorance of the ecological implications (Baker, 2012, p. 93). Baker (2012) also noted that GE was not consistent with the retention of rangatiratanga and kaitiakitanga obligations and reduced control over the quality and sovereignty of food organisms. It could also allow the commercialisation of medicinal plants and bioprospecting. Whilst there is rightly a discontent at using chemical toxins for pest control in our environment, options are limited and pest control using toxins and potentially more novel biotechnologies such as gene silencing, genetic editing and gene drives may continue to feature highly in our natural resource and conservation management regimes for the foreseeable future.

The way that this model uses several Māori concepts in what was previously an entirely scientifically framed assessment is valuable. It provided me with an indication of how the

Māori values and cosmology could be applied to ecological scientific concepts and resource management outcomes. This framework did outline the impact of current resource management practices on Māori and the environment, but I feel there remains a need to translate the Māori concepts applied into something that scientists could comprehend. This would make mātauranga more accessible and relevant to scientists and this needs to be done by making science comprehend the mātauranga and not by describing the mātauranga using scientific rationale. This framework was designed specifically as a response to the impact of decision-making processes relating to the HSNO Act. This framework defines one way in which Māori concepts can be used in a decision-making space. It is specific to HSNO Act policy decisions and New Zealand may need an ecological assessment tool that can be used more universally. By employing standard and well known scientific metrics, He Kete Hauora Taiao builds in universality. The Korowai framework links Māori ecological indicators to mainstream ecological outcomes but does not quantify these outcomes, He Kete Hauora Taiao can.

### Cultural Health Index for Streams and Waterways (CHI)

> The CHI responds to the values, beliefs and aspirations of Māori , as well as outlining how its application could assist resource managers, not only to enhance contemporary resource management practice but also to fulfil their obligations stemming from the Treaty of Waitangi and New Zealand's resource management laws (G. Tipa & L. D. Teirney, 2006, p. 1)

The Cultural Health Index (CHI) in 2002 for streams and Waterways was built as a Ministry for the Environment (MfE) project (G. Tipa & L. Teirney, 2006, p. 2). It was trialled in various catchments in the Hawkes Bay and Otago. The framework was constructed around two important Māori values, mahinga kai and mauri and expanded on the purely technical indicators measured by ecological science (G. Tipa & L. D. Teirney, 2006, p. 1). The CHI can be applied at a catchment or the site level and respects the Māori ki Uta ki Tai (from the mountains to the sea) holistic catchment management approach. JM, one of my interviewees, stated that for Tūhoe, the resource management paradigm is from the mountains to the sea. Tuna (longfin eel *Anguilla dieffenbachia* and the shortfin eel (*Anguilla australis*) management extended across the entire ecosystem to enable the eels to complete their natural life cycles.

Waterways were kept open to allow migration and the water quality was maintained by managing the vegetation and disturbance in the catchment. The CHI framework has three main components (G. Tipa & L. D. Teirney, 2006).

Component One is Site Status. This is determined by the iwi and is an assessment of the cultural significance of a site historically and in the future (except for mahinga kai collection, which is covered by component 2). The following index is applied:

- A1 Culturally significant site that would be used in the future
- A0 Culturally significant site that is no longer being utilised
- B1 Not a significant site but would be used in the future
- B0 Not a significant site and not likely to be used in the future (G. Tipa & L. D. Teirney, 2006, p. 1)

Component Two is Mahinga Kai. This component examines the health of the mahinga kai resource, the indigenous flora and fauna present, the physical characteristics of the water, its cultural use and its productivity. In essence, the mauri of the waterway. The mahinga kai component is measured using the following indicators, which are scored from 1-5, ranked and then averaged to get an index:

- The number of mahinga kai species present (diversity and abundance of kai species, equating to the site productivity)
- Identity of kai species traditionally at this site and what kai species are there now (what suite of species is present and how this has changed)
- Access barriers, physical and legal, to the site
- The future value of this site as a mahinga kai source (G. Tipa & L. D. Teirney, 2006, pp. 1-2).

Component Three is the Cultural Stream Health Measure, consisting of eight physical characteristic indicators:

- Water quality
- Water clarity
- Flow and habitat variety
- Catchment land use

- Riparian vegetation
- Riverbed condition/sediment load
- Use of riparian margin
- Channel modification (G. Tipa & L. D. Teirney, 2006, pp. 1-2)

These indicators were defined by iwi using their relationship to departmental atua (Young et al., 2008, p. 33). The indicators attributed to Tangaroa included riverbank condition, sediment load and water clarity and flow, the shape and form of the river and the biodiversity the river supports. Tāne Mahuta was represented by the riparian and catchment vegetation, bird and forest health, terrestrial diversity and community structure and the presence of pest species. Haumia Tiketike and Rongo Matā nē were evoked by species abundance and kai or medicinal species. Tūmatauenga was embodied by the human use of the river and its margins, the ability to access the river and the presence of culturally significant sites. Tāwhirimatea was incarnate by the smell of the river and the local weather conditions. Finally, the overall impression or 'gut feeling' of the health of the river was ascertained. Having an ecological assessment that includes cultural values and is conducted using scientific methodologies makes assessments more relatable and relevant to the community (Young et al., 2008, p. 3).

This framework provides Māori with a way of monitoring the health of an ecological habitat that can be done alongside scientific methods. For example, water clarity and quality are assessed scientifically using clarity disks and periphyton biomass analysis and assessed using mātauranga by using the smell, appearance of the bank, the health of the fish in the water, the appearance of algae and the stream bed composition. Water flow can be assessed in the mātauranga way by the sound and tone of the water, or in the scientific way, using flow meters. Bird and pest monitoring can be done either by using kaitiaki knowledge or by using scientific protocols. Many of these scientific assessments for stream health are provided in the Stream Health Monitoring and Assessment Kit (SHMAK) (Townsend, Tipa, Teirney, & Niyogi, 2004). The CHI was reportedly as good as the SHMAK assessments at assessing the impact of land-use change on stream health (Townsend et al., 2004, p. 184). The correlation was particularly strong for small and medium-sized streams (Townsend et al., 2004, p. 191).

Having CHI indicators related to cultural values and the atua makes them more relatable and relevant to the community. Measuring them in a scientifically methodological way makes them more translatable to scientists and resource managers (Young et al., 2008, p. 3). Having the mātauranga alongside science is an important feature of this model and there is value in adopting this approach for terrestrial habitats. However, if mātauranga indicators are to be afforded the same level of influence as scientific ones, it is important that they are not only comparable with one another but can be interchangeable, although not substitutional. The Cultural Health Index was employed by a kaitiaki from PH's iwi, Rangitāne O Manawatū. They used this method to conduct monthly monitoring to capture seasonal variation. Their experience is that some of the atua fields were problematic. He explained that atua fields sometimes contradicted each other and failed to provide an accurate assessment. The site may score low for fish habitat and at the same time high for bird habitat and therefore did not reflect the actual state of the environment. Often, Māori consider a health ecosystem if it scores highly in multiple indicators. He also suggested the need to have a negative score for when the habitat was completely obliterated.

### The Māori Wetland Indicator project

The Māori Wetland indicator project is based on the PSR framework and incorporates mātauranga Māori based indicators:

- Pressures- what causes the problems?
- Taonga and mauri
- Trends over time from a cultural perspective (G Harmsworth & Gadgil, 2002; Jollands & Harmsworth, 2007, pp. 722-723)

This project was designed to develop a co-ordinated national monitoring approach for wetlands using Māori indicators within the larger MfE Wetlands monitoring project. Taonga and mauri indicators were broken into four groups. Group 1 indicators relate to culturally important plants and animals and are assessed using productivity, health, yield and abundance (catch rate and sound level/intensity). Group 2 indicators related to invasive species. Group 3 indicators related to the quality or mauri or the water including pollution, contaminants, degree of modification (canalisation, dams, roads, buildings, etc.), and the clarity, colour, feel, smell and volume of the water. Group 4 indicators relate to cultural heritage and the state of cultural sites, the wāhi taonga and wāhi tapu present in the area. All of these assessed the physical, psychological, spiritual, cultural, social and economic impacts on Māori wellbeing and were linked to management objectives (G Harmsworth & Gadgil, 2002, pp. 14-27). This framework has been incorporated into many iwi and hapū monitoring plans and is recognised in the national wetlands monitoring framework as complementary to existing scientific methods. It is an excellent way of assessing the impact of pressures on Māori wellbeing. This framework illustrated how Māori concepts such as taonga, mauri and tapu can be placed at the centre of an assessment framework and how they can be measured by constituent parts.

### Other Māori assessment models

Te Rūnanga O Ngai Tahu developed the State of the Takiwā tool. It is a monitoring framework for marine and freshwater habitats, incorporating mauri and mahinga kai, using Māori ecological indicators and ecological scientific monitoring indicators. It was based on the Marine Cultural Health Index and the output of this project is a database enabling data capture, analysis and reporting (G Harmsworth & Tipa, 2006, pp. 13-14; Selby et al., 2010). The tool includes an overall health index, a species abundance index, the Cultural Health Index for Waterways assessment tool and the SHMAK assessment tool. This tool demonstrated a method of capturing mātauranga assessment data and a way of applying existing scientific monitoring frameworks to iwi tikanga.

The Kaimoana Study Guidelines for Hapū and Iwi were developed by Otaraua hapū in partnership with Shell New Zealand and involved Taranaki Regional Council and Ngāti Rāhiri (G Harmsworth & Tipa, 2006, p. 13). This framework provides guidelines and survey templates for iwi and hapū to monitor and manage their kaimoana.

The Marine Methods and Indicators for Marine Protection is a joint DoC (Department of Conservation) and MfE (Ministry for the Environment) project in collaboration with Ngāti Kere in the Hawke's Bay and Ngāti Konohi near Whāngārā (G Harmsworth & Tipa, 2006, p. 13). Its purpose was to determine the efficacy of marine conservation sites. Iwi provided mātauranga in the form of cultural values, cultural indicators and baseline historic data and assisted in producing species and habitat inventories and mapping. This model provided a basic use of mātauranga indicators and was unique and valuable because it did this at a national Ministerial level.

Cultural Impact Assessments are used to assess specific cultural issues, including environmental impacts affecting iwi, in a way that is translatable to science. Cultural Impact Assessments are designed to report on the impacts of development on iwi. They are a good way for iwi to describe how they may be impacted by resource management decisions, however, impacts are framed from a Māori perspective and unless there is a way to translate these perspectives into science for mainstream resource management consumption, they can be overlooked.

*Cultural use of Geographic Information Systems*

Indigenous people have a lot of their own spatial information which has been transmitted down the generations as stories, proverbs, song, dance and art. Māori use kōrero, whakataukī, waiata, haka and poi. The 'Oral Pegs' they used were the locations of the rising and setting of celestial bodies and the location and direction of islands, rivers, etc., as well as the behaviour of the ocean currents and swells, the prevailing winds, mounga and awa landmarks and even manmade markers and tracks (T. Davis, O'Regan, & Wilson, 1990; Kelly, 1999, pp. 8-10). Presently, even more cultural cartographic information exists in written form as historical documents, manuscripts, photographs, old maps and in Treaty claim documents (G Harmsworth, Park, & Walker, 2005). Cultural cartography may commemorate places, people, historical events, social boundaries, landmarks, harvesting and nursery sites, resource rights, or spiritual sites and provides direction to and from locations. Cultural maps celebrate, cement and contextualise our links with our tūpuna and tūrangawaewae (Pacey, 2005, p. 1). 'The names *are* the map' and place names remind us who and where we are (Kelly, 1999, p. 14).

G Harmsworth (1999, p. 1), discussed the importance of capturing this information before it is lost forever when elders who have this knowledge pass away. GIS enables data, such as the locations of wāhi tapu, uru pa and other important cultural sites, to be stored and protected (see **Table 6**) (G Harmsworth & Tipa, 2006, pp. 19-20). Preserving this knowledge may be important culturally and iwi with access to GIS systems of their own can design methodologies to ensure their data is captured in a culturally acceptable manner that respects tikanga, kaupapa, mātauranga and tapu, thereby protecting sensitive information (G. Tipa & Nelson, 2008, p. 313). The issues of data sensitivity and intellectual property protection can be managed using fuzzy mapping (indistinct locations are given to indicate general areas but not exact locations), access protocols and licencing (Pacey, 2005, p. 44).

| Māori spatial data sets |
|---|
| • Māori soil classification<br>• Cultural sites (archeology)<br>• Māori tracks and trails<br>• Historic settlements<br>• Resource consent impacts on iwi values<br>• Cultural and natural heritage mapping<br>• Cultural impact assessment data<br>• Environmental management, planning and monitoring data<br>• Iwi environmental indicator information<br>• Data on ecological restoration projects<br>• Spatially referencing Waitangi tribunal claims and supporting oral and contextual evidence (hydrological, cultural site and use maps, land ownership and parcel maps) |

**Table 6.** Shows the list of Māori data sets that could be captured with GIS (G Harmsworth et al., 2005, pp. 8, 16; Pacey, 2005, pp. 32-33).

Cultural mapping and assessment allow iwi to explore their relationships with places, cultural activities, the spoken word and the gap between the iwi's traditional interactions with the environment and their current ability to do so. Māori cultural cartography data can improve sustainable management, iwi reporting, planning, implementation of cultural heritage and biodiversity projects, collaboration between stakeholders and management partners and can aid cultural enrichment through connectivity to important sites (G Harmsworth et al., 2005, p. 7). Mapping and describing Indigenous people's territories and geography has been a powerful colonial tool. However, if appropriated by Indigenous people for our own benefit, we can retake and reassert control over the cartography of our cultural landscapes (Frantz & Howitt, 2012, p. 727).

G Harmsworth and Gadgil (2002) explained that 'There is also a vital need for Māori concepts and approaches to be better understood, recognised and acknowledged as a legitimate part of the environmental and science sector in New Zealand (G Harmsworth & Gadgil, 2002, p. 37)'. This need has driven the development of the Māori monitoring frameworks, described above, in order to monitor the pressures and impacts of human activity on cultural heritage sites and archaeological sites and to assess contamination, biosecurity threats and the impacts of and on customary harvest practices. Monitoring that includes mātauranga and tikanga should go beyond a quality ranking of mauri, mahinga kai, or the identification of important cultural sites. All of the assessment tools described above provide conceptual frameworks for environmental assessments based on Māori values (G Harmsworth & Tipa, 2006). All of them try to include a Māori perspective in one form or another. The methods these models employed guided the construction of He Kete Hauora Taiao. I adapted the indexing framework from the Mauri model and the methodology for comparing mātauranga from the CHI.

## Conclusion

> …the four-leggeds have the right to live in an environment that has clean air to breathe and the two-leggeds have the responsibility to ensure that the air is not made unclean by any of our actions (Hatcher et al., 2009, p. 151)

Understanding Indigenous monitoring tools helps us to comprehend the ontology behind them and how they function. This understanding may enable the consolidation of Indigenous and mainstream science-driven resource management. TEK practitioners employ several management practices. Rangelands, cultivated land and forests are described, categorised and managed according to the underlying soil and the soils' relationship to the vegetation, climate, animal productivity, fertility (plant and animal), and cultural use (Talawar & Rhoades, 1998, p. 3). Animals may be managed (hunted and farmed) according to defined cultural philosophies and practices passed on and implemented as rules of thumb and taboos, such as the use of fire and sacred groves, among other things. This cultural knowledge is situated against the backdrop of our cultural landscape and embedded in our cultural calendars. Cultural landscapes represent the embodiment of knowledge in 'mental maps' of the landscape (Barrera-Bassols & Zinck, 2003b, p. 233). Cultural calendars are the timetables reflecting ecological variations (spatially and temporally) and resource availability (Prober et al., 2011, p. 2).

Māori environmental assessment models help quantify Māori environmental indicators. Many Māori environmental assessment models are esoteric and behave more like ecological values. These can function as environmental states. The Māori ecological assessments investigated in this chapter use mahinga kai, important cultural sites, mauri, whakapapa, tohu, tapu and kaitiakitanga. Some of these assessment models applied a quantitative ranking to Māori indicators. Another approach taken in the korowai framework was to define the impact on these indicators from an action, such as the introduction of genetically modified organisms into the environment. Most Māori assessment models are employed to assess freshwater ecosystems rather than terrestrial ones. Current wai-focused environmental assessment frameworks that employ both mātauranga and mainstream science do not attempt to apply Māori ecological indicators to mainstream science methodologies, which effectively maintains a gap between the two (Fenemor et al., 2011, p. 317).

The next chapter investigates the drivers and pressures that have created the current ecological landscape in Aotearoa. Chapter 5 explores the geographic, geological, environmental and evolutionary influences on the biota in Aotearoa and how anthropocentric impacts continue to affect the ecology of the country. The next chapter will also explore how the current political landscape has been shaped and how these factors influence the health and wellbeing of Māori.

# Ūpoko Rima - Ngā raru

# Chapter Five – Ecological pressures

> Most types of chronic environmental stresses will eventually lead to a change in overall health that is visible to a trained observer (Rutters et al., 1992, p. 26)

For most Indigenous people and, in fact, anyone with a deep spiritual and emotional connection to the land, environmental degradation is extremely worrying. As discussed in Chapter 2, Indigenous people may see habitat degradation as a violation of the rights of future generations. Failure to kaitiaki our land may be viewed as disrespectful to the land, our tipuna and the atua. This perspective makes the need to prevent degradation of the environment automatic, urgent and absolute (Torri & Herrmann, 2011, p. 179). In this chapter, I will provide a brief history of humans in Aotearoa and discuss the changes wrought by successive colonisations. I will investigate the pressures acting on biodiversity and ecosystems and the anthropogenic drivers that cause habitat modification and degradation, weed and pest introductions, overexploitation and pollution (Victoria Ann Froude, 2011, p. 207). Anthropogenic drivers apply pressure to an ecological state, potentially impacting and altering its functioning to the extent that a modified ecological state emerges. Drivers and pressures are the first elements of the internationally recognised Driver – Pressure – State – Impacts – Response (DPSIR) framework (Collen & Ebrary, 2013, p. 310).

Human-induced ecological degradation can be broken down into five elements (Goldman & Tallis, 2009, p. 69). The first of these is habitat loss, including habitat fragmentation, deforestation, agricultural intensification and the advent of factory farms. The second is over-harvesting or over-extraction of resources, including unsustainable hunting of native species and the over-allocation of freshwater. Overharvesting of animals is taking more than the population can sustainably support in the long-term and leads to population declines and the potential for loss of genetic diversity. The third is invasive species and diseases. These are becoming ever more pressing issues as rapidly increasing global commerce over the last few decades has opened up many more incursion pathways and as a warming climate allows diseases to spread wider and faster than before. The fourth is pollution and includes the excessive use of agricultural chemicals and their impacts on biochemical cycling in the environment. The fifth, climate change, has the potential to change ecosystems beyond recognition. Human-induced climate change may alter temperature, hydrology regimes (precipitation and groundwater infiltration rates due to rain pattern changes and drought), and exacerbate storm events, which can cause significant habitat disturbance. Change may be so rapid that populations cannot adapt quickly enough and die out locally. Habitats and biomes may be changed irrevocably and the ecology (biotic processes and functions) altered permanently.

## Aotearoa - New Zealand's unique native biota

> 'We call the forest 'the cloak of Papa-tūā-nuku,' the Earth-Mother. When we see these bare hillsides, it is like leaving our own Mother naked and exposed - A Māori landowner' (Funk & Kerr, 2007, p. 203)

Aotearoa has a unique geological, geographic and evolutionarily legacy. Aotearoa has had eighty million years of geographical isolation, geological volatility and a lack of terrestrial mammals, which has created a unique biota of ancient species alongside new ones that evolved here (M. McGlone, Richardson, & Jordan, 2010, p. 137; M. S. McGlone, 1989, p. 137). According to Māori, Maui fished up Aotearoa and the atua populated it with their children, each with histories that impact how they look and behave now. In any case, before humans came, Aotearoa was an avian Eden inhabited by the world's largest ratites (flightless birds with a keel sternum, including the kiwi genus, *Apteryx and* nine extinct moa species) and the world's only flightless and alpine parrots. Many floral and faunal lineages in Aotearoa also exist in South Africa, South America and Australia, reflecting their Gondwanian origins. The pūkeko (*Porphyrio melanotus*), or Australasian Swamp Hen, also occurs in Eastern Indonesia, the Moluccas, Aru and Kai Islands, Papua New Guinea and Australia and is a relatively recent arrival to Aotearoa.

A maritime climate with strong prevailing westerly winds, weak diurnal and seasonal variations, a relatively large axial mountain range, active volcanic zones and relatively young, nutrient-poor soils have all acted to shape the flora and fauna of Aotearoa (Dymond, 2013, p. 37; Leathwick, Overton, & McLeod, 2003, p. 1613). The complex geological history of volcanism, mountain building, glaciation, and subduction events has resulted in multiple speciation events and a relatively high level of species richness. Allopatric speciation occurred in the late Tertiary (Neogene) as Aotearoa was split repeatedly into isolated islands followed by orogenies (geological uplift and mountain building events) that reconnected them. Aotearoa has many Mesozoic and Paleozoic taxonomic lineages including centipedes, spiders, moths, dragonflies, frogs, birds and trees (Daugherty, Gibbs, & Hitchmough, 1993, p. 438). Tuatara are older than the dinosaurs and are their own order of reptile, Rhynchocephalia. Kiwi diverged 40 million years ago and are distinct from the ratite lineage that produced the moa. The rapid divergence of lizard species in Aotearoa is evidence of the evolution of remnant and ice age relic populations that persisted in habitat refugia.

Aotearoa's isolation allowed extensive 'in situ' evolution, resulting in a high rate of endemism, at or near 100% in some groups (ninety percent of invertebrates, 85% of vascular plants and one-quarter of all birds), and low tolerance to environmental extremes (A.-G. E. Ausseil, Dymond, & Weeks, 2011, p. 202; Leathwick et al., 2003, p. 1614; West & Thompson, 2013, p. 286). The tuatara, kiwi, bat-flies, wattlebirds, harvestmen, moths and frogs are taxonomic groups with 100% endemicity (Daugherty et al., 1993, p. 439). Aotearoa has 85 species of sea birds, of which 42% are endemic (Towns et al., 2012, p. 1). Eighty-five percent of the flora is endemic, most New Zealand species from the Asteraceae, Poaceae, Cyperaceae, Scrophulariaceae and Orchidaceae families are endemic (Leathwick et al., 2003, p. 1614). Aotearoa is arguably the most important global hotspot for bryophyte (hornworts, liverworts and mosses), diversity and is one of seven global hotspots for planarians (flatworms), boasting 89 known species, at least 50 of which are yet to be described by science (Dymond, 2013, p. 178).

New Zealand has nearly double the vascular plant richness of North America and Europe, consisting mostly of small trees that have evolved from a small number of shrub and herb lineages (M. McGlone et al., 2010, p. 148). Our forests are also some of the most productive in the world (M. McGlone et al., 2010, p. 139). Prior to human contact, the land was mostly covered in subtropical rainforest comprised of broadleaf angiosperms and conifers (predominantly podocarp), which gave way to beech forest at higher elevations (Dymond, 2013, p. 34; West & Thompson, 2013, p. 286). The largest forest trees in Aotearoa are mostly from the *Podocarpaceae*, *Beilschmiedia*, *Metrosideros*, *Nothofagus* and *Weinmannia* genera (Leathwick et al., 2003, p. 1621).

The trees in Aotearoa tend to be smaller and narrower than Norther Hemisphere species and are mostly evergreen. We have the most southern growing palm, the nīkau (*Rhopalostylis sapida*) and the largest fuchsia, Kōtukutuku (*Fuchsia excorticate*). The highlands were covered in tussock and subalpine plant communities dominated by snow tussocks (Chionochloa) and short tussock (Rytidosperma) species. The foraging system in Aotearoa is different from that in other counties because birds, rather than mammals, were the grazers and browsers. NZ grass species have a higher rate of leaf abscission in response to avian feeding ecology (Antonelli, Humphreys, Lee, & Linder, 2011, pp. 695-699). Birds feed differently to mammals and the removal of birds as foragers in Aotearoa ecosystems has changed the grassland/tussock land species composition and has had a domino effect on many other ecological processes and functions, such as CO2 uptake and nitrogen cycling.

A key feature of the ecology of Aotearoa is that it was a fauna devoid of mammals and instead dominated by birds, reptiles and invertebrates. The only terrestrial mammals present in Aotearoa before humans arrived were three species of bat (there are now only two) (West & Thompson, 2013, p. 286). In the absence of small mammals, some birds, bats and large invertebrates (weta) became nocturnal or diurnal foragers and some became flightless. Many of the native species evolved to fill ecological niches occupied by mammals in other countries. This niche shifting resulted in moa and kaka becoming like large-bodied browsers in the place of ungulates. An ecological niche is the ecological function or position an organism occupies. For example, a lion is an apex predator, an earthworm is a detritivore vital for soil formation and health and a deer is a large browsing ungulate that consumes foliage. Niche shifting is an evolutionary term that describes how lineages can change physically or behaviourally to fill a vacant niche in a community, leading to evolutionary change. The ecological niches filled by small mammalian predators in other countries were instead filled with large carnivorous snails (*Paryphanta* and *Powelliphantazl*) and a large centipede (*Cormocephalus rubriceps*) (Daugherty et al., 1993, p. 439). Our weta fill a niche occupied by mice in other regions of the world. Likewise, the weka (*Gallirallus australis*) is the counterpart to the badger, a small-bodied omnivore and the takahē (*Porphyrio hochstetteri*) is a grazer like the rabbit (Antonelli et al., 2011, p. 695; R. N. Holdaway, 1989, p. 14).

## Aotearoa - a brief history of human involvement

> Then came the Europeans, ignorant of the land and disinclined to learn from its people. They tried to change what they found too harsh or strange, and inevitably they failed (Collis, 2001, p. 27)

I will now take a moment to describe the history of human interaction with Aotearoa, New Zealand. Before human arrival, 70% of birds and 85% of plants were endemic, the remainder being indigenous but not endemic (Victoria Ann Froude, 2011, pp. 203,207). Lush temperate forests covered 90% of the land (Leathwick et al., 2003, p. 1614). Polynesians arrived in Aotearoa roughly one thousand years ago, after which the ecology began to change and the extinctions began. Most of the avian extinctions caused by the arrival of Māori occurred in the first 200 years following colonisation (Lee, Wood, & Rogers, 2010, p. 34). Notable among these was the moa (all nine species in six genera) and the pouākai or Haast eagle (*Harpagornis moorei*). In total, forty species of birds became extinct after Māori arrival. These include a bush eagle, a pelican and a flightless goose (Hamer, 1992, p. 2). The Polynesians brought with them the Polynesian rat or kiore (*Rattus exulance*) and the dog or kurī (*Canis lupus familiaris*). Radiocarbon dating indicates that *Rattus exulans* arrived in Aotearoa sometime in the thirteenth century (Wilmshurst, 2004).

Māori cleared forest and undertook small-scale cultivation of kumara (*Ipomoea batatas*) and taro (*Colocasia antiquorum*) that they had brought with them. The bush was burned to clear the land for habitation and crops and these fires could last for days. Māori used fire as a vegetation management and hunting tool (Cumberland, 1941, pp. 533-534; Wilmshurst, 2004, p. 801). Māori also modified wetland hydrology, establishing earthworks and constructing pā and gardens (Forster, 2012, p. 39). The amount of forest that Māori cleared prior to the arrival of Europeans has been estimated by different authors as between 32% and 54% (Cumberland, 1941, p. 531; Leathwick et al., 2003, p. 1614; McWethy et al., 2010, p. 21343; Rudge, 1986, p. 1).

We have now lost 40% of Aotearoa's original species assemblages. In the last 750 years since human habitation, 41% of all our bird species, 12 invertebrates (that we know of), and 3 frogs (50% of frog species) have gone extinct. A further 2,500 of the remaining species are threatened, 80% of native bird species are at risk, 72% of native fish and 90% of lizards (A.-G. E. Ausseil et al., 2011, p. 202; Byrd, 2008, p. 10; Minsitry for the Environment & Department of Conservation, 2016, p. 32; Towns et al., 2012, p. 1). Between 2005 and 2011, 30 plants, 13 birds, two skinks and one bat joined the threatened species list, however, the status of eight birds, three weta and one bat have improved (Minsitry for the Environment & Department of Conservation, 2016, p. 32).

We now have only relict populations of *Powelliphanta* snails (Mollusca: *Paryphantidae*), large weta (Insecta: *Stenopelmatidae*), tuatara (*Sphenodon punctatus*), *Leiopelmatid* frog and the endemic bat (*Mystacina tuberculate*), which were all common and widespread prior to human contact (R. N. Holdaway, 1989, p. 12). The number of vascular plants on the threatened list rose from 243 in 2008 to 289 in 2012. Of the 2378 plant species (729 vascular), 900 (40%) are at risk, four are now extinct and 122 are acutely threatened, most occupying unstable cliff face habitats (De Lange et al., 2004, p. 45; Lee et al., 2010, p. 39; Minsitry for the Environment & Department of Conservation, 2016). Indigenous forest now covers only 23% of Aotearoa and scrub (manuka, gorse, broom, māhoe, tarata, etc.) covers an additional 10% (Atkinson & Cameron, 1993, pp. 447-448). This equates to a 70% reduction from the pre-human extent. Much of what remains is upland forest ecosystems in hill country and lowland forests are especially poorly represented (Dymond, 2013, p. 34). In 2008, only 2.6 million hectares of indigenous forest remained in the North Island out of a pre-human 11 million hectares. In the South Island, forest cover has reduced from 12 million hectares to 3.9 million.

Ecosystems too have become threatened. Our critically endangered ecosystems include coastal turf, shell barrier beach, old tephra plains, leached terraces, fumaroles and other geothermal influenced land, seabird guano deposits and burrows and marine mammal influenced sites (Dymond, 2013, p. 53). Many of these are naturally uncommon but have now become critically threatened. Historically, rare ecosystems contained half of NZ's national threatened plant species and were biodiversity hotspots (P. A. Williams, 2007, p. 120). All of this change has occurred within the lifespan of some of our longer lived trees (M. S. McGlone, 1989, p. 115).

Wetlands have been reduced from their 2.4 million hectares pre-human extent to 250,000 hectares in 2008, this is 10% of the original area (A.-G. Ausseil, Dymond, & Shepherd, 2007, p. 136; Martinez Sanchez, Ramil Rego, Hinojo Sanchez, & Chuvieco Salinero, 2011, p. 204). By 2011, only 5% of wetland area remained in the North Island and 16% in the South Island. Most of the wetland area is accounted for by a small number of large wetlands, 77 wetlands that are greater than 500 hectares in extent (A.-G. E. Ausseil et al., 2011, p. 209). Wetlands are important for biodiversity, a fifth of our indigenous birds and eight of the 29 species of native fish live in wetland habitats (Forster, 2012, p. 44). This is the greatest rate of loss in the world and those that remain are in agricultural lands and are generally in poor condition and under pressure from altered hydrology (lowered water tables), nitrification, invasive plants and animals and encroachment (Dymond, 2013, p. 200). The proportion of threatened freshwater fish rose from 53% to 67% between 2005 and 2009 (L. Roberts et al., 2015, p. 10). The giant kōkopu (*Galaxias argenteus)*, kōaro (*Galaxias brevipinnis)*, inanga (*Galaxias maculatus),* tuna - longfin eel (*Anguilla dieffenbachia*), kākahi - freshwater mussel (*Echyridella menziesii*) and the kōura – freshwater crayfish (*Paranephrops planifrons*) are all listed as gradually declining. All of these species were staples in the diet of Māori and losing them has had knock-on impacts for iwi economically and in terms of social wellbeing (Dymond, 2013, p. 211).

The wave of extinctions that followed the arrival of Polynesians in the 13th century became a tsunami when Europeans arrived in the 19th century (R. N. Holdaway, 1989, p. 11; McDowall, 2001, p. 344). The acclimatisation of English animals in colonised lands was symbolic of British victory over an untamed wilderness (Hamer, 1992, p. 60). Acclimatisation societies were established all over the country to remove native species and create space for English species (Hamer, 1992, p. 61). In 200 years of European colonisation, more than 25,000 species of plants have been introduced and 2,200 of these now grow wild. This equates to one new species every 39 days since Capt. J Cook first sighted land in Aotearoa compared with only 10 new species introduced by Māori (R.B. Allen & Lee, 2006, p. 33). Julius von Haast (for whom the Haast Range and the Haast Eagle are named) is single handily responsible for the introduction of 700 of these species  (R.B. Allen & Lee, 2006, p. 1). This group of 1900's Victorian colonial naturalists, dubbed the 'biota barons', terraformed Aotearoa (Star, 2011). Most of the new species introductions happened between 1850 and 1890 (Atkinson & Cameron, 1993, p. 448).

The acclimatisation society of Otago introduced rabbits in the 1870's and within 20 years they had already been declared pests. Mustelids were introduced in 1883 to deal with the rabbits, but they found native birds far easier to hunt and were soon also declared to be pests. The famous colonial botanist Leonard Cockayne, who founded Otari-Wilton's bush, lamented the ecological damage being done in the late 1800's - early 1900's. He noted that the carrying capacity of the tussock lands was declining, resulting in 'manmade deserts'. This was caused by overstocking, burning and rabbits, which were accelerating wind and frost erosion (Cumberland, 1941, p. 549). Some of the naturalists, including Cockayne, who had themselves introduced many plants and animals as a part of the acclimatisation movement, soon became strong advocates for the protection of native biota (Hamer, 1992, p. 115). These reformed naturalists formed the Native Bird Protection Society in 1923, which later morphed into the Royal New Zealand Forest and Bird Society (Hamer, 1992, p. 61; Wikipedia online encyclopeadia 2018). Millions of dollars is spent annually trying to control introduced flora and fauna in Aotearoa by the crown, local government and private land owners.

During the 19th century and in the context of 'Social Darwinism', the indigenous flora and fauna of Aotearoa were considered inferior to the introduced British flora and fauna (Thrupp, 1989, p. 14). The valueless ruru (*Ninox novaeseelandiae*), fern and manuka tree (*Leptospermum scoparium*) would be replaced with golden fields of wheat and profitable utilitarian farm animals (Hamer, 1992, p. 60). The settlers celebrated this destruction, as is exemplified by Lady Barker in her work 'The Station Life in New Zealand' (1883). She described revelling in the 'beauty of burning tī tī palm' (unclear whether she is referring to the kiekie palm *Freycinetia banksii* or to Tī kouka *Cordyline australis*) (Hamer, 1992, p. 63). Settlers spoke of the exhilaration and the sense of power and accomplishment felt after destroying great kauri '…looking at it laying at your feet…my bump of destruction….makes my life-blood tear through my veins…' (Hamer, 1992, pp. 67-68). According to Hamer (1992, pp. 67-68), the settlers vigorously and viciously attacked the native forest that frightened, awed and angered them. They could not fathom that such a vast and powerful foe could ever be expended or need conserving. They justified their assault on Aotearoa's denizens by claiming, for example, that weta damaged trees, kiwi ate pheasants' eggs and kea killed sheep (Hamer, 1992, p. 63). Politicians who spoke out against the destruction were accused of interfering with the settler's 'way of life' and were denounced as self-serving, stupid or greedy (Hamer, 1992, pp. 64-65).

According to Clavero and García-Berthou (2005, p. 110), 20% percent of species extinctions in Aotearoa are due to the effects of invasive species. Aotearoa's avifauna evolved in the absence of mammalian predators. Consequently, they are 'predator naïve' and are extremely vulnerable to mammalian predation. Many are nocturnal or cryptically coloured and have a strategy of freezing when threatened to avoid predation by predatory birds such as raptors, the only predation to which they were previously exposed. These are totally inadequate strategies against mammalian predators (R. N. Holdaway, 1989, p. 19). Fifty-four mammals, including 19 herbivores, six carnivores and five omnivores, as well as 2000 invertebrates and 21 fish (seven salmonids, seven carps, a catfish and a perch) have been introduced to Aotearoa (R.B. Allen & Lee, 2006, p. 56; Victoria Ann Froude, 2011, p. 203; McDowall, 2001, p. 346). The estimated density of rats is now five to nine per hectare and they may have home ranges exceeding 700 square meters in beech forest (Wilson, Efford, Brown, Williamson, & McElrea, 2007).

Over the last few thousand years, there have also been geologically recent self-introduced species alongside the deliberate human-introduced species. These include the pīwakawaka or fantail, ruru or morepork (*Ninox novaeseelandiae*), silvereye and harrier hawk (*Circus approximans*). Some species have even benefited from human presence and have become more numerous, including the pied-stilt (*Himantopus himantopus*) and the black-backed gull (*Larus dominicanus*) (R. N. Holdaway, 1989, p. 19). Sometimes even native species can become pests that need managing. Examples include the kiore on Mauitha and Araara (Hen and Chickens) Islands and the karaka (*Corynocarpus laevigatus*) in Wellington. Karaka was planted by Māori to supply food but is becoming invasive outside of its natural extent (West & Thompson, 2013, p. 298).

The key issues facing the ecology of Aotearoa are declining biodiversity, lack of protection for threatened habitats and species, habitat fragmentation and degradation and the increasing threat of invasive species (M. Davis, Head, Myers, & Moore, 2016, p. 3). We have the worst loss of native biodiversity of the 142 countries that have been studied, including over 2000 threatened species, only 31 of which have active recovery plans (Cullen, Fairburn, & Hughey, 2001, p. 54; K. F. D. Hughey et al., 2004, p. 91). The lowest, flattest, warmest and driest areas have suffered the greatest losses, while the highest, steepest, coolest and high rainfall areas tend to be better protected (Cieraad et al., 2015, p. 314).

Habitat fragmentation, or rather the size and shape of habitat fragments and their proximity to other patches and to unbroken forest habitat, influences the biodiversity that the ecosystem can support. Small patches, with large edge to core ratios, are more susceptible to wind penetration and damage and have a reduced core area that is buffered from wind by the trees on the edge. A stand of 20m tall trees needs to be at least 2-4 km wide to have 'normal' wind profiles (Saunders, Hobbs, & Margules, 1991, pp. 21-22). Removing deep-rooted trees alters water infiltration and evapotranspiration. Deforestation increases wind erosion on sandy soils and opens the land up to pest species invasion, particularly weeds (Crossman & Bryan, 2009, p. 656). The larger edge ratio provides more entry points. Small fragments may support less biodiversity than larger ones, which in turn lowers genetic diversity and reduces ecosystem functions such as decomposition, nutrient cycling and hydrology (Aerts & Honnay, 2011, pp. 1-2). An array of small reserves may host more habitats than a single large one but may hold fewer individuals of a given species (Saunders et al., 1991, p. 25).

Small, genetically isolated populations may have a smaller gene pool, are less adaptable and able to resist perturbations and may suffer from inbreeding depression, resulting in local extinction. Habitat fragmentation and overharvesting may reduce recruitment to below sustainable levels. If this happens to too many populations, the species may become regionally or nationally extinct. Local extinctions of long-lived, cryptic, nocturnal, migratory, or widely-dispersed species may go unnoticed. Migratory species that cross multiple geopolitical boundaries or species that live in commonly owned land, such as parks and reserves, may be relatively vulnerable to overexploitation. This may be particularly relevant for marine species, as populations are not easy to monitor because of the distances they travel and the physical difficulty in counting them.

The impact of pest animals on the native forests is arguably unsubstantial. Ungulates can cause significant browse damage and are disease vectors. Ungulates selectively browse the palatable species in our native forests and may change a forest's composition in favour of non-palatable species. Browsing may cause the mortality of canopy trees and alter the successional trajectory. Rodents, possums and ungulates all predate seeds, potentially affecting the persistence of some species. Their deposited faeces may contain the seeds of weed species, alter carbon cycling and storage processes and change nutrient balances. These species also cause soil disturbance and compaction, changing the soil biota (R. Holdaway, Burrows, Carswell, & Marburg, 2012, p. 5). Forests subjected to browsing animals have reduced vegetation density and the composition is skewed towards unpalatable, small-leaved species and ferns, with a ground layer dominated by monocotyledonous species (Wardle, Barker, Yeates, Bonner, & Ghani, 2001, p. 603).

We must also consider that in many parts of Aotearoa, we may never be able to restore the pre-human ecology. It is unlikely we will ever get rid of the animals we farm or the pets we keep, so we must now consider them as part of the ecosystem. We have also lost too many native species and many now exist only as remnant populations. Translocations are often performed to spread the remaining individuals of a population in space. This is in an effort to minimise the chances of an adverse stochastic event eliminating entire populations at one site, as well as to improve genetic diversity in disparate populations and to repopulate newly restored habitats. We should consider if we will accept introducing individuals that originate from other parts of the country to restore species that have been extirpated locally. A kaumātua (not one of my interviewees) once suggested that we could consider whāngai (adoption) as a guiding principle in circumstances where individuals are moved to an area they are not from in order to reintroduce a locally extinct species. PH, a Rangitāne O Manawatū kaitiaki added to this discussion, suggesting that sometimes the habitat being restored is so degraded that there are not enough eco-sourced species available, so we may have to turn to cultural sourcing. Cultural sourcing involves utilising a locally derived set of taonga species that are important for their cultural function and are obtained from a 'cultural source'. This is particularly relevant for birds such as kaka and kakapo.

Ecologists often take great care to eco-source plant stock from the local area to be sure that genetic and phenotypic types are derived from the local population. In this way, we try to preserve the local strains, variations and populations of species that are specifically adapted to the local microclimate. We also have the thorny issue of indigenous 'weeds' to deal with. Karaka (*Corynocarpus laevigatus*) and pohutukawa (*Metrosideros excelsa*) are examples of this. Karaka was brought south by Māori and deliberately planted for food. It is now taking over the native bush in the Wellington region and is presenting a biodiversity issue. Pohutukawa are not naturally found south of the volcanic plateau but were brought south by people and are capable of cross-pollinating with the northern rata (*Metrosideros robusta*), diluting the gene pool of the rata. Climate change is changing the natural ranges of many plant species and is probably increasing the incidence of diseases evident over the past few years. Kauri (*Agathis australis*) dieback may be one of these diseases. Kauri do not naturally grow in the Wellington region but can do so. Should we manage populations of threatened species outside their natural range, in a place they are not linked to through whakapapa, in order to protect them for the future? These are issues iwi, hapū and mainstream resource managers will have to grapple with, probably on a case by case basis.

## Climate Change

> In the past, the Omungunda plain was grazed by numerous wild animals. There were elephants, kudus, zebras and springbok. ………. The vegetation of the Omungunda plain looks very different nowadays. Omihama trees are only found at its lower end. Many grasses are not found anymore. Only okarieamenye is still found abundantly and ongumba is at least found in some patches. This is because of the current drought. Once rains fall abundantly again, the grasses will also return- Joseph Mbunguha, Omungunda 16/3/1990 (Bollig & Schulte, 1999, p. 505)

Climate change may increase the frequency and intensity of floods, droughts, storm events and cause sea levels to rise. Species distributions may change as the temperature climes shift and habitats change. Cryophilic species may have to move closer to the poles or higher into the mountains. As the snowline rises, there are fewer habitats for cryophilic species at higher altitudes and the carrying capacity of the montane ecosystems can be reduced. Migration routes can be jeopardised as once-vital stopovers are no longer able to provide adequate food for travellers or routes are no longer navigable. This may lead to a significant impact on biodiversity. Rising sea levels may accelerate coastal erosion, increase the exposure to extreme storm surges and have caused saltwater intrusion into land, estuaries and aquafers (Parrotta, 2011, p. 13.12). Traditional knowledge practitioners may have been noting the impact of anthropogenic climate change on key ecological processes for some time. They have noted the change in rainfall patterns, which has been confirmed by scientific data (Stave, Oba, Nordal, & Stenseth, 2007). Berkes and Berkes (2009) discussed a small Arctic community that provided 25 environmental variables as evidence that the climate is changing. Their indicators include physical changes, the safety of travel and the condition and distribution of animals (Berkes & Berkes, 2009, p. 10). One of my interviewees, JM, described climate change impacts that he and his iwi have noticed. According to JM, the trees are blossoming and fruiting later and are fruiting for shorter periods, which in turn affects the insects.

## The wellbeing of Māori

> Ka ora te tāngata, ka ora te moana/whenua
>
> If the people are healthy, the land/sea is healthy (Dick, 2012, p. 128)

Since 1840, Māori have lost ownership and therefore kaitiakitanga of 25.2 million hectares of land and now collectively own 4.6% of Aotearoa (Keiha & Moon, 2008, p. 4). Removing Māori from our whenua and awa has broken our bonds with the atua and tupuna, damaged our economy, social order and mana, causing deep trauma (Panelli & Tipa, 2007, p. 425). Human wellbeing is an individual perception of peoples' lives in the context of their cultural values, goals, expectations and feeling of empowerment, autonomy and control of their own destiny (Agarwala et al., 2014, pp. 6, 8). For Māori, personal wellbeing is arguably contingent on ecological wellbeing. A healthy ecology may build and support a healthy society, which in turn supports a healthy cultural existence on which a prosperous economy and healthy individuals are built (Dymond, 2013, p. 277). The environment may be the most important and the economy the least important component of wellbeing. If the ecology is healthy, a healthy economy should follow. Our wellbeing is arguably tied to our cultural and social identity and our emotional and physical links to the land. According to one of my interviewees, TM, a kaitiaki for the Wellington-based Taranaki iwi, Matiu Island in Wellington harbour is a rongoā space, a place to get physical and spiritual healing. If you stay and get in tune with the island your biorhythms change.

The access and visitation rates to important sites, taniwha, pakiwaitara, the use of Māori nomenclature and the amount of historical knowledge about an area can define our cultural identity. Taniwha are mythological creatures that are both monsters and guardians. They are neither good nor evil; they just are. They can take many forms and they can harm or they can help, depending on our relationship with them and the land they occupy (Taniwha, 2019). Knowledge of them and how to interact with them was imparted in pakiwaitara, or legends and narratives. How we use and manage the land may define what we get from it. What we do with the land obviously has a large impact on the ecosystem services the land provides and therefore our wellbeing. For this reason, land use, our human capital investments and the location and extent of management areas are important indicators of toiora, because this defines our investment to support our wellbeing (Bibby, 1999, p. 83).

Three well-known models for individual wellbeing illustrate the importance of environmental health to wellbeing. The first is Te Whare Tapa Whā – The Strong House (L. Roberts et al., 2015, p. 31). This model represents wellbeing as a house. The house is sited on a foundation of land/roots (ecology), physical wellbeing, family and social wellbeing are the walls. Mental and spiritual wellbeing forms the roof. The second is Ngā Pou Mana – Supporting Structures. This model depicts poles supporting wellbeing. The poles represent family, cultural heritage, environment and land base (G Harmsworth & Shaun Awatere, 2013, p. 278). The third, Te Whetū, is symbolised as a star. Wairua (spirit), hinengaro (mind), te tinana (body), whenua (land) and whānau (family) occupy each point of the star (Mark & Lyons, 2010, p. 1761). According to L. Roberts et al. (2015, p. 31), they all have the inclusion of the land/ecology as a facet of wellbeing in common.

Land was still being explicitly confiscated from Māori ownership. As recently as 1960, Māori land near Gisborne was compulsorily acquired for erosion control (Coombes, 2003, pp. 345-346, 350). Significant slash and burn deforestation in the Waipaoa River catchment had resulted in significant erosion. The solution was to reforest the upper catchment in pines and Māori land was targeted for this purpose. The neighbouring European owned farms were not targeted in this way and the Māori owners were subjected to a media campaign vilifying them as poor farmers who were not looking out for the public good. The Mayor of Gisborne city was reported to have said that Māori should give the land to responsible land users and if they did in fact 'belong to the land' they should see the benefit of doing this. He accused them of not living up to their landholder obligations. This land became the Mangatū state forest, which is now clearly a commercial venture benefiting the new landowners. Some argue that the Foreshore and Seabed Act 1994 is another very recent instance of the removal of Māori land and custodial rights.

The pressures of custodial land rights in Aotearoa and the subsequent impacts on Māori are articulated by one of my interviewees. I will identify her as OM. OM is Ngāti Porou and is a prominent wāhine physicist and academic. She is an urban Māori living away from her ancestral whenua, as are many of us and her perceptions of the ecological issues impacting Aotearoa will probably resonate with many other urban Māori. She, like many of us, has noticed changes that have occurred even within our lifetimes. OM remembers iwi members collecting karengo, an edible seaweed (*Porphyra columbina*) for traditional use, a practice that has now ceased. Over time, as her elders have passed away, the need, knowledge, physical access and use of the resource have diminished. OM has identified several other environmental pressures that are important. She noted that urban sprawl has put pressure on native habitats and has exposed the environment to pollution. She notes the poor health of the Kaiwharawhara steam and the quality of groundwater being impacted by leaking septic tanks. OM also mentions the loss of the hīnau trees relied on for food by native birds, which were removed to make way for housing, as well as the removal of areas that have previously functioned as critical corridors for native birds. OM insightfully acknowledges the roles that the political structure, resource management paradigm and the current social landscape have in resource management and notes how these things are tied up with water rights and property ownership.

One of my interviewees, JM, a Tūhoe–kaumātua, identified farming as the most pressing environmental issue of the day, because farms dominant the land use in Aotearoa. JM believes we should have smaller farm holdings and move away from large scale factory farms. However, JM acknowledges that it is too late to recreate the past, what we had and how we lived and he points out that this isn't necessarily desirable. The substantial changes in species composition and the loss of critical native seed dispersers and other functionally important groups mean it is highly unlikely that succession could ever return Aotearoa's forests to their pre-human state (Robert B. Allen et al., 2003, p. 210). We are reliant on modern farming practices and these are so heavily embedded in our economy and ecology, it would be undesirable and impossible to eliminate them from our landscapes. As JM observed, the necessary and important infrastructure of dams, roads and railways have altered traditional practices and the urbanization of our people means Māori have lost our kaitiaki knowledge. Even if we could physically return Aotearoa to a biological Eden, we have lost the knowledge to do so.

Another of my interviewees, PH, a kaitiaki from Rangitāne O Manawatū, discussed the devastating impact of legislative changes that eliminated access to ancestral lands and kai collecting areas, particularly culturally important fishing sites. These laws are still in effect. The Pukepuke wetlands housed a prosperous eel fishery, extending from Palmerston North to Fielding and have now been drained. Pukepuke was the most productive fishery in the world, but recently 3,000 people only caught 5 eel over 10 days. An eel factory (now closed) was built in Foxton to process the harvested fish commercially. Commercial harvesting of this resource and not abiding by Māori rāhui resulted in the collapse of the fishery. The manu have also been impacted. Kereru (*Hemiphaga novaeseelandiae*) were once so abundant that a settler and naturalist Walter Buller said that, before the forest was cleared (First World War time), their wingbeats drowned out conversation and whitebait could be caught off Te Motu O Poutoa – Pork Chop Hill. According to PH, his iwi has lost its mahinga kai resource, so customary rights are a moot point. A stumbling block for the iwi was legal recognition of mana whenua status. Another stumbling block is that diffuse discharges to waterways cannot be regulated and point source discharges have consent, so can't be regulated until the consent expires.

## Land tenure change globally

> Once the collectives were dismantled, there was no longer a formal regulatory institution to govern pasture use. The infrastructure that collectives had provided (e.g., transportation for nomadic movements and auxiliary herding labour) also vanished (p. 1320)….A corollary to these norms is the herders' nearly universal conviction that individual private ownership of pastureland in their semi-arid and variable environment would lead to disaster…..Privatization is a measure to restrict the freedom of both herd and herdsman. Privatizing land to individuals harms the right of the herd to move (Fernandez - Gimenez, 2000, p. 1322)

Human population growth often places increasing pressure on the land to feed us and we convert land to grow food or provide resources at an increasing rate. Land-use change may be the biggest factor contributing to terrestrial biodiversity loss. It can happen incrementally and may result in heterogeneous fragmented landscapes. Importantly, land-use change is often permanent and cannot be totally reversed (T. R. Allen et al., 2013, p. 96). For sustainable resource management to be effective, all stakeholders and the community should be involved and local conditions considered (Bedunah & Angerer, 2012, p. 610; Keiha & Moon, 2008, p. 12). TEK is often adapted to utilise local resources and it is closely linked to the small territories and geographically localised communities or families. One of the most important drivers of land-use change is land tenure change and land tenure change has important social and cultural impacts for Indigenous people, destroying entire knowledge systems, as well as having serious biodiversity impacts (Whitt et al., 2001, p. 13). For Indigenous people, removal from the land is literally removal from ourselves. We belong permanently to the land and that connection can never be severed (Whitt et al., 2001, p. 4).

Changes in land tenure are often politically driven and tend to reduce communal land and promote private ownership. This may reduce traditional practices such as communal semi-nomadic herd grazing and impede the community's ability to manage temporal environmental variations and withstand drought or flood (Abate et al., 2010; Corbeels et al., 2000, p. 19). Individualising property ownership (privatization of communal lands) has removed community safeguards that protect biodiversity, the ecology and the resources (Dei, 1994, p. 29). Privatisation removes local control and the ability to implement traditional adaptable and diverse management practices (Bedunah & Angerer, 2012, p. 608). Traditional land management practices and social controls are lost. Communities then become less economically sustainable and socially self-reliant and their cultural identity is impacted (Barrera-Bassols & Zinck, 2003b; Bollig & Schulte, 1999; Duffield et al., 1998, p. 44; Fernandez - Gimenez, 2000; E. D. G. Fraser et al., 2006, p. 118; Mapinduzi, Oba, Weladji, & Colman, 2003, p. 204; Petropoulou, 2007, p. 163). Social cohesion and strong leadership are required to prevent habitat and resource degradation (Xu et al., 2005). K. Chan, M. A. et al. (2012, p. 745) argued that neglecting social values impedes local resource management, changing local ecology and impacting biodiversity. A member of the Warlpiri people of Australia suggested that if people can't perform traditional cultural rituals, they won't be able to 'recharge', which will adversely affect their wellbeing (Holmes & Jampijinpa, 2013, p. 7).

There may be tension between Indigenous rights to the land and individual property rights (Forster, 2012, p. 216). Farmers may face increasing economic pressure to improve productivity on small plots and to use imported fertilizers, pesticides and alter the hydrology of the site. Marginal land can be overgrazed, fallow times are reduced, there is an inability to use ex-closers (areas reserved from grazing), cropping is intensified, pressure on water resources is increased and fire management regimes are altered (Ziembicki et al., 2013, p. 85). This may increase toxin runoff, alter carbon, nitrogen and phosphorus cycling, reduce soil fertility and stability, increase pest and disease incidence and woody weed invasion and ultimately decrease biodiversity (Andersson, Nykvist, Malinga, Jaramillo, & Lindborg, 2015, p. 107; Watkinson & Ormerod, 2001, p. 234). All of these pressures may cause ecological impacts, such as disrupted wildlife migration (physical barriers), disturbed seed dispersal and distribution patterns and alter species occupancy. Important ecological functional relationships, such as predator/prey, pollinator/pollinated, parasite/host and pathogen/competitor may be uncoupled. The physiological stress on the ecosystem and the individual animals within it can lead to disease, a drop in animal fecundity, altered sex ratios, competitive faculty and ultimately decrease productivity (Collen & Ebrary, 2013, pp. 271, 138).

Land reforms in Ethiopia that privatised land ownership started in 1975. Since then, calf-grazing land has been converted into enclosures containing crops. In the space of 30 years, the number of Ethiopian farmers farming livestock exclusively dropped from 94% to 36% (Abate et al., 2010, p. 202; Angassa & Oba, 2008, pp. 202, 203, 205-206). In South America, the number of communal maize landraces has also reduced significantly. These landraces were adapted to the topography and ecology of the region and maintained soil fertility (Barrera-Bassols & Zinck, 2003b, pp. 242-243). The consequences were dire for the Purhépecha people, who had to give up their decision-making autonomy, weakening community institutions. They could no longer implement proven strategies for seed selection, agro-ecological management and erosion control and soil fertility maintenance. They lost their language, their local knowledge and the ability to pass that knowledge onto future generations (Barrera-Bassols & Zinck, 2003b, p. 243). In Morocco, the government implemented land privatisation, increased irrigation and expanded cultivation to marginal lands. This superseded local pastoral management regimes that were more appropriate for the arid, stochastic environment (D. K. Davis, 2005, p. 521). The resulting damage to the rangeland was blamed on overgrazing by farmers. D. K. Davis (2005) argues that governmental management practices caused the degradation and suggests that power differentials and political goals enabled this narrative and that overgrazing was used to justify it. The story was similar in Tibet. Removal of customary institutions has resulted in ecological degradation and deforestation, as accountability is removed from local leaders, along with an intimate understanding of the indigenous ecology (Xu et al., 2005, p. 8).

## Environmental law in Aotearoa

Many Māori continue to feel excluded and marginalised and that Māori voices, rights and capabilities have been removed (Ellison, 2006, p. 87). The Treaty of Waitangi, our nation's founding document, defined the relationship between Māori and the European colonialists (Keiha & Moon, 2008, p. 4). Two versions of the Treaty were written, one in English and a translation in Māori and the Māori version was signed on February 6, 1840. Since 1975, over 30 pieces of legislation and numerous policy documents that reference the Treaty have been written (Forster, 2012, p. 143). These documents enshrine in law the obligation for the Crown to involve iwi and hapū in resource management (G. R. Harmsworth & Pauling, 2013, p. 3).

A power imbalance, the controversy over the interpretation of the two versions and the vastly different cultural objectives and perspectives may still impede progress towards complying with the articles on the Treaty/Te Tiriti. From a Māori perspective, Te Tiriti o Waitangi ensures Māori rights and authority over their territories, including natural resources, lands, villages, taonga (treasures) and sacred sites (Ellison, 2006, p. 87). Settling Treaty claims is one way te ao Māori and mana Māori may be restored. An example of this is the recognition that te Urewera and te Awa Whanganui are entities with their own legal rights and protections, as they were under te ao Māori (Adams & Mulligan, 2003, p. 102). TM, a kaitiaki for Wellington Taranaki mana whenua, maintains that the Treaty settlement processes gives iwi a voice at the table. Iwi kaitiaki rights are now included in legislation. For TM's iwi, this means that DoC, who manages the island, has to change how they interact with iwi and how they operate.

New Zealand's resource management legislative framework is detailed in **Table 7** below and our principal policy documents are listed in **Table 8**. Many of our important legislative and policy documents were written by non-Māori, with Māori cultural values and interests addressed in separate sections rather than being incorporated within the documents and shaping their perspectives. For a start, the conservation ethic of preservation and protection as prescribed in the Conservation Act 1987 is at odds with kaitiakitanga and separates Māori from our customary uses and practices (S. Awatere, 2005, p. 8). The Resource Management Act talks about respect and recognition of Māori kaitiakitanga, our links to the land and addresses our customary rights, but in practice, poorly reflects what kaitiakitanga could be (Forster, 2012, p. 229). Forster (2012, p. 227) argues that the current level of recognition and integration of Māori perspectives into legislation and policy is insufficient to satisfy Māori environmental rights, interests, obligations, responsibilities and our mana whenua relationships with our ancestral lands.

In Aotearoa, the Crown still actively controls the management of natural resources in New Zealand (Forster, 2012, p. 183). There is an automatic presumption that the Crown will be responsible for public land. The Crown managed conservation estate includes more than 300,000 hectares of scenic reserves, 10,300 ha of scientific reserves, 3200 ha of historic reserves and 18,500 ha of wildlife reserves. Local government is mandated to manage ecological assets, such as parks and reserves and deliver core services, such as invasive species control, water reticulation, flood protection, waste management, etc. in an environmentally sustainable way (Forster, 2012, pp. 217-218). Councils are required under legislation to produce State of the Environment (SoE) Reports validating the management they implement. More than this, New Zealand is a signatory to the OECD 1997 report on Environmental Performance and is required to report on policy indicators relating to waste management, biodiversity, sustainable development, agriculture and forestry and participation in international initiatives (G Harmsworth & Tipa, 2006, p. 18).

Article 5. Indigenous peoples have the right to maintain and strengthen their distinct political, legal, economic, social and cultural institutions, while retaining their right to participate fully, if they so choose, in the political, economic, social and cultural life of the State. (United Nations, 2007, p. 9)

**Table 7.** The natural resource legislative framework operating in New Zealand (Byrd, 2008, p. 27; Forster, 2012, p. 246; Lee et al., 2005, p. 10; P. Lyver et al., 2009, p. 2; Norton & Roper-Lindsay, 2004, p. 295)

| | |
|---|---|
| Animal Protection and Game Act 1911 | • Banned the harvesting of kereru in 1921 |
| Forests Act 1949 and Forest Amendment Act 1993 | • This act and the amendment in 1993 deal with logging and export of native timber and trees |
| Wildlife Act 1953 | • Relates to the protection and control of wild animals and birds |
| Reserves Act 1977 | • Regulates the acquisition and management of public reserves |
| Wild Animal Control Act 1977 | • Relates to the control of harmful and introduced species |
| National Parks Act 1980 | • Regulates the acquisition and management of national parks |
| Environment Act 1986 | • MfE and the Parliamentary Commissioner for the Environment were established under this act |

**Conservation Act 1987**
- Mandates Department of Conservation to co-manage with Māori

**Resource Management Act (RMA) 1991**
- Recognises iwi environmental interests in sections 6(e), 7 (a) and 8

**The Biosecurity Act 1993**
- Manages invasive organisms

**Hazardous Substances and New Organisms Act 1996**
- Controls the importation and movement of novel species and hazardous substances

**Local Government Act 2002**
- Mandates biodiversity, land, cultural site, and pest management to Regional Councils and Territorial Authorities

**Resource Management Amendment Act 2003**
- State of Environment reporting is required using five prescribed criteria: rarity, distinctiveness, representativeness, ecological context (location in relation to other habitat patches and the geography), and sustainability

**Table 8.** Some key resource management policy documents (G Harmsworth, 2014; Lee et al., 2005, p. 10)

**Te ao Pākeha**
- Regional and unitary plans using Western science specialist methods and evaluated with performance indicators
- The New Zealand Biodiversity Strategy (2000) - Jointly sponsored by MfE and DoC, this outlines a framework to restore biodiversity
- The Environmental Performance Indicators: Signposts for Sustainability (1997) - in which MfE frameworks environmental monitoring in New Zealand
- National Policy Statement for Biodiversity on Private Lands
- Department of Conservation Policy Statements – Policy statements issued by DoC setting out its management principles for various habitats

**Te ao Māori**
- Iwi, hapū, and kaitiaki management plans implemented using kaupapa Māori research evaluated with tohu (cultural indicators)
- Vision Mātauranga

### State of the environment assessment in the New Zealand context

> In much of the world, conserving nature out of moral obligation is a luxury [that] most [people] simply cannot afford. Nevertheless, human well-being is intimately linked to the immediate environment and natural capital is a vital part of the economic base (Armsworth et al., 2007, p. 1383)

In New Zealand, terrestrial State of the Environment (SOE) monitoring indicators include land cover (remote sensing), land-use changes and soil health (only under agricultural land), native vegetation area and the distribution of indicator species (Hoare, Donnell, & Wright, 2010, p. 78; Parlimentary Commissioner for the Environment, 2016). The SOE utilises seven indicator species that were selected for their national significance and the availability of data: one bat (lesser short-tailed *Mystacina tuberculata*), five birds (kiwi – 5 species *Apteryx* spp., kākā *Nestor meridionalis*, kōkako *Callaeas cinerea*, mohua *Mohoua ochrocephala and* ngutu pare or wrybill *Anarhynchus frontalis*) and one plant (woodrose *Dactylanthus taylorii*) (Hoare et al., 2010, p. 77). The short-tailed bat is a general indicator of the forested ecosystem structure and represents native land mammals. In addition to being taonga endemic species the mohua, kākā, kōkako and kiwi are all sensitive indicators of mammalian pest abundance. The ngutu parore (wrybill, *Anarhynchus frontalis*) is an indicator of the health of braided river systems. The woodrose is a parasitic plant that can indicate the health of the forest, the pressures from browsers and the abundance of native pollinators and seed dispersers (Hoare et al., 2010, p. 78). Six of these seven taxa live in forests and only one in an aquatic habitat, so drylands (agriculture, sericulture, horticulture, urban, etc.) wetlands, alpine, coastal and marine habitats are not represented. In addition, 11 major taxonomic groups, including bryophytes, invertebrates, frogs, fungi, macroalgae and reptiles are not represented in the SOE. New Zealand's State of the Environment (SOE) monitoring framework is based on the OECD's Pressure – State – Response (PSR) reporting framework (Hoare et al., 2010, p. 78). These indicators relate to land and are one set of biotic indictors employed. Abiotic indicators of land heath include soil health, erosion and contaminated land. There are also other indicator sets relating to atmosphere and climate, air, fresh water and marine (Parlimentary Commissioner for the Environment, 2016).

## Conclusion

> Our traditional knowledge on sustainable use, conservation and protection of our territories has allowed us to maintain our ecosystems in equilibrium (Ti Kipa Kepa Brian Morgan, 2006)

Colonisation of the land and the people has occurred. The othering of the people removed ideological attachments to the land and allowed the rationalisation of land acquisition and plunder (Adams & Mulligan, 2003, p. 139). The 'paternal wise ruler' has enacted his version of order and control to preserve his view of nature using the rationality of science. Ultimately, man brings discord, unbalancing the sacred ecological with his presence (Adams & Mulligan, 2003, p. 17). Colonising nature has often meant removing land ownership and management from Indigenous people and even removing the people themselves from the land. Places were renamed and Māori were removed from their land in favour of the settlers, who would remove the 'useless forests and wetlands', tame them and make them 'productive' farmland. Renaming the land and biota effectively silenced the Indigenous people, severing the links to cultural heritage, our tupuna, history and nomenclature (Adams & Mulligan, 2003).

The biggest difference between Māori and Pākeha interactions with the land may be because Māori largely lived off the native resources provided by the awa, ngahere and wetlands, while Europeans did not. The colonisers believed they would manage the land better and make the land 'productive', justifying their actions. They either couldn't conceive or actively disregarded the production and practices that had fed generations of Māori prior to their arrival (Adams & Mulligan, 2003). Even now, resources are often diverted to 'worthwhile' endeavours as judged through the colonial worldview. Beder (2000, p. 236) labelled the continuing practice of sending pollution from one place to another for disposal as environmental racism, because it was always the rich communities that send their waste to poor communities. The poor often matter less because they are from a different race or class. Industry is always located in poor areas, never in the tree-lined avenues of the rich. A pricing structure that includes the costing of lost wages, poor health outcomes, social isolation and disenfranchisement may finally lead to economically driven social change (Beder, 2000, pp. 236-237).

In this chapter, I have outlined the human-induced ecosystem pressures and their impacts brought about by upsetting the natural balance. I have discussed how these impacts manifest in Aotearoa and I have given a brief outline of how the ecology of Aotearoa has been impacted by waves of human colonisation that have changed the landscape. Aotearoa had a unique Gondwanaian biota of ancient reptile, frog, bird and invertebrate fauna created by isolation and a lack of mammals. These precious species are now at more risk than ever before and are vastly outnumbered by invasives. As kaitiaki of this land, it is the responsibility of us all to protect, nurture and treasure the children of Tāne-mahuta. If we fail in this, we fail our children and their children's children.

The purpose of this chapter was to familiarise the reader with the ecological pressures that may be triggering management. As discussed in previous chapters, ecological pressures are generally the main driver for monitoring and management programmes. Identifying the key ecological pressure geospatially is a key component of the many management programmes and also forms a key component of He Kete Hauora Taiao. A fundamental requirement of any management programme is to describe its key ecological theme and purpose. This can provide a way to operationalise management goals and objectives. The ecological pressures described here are the 'Driver' and 'Pressure' components of the DPSIR framework described in the previous chapter. In the next chapter, I will describe how ecological stressors are measured, the 'response' component of the PSR model.

The next step is seeing how Māori ecological knowledge and ecological science paradigms meet and intersect. Then we can determine how they can be forged into an ecological assessment tool that utilises and supports both. The intersection of the two paradigms is the focus for translating the two. Developing a framework that translates Māori cosmology into mainstream science methodology is the primary goal of this thesis. The next chapter will examine a framework used to understand ecological indicators and will explore how this framework enables the interpretation of Māori ecological indicators and epistemology as ecological science metrics. The key to the translation is linking the Māori deductive and largely qualitative ecological knowledge models and concepts into the ecological science reductive, quantitative ecological knowledge models and concepts to which scientific metrics can be applied. This is the rationalisation of Māori ecological beliefs and values into scientifically demonstrable data.

# Ūpoko Ono – Te anga
# Chapter Six – He Kete Hauora Taiao
# Environmental State Assessment Framework

> ‘If we are to discover and describe fully the importance of biodiversity to human well-being then we have to understand just how the connections to well-being are made’ - Haines-Young & Potschin (2010: 120) (L. Roberts et al., 2015, p. 10)

The purpose of this chapter is to explore the frameworks that I will be drawing on to link Māori ecological knowledge (MEK) and ecological science and resource management (ERM) in the creation of a new ecological assessment framework, He Kete Hauora Taiao. He Kete Hauora Taiao will weave MEK concepts and ERM metrics together through shared ecological concepts. Ecological components are the same whether natural resources are assessed with an Indigenous or a Western paradigm. This common ground is where I may interpret the two epistemologies and will be the basis of an ecological assessment framework utilising both knowledge sets.

He Kete Hauora Taiao may function as a set of baskets or kete. There will be three kete or facets to He Kete Hauora Taiao. The first kete is the Māori ‘perspective’, the lens through which the scientific data will be viewed. The second kete consists of the ecological concepts (ecological element) that the user determines as being the most appropriate for their management programme. This is where the connection between ERM and MEK may be made and this may allow exploration of the aspects of ecology most relevant to the mana whenua. The final kete involves the actual tools used to measure the environment. This is the set of scientific monitoring methods, tools and technologies that may be used to assess ecological structure, function, processes and services. Scientific monitoring techniques should allow the user to quantitatively assess Māori ecological concepts through metrics and data. The first kete consisting of the mātauranga Māori ariā (concepts) will be explored in detail in this chapter. This chapter will also examine how the ariā are linked to ecological science concepts, the second kete. The final kete relating to the scientific tools and metrics and their connections to the ecological concepts and indicators will be the subject of the next chapter. Using these three kete, an assessment structure and monitoring programme may be constructed that is appropriate for the specific whenua and mana whenua employing both ERM and MEK worldviews.

## He Kete Hauora Taiao

> '……we're there with our tikanga, our ways, our manaakitanga, our kotahitanga, our rangatiratanga.' TM

Ecological science may express the concept of ecological health as a spectrum of states. The change in the ecological state may be evaluated by a change or response in one or more ecological features or functions. The state of the environment often describes the outcomes of pressures on ecological features or functions using particular environmental indicators that are measured using scientific metrics and protocols. In 1993, the OECD and the Swedish government developed the Pressure – State - Response framework to evaluate changes in ecological health. This framework was then adopted by the New Zealand Ministry for the Environment and it has since been adapted to become the Driver – Pressure – State – Indicator – Response (DPSIR) framework (Victoria Ann Froude, 2011, pp. 107-108; G Harmsworth & Tipa, 2006; K. F. D. Hughey et al., 2004, p. 85). Describing environmental health and changes in terms of the DPSIR framework may clarify the link between the driver and the response – the impact of our actions and the outcome of our management decisions. The New Zealand Ministry for the Environment uses the DPSIR framework for New Zealand's state of the environment reporting, as it is well understood and used internationally.

He Kete Hauora Taiao's framework is Driver – Pressure – Ariā – Ecological Element – Indicator – Response (DPAEIR), adapted from the DPSIR framework. He Kete Hauora Taiao is a new framework that combines mātauranga Māori and mainstream scientific knowledge to evaluate the state of the environment. He Kete Hauroa Taiao is illustrated in **Figure 3**. The first part of this framework is Drivers and Pressures. These are the human impacts on the environment and I have explored these in detail in Chapter 5. Examples of anthropic pressures include agricultural nitrate emissions to waterways or the clearing of native forests. The 'state' component of the DPSIR framework refers to the ecological state that the pressure/s act on. I have interpreted 'state' as the ecological element (structure, function, process, or service) that defines the integrity and resilience of an ecosystem, i.e. its health. The indicators component of the framework are the descriptors of ecological change. All environmental assessments, Indigenous or otherwise, use indicators to define changes in the environment. The changes in the ecological indicators are the response component of the framework. The response shown by the indicators describes the direction and degree that the environment is changing due to anthropogenic pressures or from natural changes in the environment, such as climatic and geologic stochasticity.

In constructing He Kete Hauora Taiao, I have inserted Māori ariā at the 'state' level and shifted traditional mainstream ecological 'states' down a level. Ariā is the Māori word for concept and I have used it to describe the Māori ecological assessment indicators/perceptions/values that I have used in this framework. Ariā are the perspectives used by Māori to assess the health of the environment so that they function as descriptors of the state of the environment. Ariā describe ecological concepts that are familiar to both Māori and mainstream scientists. I have characterised these concepts as elements of ecological organisation. These elements describe the relationship between the abiotic and biotic components of the ecosystem, its functional diversity and habitat integrity, the functions and processes performed in the ecosystem and the services produced. These ecological elements may be measured using the wide variety of well-established mainstream scientific metrics, tools and methodologies. In this way the He Kete Hauora Taiao framework allows scientific metrics, which may otherwise be viewed as reductionist, to be used as indices of the ariā.

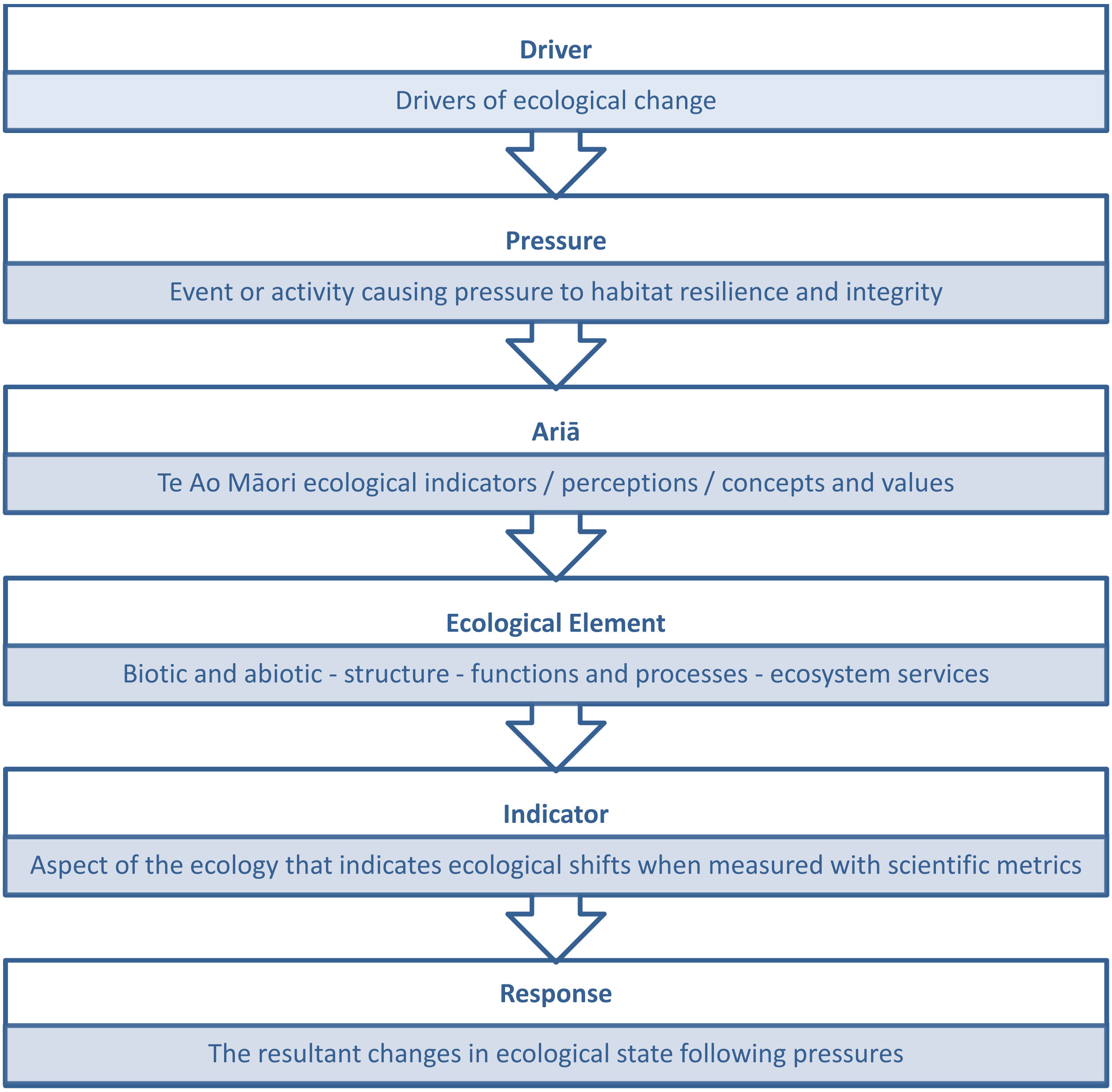
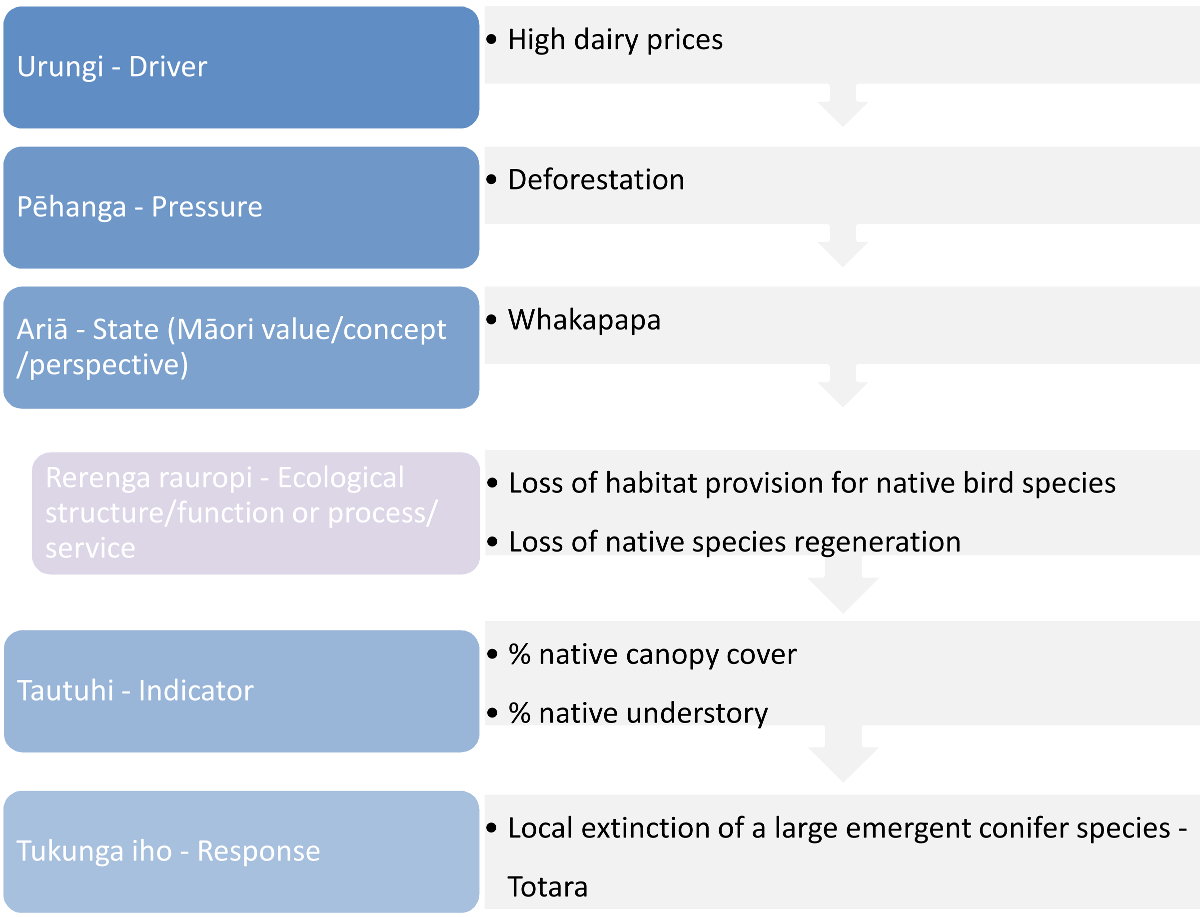



**Figure 3**. He Kete Hauora Taiao - ecological assessment framework based on the DPSIR model, incorporating Māori ariā linked to ecological elements that are measured by metrics associated with ecological indicators.

**Figure 4** illustrates the He Kete Hauora Taiao framework, providing an example of how it functions. A driver, such as high milk solid prices, may cause more native forest fragments to be converted into dairy pasture. This removes indigenous species that whakapapa to the whenua and replaces them with grass species and cattle that do not. The ariā applied in this instance is whakapapa and this indicates that indigenous dominance is the ecological state that is being impacted. The scientific ecological elements (ecological state, function, process and service) that are disrupted could include habitat provision and the quality and loss of forest regeneration capability. The indicator/s of the change to the ecological element could be percent native forest canopy cover in the catchment, the abundance of fruit produced that feeds birds, or the number of native seedlings and saplings present. The tools used to assess these indicators could include a FORMAK (Forest Monitoring and Assessment Kit), native forest assessment to determine the regeneration trajectory and change in canopy cover, five-minute bird counts to assess the abundance of native bird species and habitat mapping to define the landscape fragmentation and connectivity. This may enable the identification of some key ecological responses, for example, the local extinction of tōtara in the study/management area. This is just an example of how the He Kete Hauora Taiao framework could be employed.

**Figure 4.** The He Kete Hauora Taiao framework and one example of its use. The box in purple displays the ecological concept that links the ariā or ecological state to the indicator. The box is in purple to indicate that it has been inserted into the DPSIR framework.



Ariā can relate to any number of different ecological elements, such as ecosystem structure, function and outputs (services produced). For example, whakapapa, kaitiakitanga, mahinga kai, mauri, or even wairua are ariā that define ecological concepts or desired ecological states such as biodiversity, native dominance, community ecology, functional diversity, or food crop yield. From a Māori perspective, an ecosystem that has a healthy wairua or mauri may have high biodiversity, native species dominance, trophic complexity and nutrient cycling processes, among other things. The indicators of those ecological concepts are well known to mainstream ecologists as are the relationships between the indicators and the scientific metrics used to assess changes in them. For example, patterns of biodiversity may be described by calculating the Shannon index of diversity.

Four examples of how the framework could be applied are shown below using the ariā mauri, wairua, kaitiakitanga and mahi. The examples below are only examples of a set of ecological concepts, indicators and monitoring methods for each ariā. Each ariā could relate to more than one ecological concept, with many indicators and associated metrics. The ecological concepts, indicators and metrics selected will be dependent on the individual management programme's goals and objectives, the resources and timeframe available and the size of the management area. The monitoring programme works within the confines of these factors to ensure that the data collected may be analysed robustly to provide a meaningful conclusion.

In the first example, habitat occupancy has been selected as the ecological concept (see **Figure 5**). Two indicators that could be used to express habitat occupancy; spatial and temporal distribution of kereru and the occupancy of tui in forest fragments. One metric for each of the two indicators has been selected. Mapping kereru distributions to monitor kereru movement in the landscape can be done to assess their use of the habitat and five-minute bird counts can be used to assess the presence and abundance of tui in forest fragments.

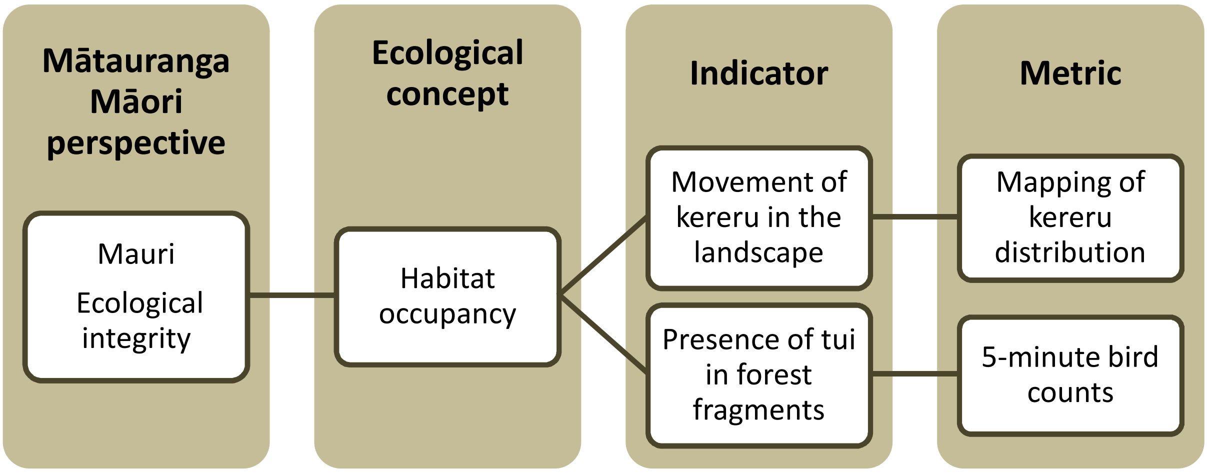



**Figure 5.** An example of how a monitoring plan can be designed using He Kete Hauora Taiao. This example uses mauri as the ariā and habitat occupancy as the ecological concept. Two indicators have been selected for the ecological concept and each indicator has one metric to assess the response.

In the second example shown in **Figure 6**, wairua is selected as the state or Māori perspective and community composition has been selected as the ecological concept. The indicators could be bird species diversity or indigenous dominance in the trees within the habitat fragment. The metrics selected may be five-minute bird counts and a FORMAK forest survey.

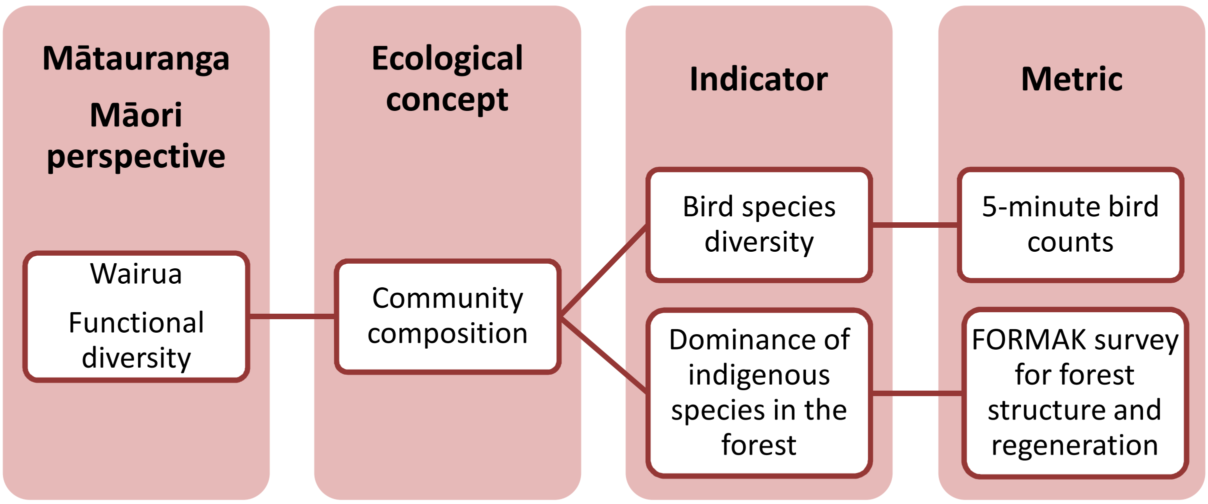



**Figure 6.** An example of how a monitoring plan can be designed using He Kete Hauora Taiao. This example uses wairua as the ariā and community composition as the ecological concept. Two indicators have been selected for the ecological concept and each indicator has one metric to assess the response.

The example shown in **Figure 7** uses the ariā of kaitiaki. Social investment is the ecological concept selected and the number of kaitiaki and the area of legally protected land are chosen as indicators. A direct count of the number of kaitiaki actively involved in the management programme and the number of hectares that are legally protected, measured using GIS, are examples of two metrics that could be used. In this example kaitiaki, therefore, translates to the number of kaitiaki involved and the amount of protected land.

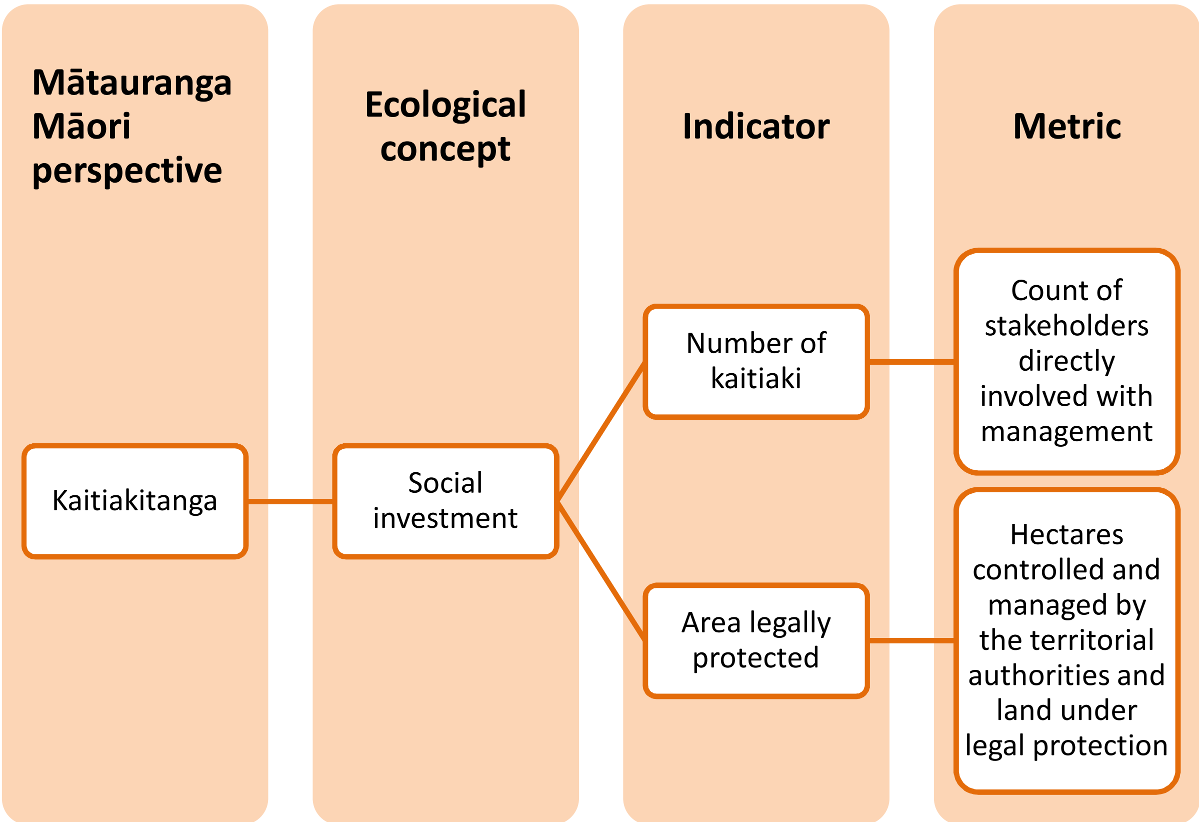



**Figure 7.** An example of how a monitoring plan can be designed using He Kete Hauora Taiao and DPSIR frameworks. This example uses kaitiakitanga as the ariā and social investment as the ecological concept. Two indicators have been selected for this ecological concept and each indicator has one metric to assess the response.

In the final example, the ariā is mahi (see **Table 8**) and the ecological concept is the extent of pest management. There are two indicators for this example, the area of land that received possum control and the efficacy of weed control. The metric for possums will be the result of a Residual Trap Catch (RTC) monitor. There are two metrics for weed control efficacy, the area of weeds successfully killed and the number of native plant seedlings that germinate following the weed control. The number of seeds germinating is an ecological outcome metric and is also a metric of forest regeneration. It may be used in different contexts depending on whether it is measuring the biodiversity outcome of weed control or the rate of succession in a forest fragment.

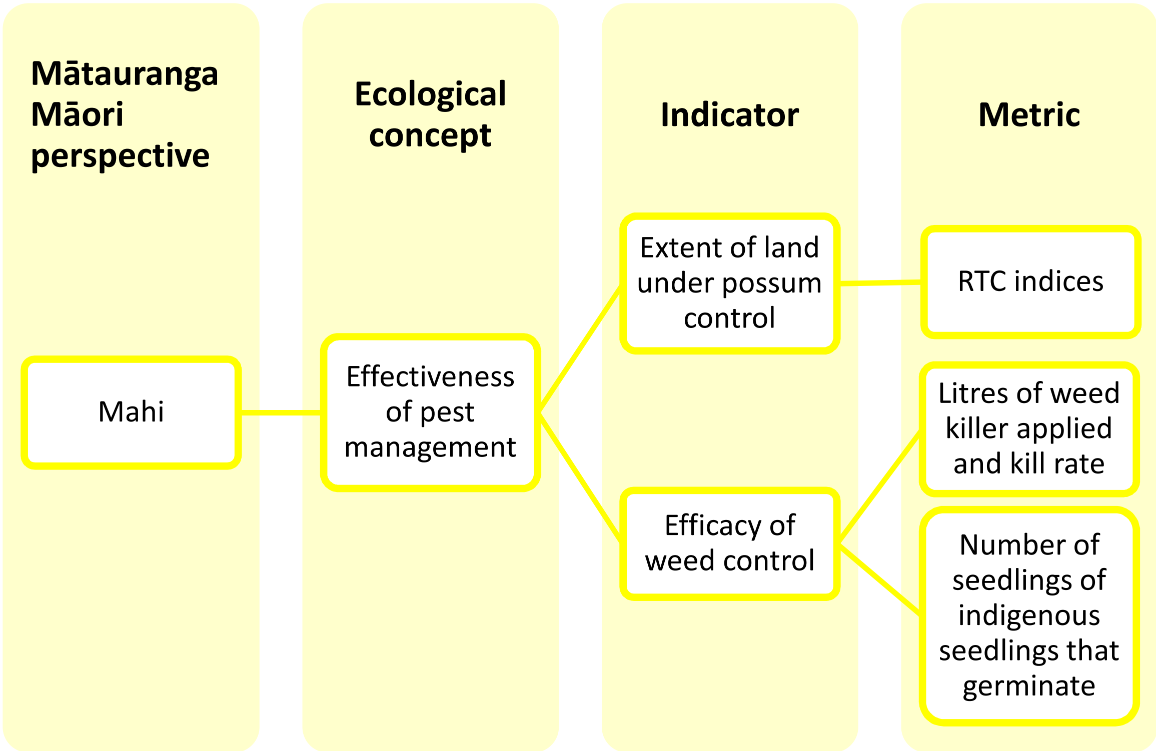



**Figure 8.** An example of how a monitoring plan can be designed using He Kete Hauora Taiao and DPSIR frameworks. This example uses mahi as the ariā and the effectiveness of pest control as the ecological concept. Two indicators have been selected for this ecological concept and the first has one metric and the other has two.

Note that the pressures, states and indicators selected to be the focus of a management programme can be politically or culturally motivated. This implies that the motivations for resource management and monitoring may differ depending on the deciding authority (Orians & Policansky, 2009, p. 393). This is why it may be important to have Māori included and their aspirations ascertained at an early stage of natural resource management planning.

If Māori are not included in the early stage of management planning, it may be difficult to meet their goals and ensure engagement later in the process.

Any number of Indigenous peoples' ecological concepts and perspectives may be broken down into the pertinent ecological elements and operational relationships that are used to describe them. The key is the link between the Indigenous cosmological, ontological and epistemological concepts and the scientific paradigm that describes the ecological structure, function, processes and services. The link between the ariā and the ecological elements therefore enables quantitative values to be applied to Indigenous concepts. One strength of the He Kete Hauora Taiao framework is that it is equally effective irrespective of the set of ariā (ecological concepts and perspectives) used. The Indigenous concepts could be supplied by any culture.

It was important to understand what Māori resource managers (kaitiaki) use as ecological assessment indicators. This was the primary objective of this thesis. While the research was able to deliver an extensive list, understanding how these indicators are employed in actual resource management is important. It is important to understand how these indicators are applied to real-life resource management and in what context they are used. In order to do this, it was necessary to interview actual kaitiaki. Four kaitiaki were interviewed for this thesis. They were chosen because they are Māori scientists and/or active kaitiaki of their iwi whenua. The interviewees selected are varied; a Māori scientist in academia, an active kaitiaki of a wildlife refuge, the head of the ecological unit of an iwi and a rongoā and kai specialist.

These interviews helped confirm that the MEK indicators discovered from the literature were actually used in practice and provided an opportunity to discover other MEK indicators not previously identified from literature reviews. It also allowed investigation into how MEK indicators are applied. It was important to understand what and how aspects of ecology are assessed using the MEK indicators and how the ecological responses measured by MEK indicators are managed. These interviews helped define management actions undertaken as a result of measuring the ecological state with MEK indicators and explore whether the same actions are undertaken when mainstream ecological science indicators are used. Kaitiaki from different iwi were interviewed so that the interpretations of MEK indicators by more than one iwi or hapū would be represented. This is important to ensure the interpretation of the ariā does not reflect only one iwi or hapū view.

Additionally, the interviews shed valuable light on the concepts such as mauri, wairua, kaitiaki and whakapapa and how ecological pressures impact these things. The interviews proved a valuable source of resource management tikanga and maramataka. The kaitiaki I interviewed are at the coalface of resource co-management and were able to describe first-hand practical experience of the issues and problems involved with implementing actual resource co-management. These discussions have been covered previously in the relevant sections.

Interviews were conducted semi-formally as discussions that followed a prescripted line of questioning outlined as pre-set questions. The questions were used as prompts to ensure that the topic or subject matter in the questions was discussed during the conversations. The conversations always began with the interviewee explaining their whakapapa and role as kaitiaki, where they come from, their position in their iwi, how they became kaitiaki and what their role as kaitiaki entails. The discussions were in large driven by the interviewee, with guidance from the interviewer to maintain the momentum and direction of the conversation. The interviewees were volunteers approached by me following recommendations from associates. Victoria University of Wellington Ethics Committee approval was obtained and the interviewees were supplied with a consent form, which was required to be signed and a list of the interview questions prior to the interview. The consent form included a clause permitting me to use the information they provided in this thesis.

## D – P: Divers and pressures

> 'People are the most pressing ecological concern. People are interfering with the wairua of the animals and changing their breeding and distribution patterns.' TM

Chapter 5 discusses the drivers and pressures that impact ecosystems. Here, I note that multiple pressures may act on a single ecological 'state' and that a single 'pressure' may affect multiple 'states'. These ecological changes place pressure on the ability of the ecosystem to perform functions and processes essential to ecological resilience and integrity. The ecological response may trigger a change in management practices if evident enough and important enough to humans.

According to Garbisu, Alkorta, and Epelde (2011, p. 2) ecosystems and ecosystem health may be considered analogous to the health of an individual organism. They argue that ecosystems behave as a superorganism made up of living and non-living parts. These authors note the analogies between ecological tipping points, feedback loops, causal cascades and certain metabolic functions. Like a body, if an ecosystem is exposed to more pressure than its systems can cope with, it could become sick. Like a body, an ecosystem with multiple functional pathways and depth of resources may be able to maintain and restore homeostasis better. Homeostasis means fending off disease in a body or resisting pressures for an ecosystem. Health means the recovery or return to homeostasis; it may be a different state than what existed before and may involve constant flux but achieves a new normal. The seashore, for example, exists in a constant state of change that is normal for this habitat, but increasingly large storm surges may be too much for the system to cope with and wellbeing may be jeopardised.

## A: Ariā – mātauranga Māori perspectives

> 'All the islands in and around Wellington (Mana, Kapiti, Makaro and Matiu) have their own individual and distinct mauri and wairua and have changeable moods. Kapiti is pulsating with life while Mana is gentle.' TM

The ariā are a set of ecological indicators, values, concepts and perceptions that Māori may use to interpret the natural world and have come from a variety of sources. The suite of ariā developed for He Kete Hauora Taiao are identified below in **Table 9.** This list has been compiled from the Māori ecological assessments reviewed previous chapters, including Māori wellbeing frameworks, various resource management planning documents (local government and iwi), as well as from interviewing kaitiaki and tohunga and from researching literature relating to Māori resource management and ecological assessment. Some of the sources from which I identified the ariā that are included in He Kete Hauora Taiao are; Dymond (2013, pp. 275-276); Forster (2012); G Harmsworth (2002, p. 4); G Harmsworth and Tipa (2006, p. 5); (G. R. Harmsworth & Pauling, 2013, p. 4); Jollands and Harmsworth (2007, pp. 719-721); (P. Lyver et al., 2009, p. 1); Ti Kipa Kepa Brian Morgan (2010).The list of ariā is not a definitive list. It can be expanded by iwi users or, alternatively, a whole new set of values may be created by other Indigenous peoples and substituted into this framework.

Some of the ariā have been grouped into categories because of their similarity in function and for the sake of simplicity. For example, Tangata is the collection of all the states that relate to the social connection to the land and includes Te oranga (social participation), Te mana whakahaere (self-determination) and whanaungatanga (consultation), etc. Tikanga, the Māori way of doing things, includes the ariā related to how people interact with the environment, the rules we employ and the management regimes enacted and includes tohu (guides, targets, etc.) muru (social deterrent), tapu and noa (sacred and common), wehi (conservation ethos) and ture (societal guidelines). The grouped ariā have similar ecological elements, associated measurable components/indicators and applicable mainstream science metrics (ecological responses).

**Table 9.** Shows the list of Māori perspectives of ariā used in He Kete Hauora Taiao.

| | |
|---|---|
| **Wairua:** Spirit - ecological diversity, species persistence, essence evolution and identity | |
| **Mauri and Mauriora:** Life-force - ecological integrity, ecological vitality, strength and resilience | |
| **Whakapapa:** Community composition and structure - belonging and genealogical links | |
| **Kaitiakitanga:** Conservation - safekeeping and environmental guardianship | |
| **Te Ao Marama:** Bbiodiversity - variation and abundance | |
| **Mana atua:** Habitat quality - ecosystem functions, processes and eminence | |
| **Whakawhanaungatanga:** Provisioning services - mutuality and ecological relationships | **Iwitanga:** Family and community |
| | **Tau utuutu:** Reciprocity, ecological flows |
| | **Koha:** Gift giving |
| | **Te Aotūroa:** Interdependence with nature |
| **Mahinga kai:** Utility - productivity, fertility, yield and sustainability | |
| **Taonga species:** Treasures | **Aroha tānga:** Care, love, and respect |
| | **Taonga tuku iho:** Endangered species management |
| **Tangata:** Cultural services-community and social connections, priorities, participation and interaction | **Te Oranga:** Societal participation |
| | **Ngā Manukura:** Community leadership |
| | **Te Mana Whakahaere:** Autonomy |
| | **Tino rangatiratanga:** Self-determination |
| | **Tō matou whakapono:** Knowledge, wisdom, and information |
| | **Tohungatanga:** Expertise and knowledge |
| | **Kotahitanga:** Respect, unity, and solidarity |
| | **Mana whenua:** Authority over the land and resources |
| | **Tūrangawaewae:** A place to stand |
| **Toiora**: Regulating services - wellbeing | |
| **Mahi:** Resource management | **Ki Uta Ki Tai:** From the mountains to the sea |
| | **Āwhinatanga:** Support |
| | **Manaakitanga:** Kindness, respect, and support |
| | **Whakapono:** Trust, honesty, and integrity |
| | **Kōkiri:** Going forward and winning |
| **Tikanga:** Tradition and customary practice, knowledge and education | **Ritenga:** Customs and protocols |
| | **Tohu: M**anagement guidelines and targets |
| | **Rāhui:** Restrictions |
| | **Muru:** Social deterrent |
| | **Tapu and Noa:** The sacred and the common |
| | **Wehi:** Reverence, conservation |

Ariā are the mātauranga indicators, concepts and perspectives that I have used in He Kete Hauora Taiao. The definition of ariā is an ideological concept or theory. In the He Kete Hauora Taiao Māori framework, ariā are described, characterised and expressed by the ecological elements that represent the underlying Māori values and philosophies. For each mātauranga Māori ariā in the framework, I have described its ecological context and the ecological elements that depict it and I have identified the scientific indicators and metrics that may be applied to measure the change in the state of the ariā. In this way, the ariā may be translated into science by deconstructing them, defining the ecological elements that describe them, selecting indicators of the ecological elements that represent them and then applying scientific metrics to those indicators.

The ariā may provide the lens through which ecology is interpreted and in effect describe the condition of an ecological state. Ariā can be interpreted differently by an individual, hapū, iwi or kaitiaki and each can apply their own interpretations. An exact interpretation of these concepts may not be required for them to be used in He Kete Hauora. It is how the ariā are linked to the ecological elements that is important. This flexibility enables the ariā to be defined by the kaitiaki. Different kaitiaki may interpret ariā differently and use different ecological elements but all will be interpreting ecological health. There is often incomplete alignment among ariā and the ecological concepts. Generally, the ariā will mean more than one thing ecologically and can apply to multiple ecological elements and multiple ecological elements can apply to multiple ariā.

The list of ariā and their interpretations presented in this chapter are only a guide and this is only one way to interpret them. One resource manager may decide that mauri, for example, represents the intactness of the forest and therefore will count the number of large emergent trees. Another manager may decide that mauri is the forest's ability to persist over time and that regeneration and succession are the key indicators. Yet another may define mauri as the structural complexity of the forest and will be interested in the abundance and diversity of the understory and ground cover species. He Kete Hauora Taiao may therefore reflect the values and goals of the kaitiaki, be they iwi, hapū landowner, community, scientist, or territorial authority (M. H. Durie, 1995, p. 464).

In this chapter, I examine the ariā in detail from an ecological context. In the next chapter I will describe how ariā may be linked to mainstream scientific ecological elements and metrics. The intent is that the list of ariā presented in this chapter and the connections described will be a guide to assist resource managers in the construction of individualised assessments of ariā/ecological status. No monitoring programme could monitor all possible indicators, therefore, I have presented a list of potential indicators that may be used to assess ariā. These indicators and associated metrics can guide kaitiaki, enabling them to build individualised monitoring programmes.

## Wairua/Spirit

### Ecological essence – ecological diversity, evolution, identity, soul and resilience

Wairua may be described as the spirit or soul of the individual or ecosystem. It can be considered the essence of the ecosystem. Wairua may be defined as the property of life and the structural and functional complexity of life. Viewed through an ecological lens, this may be interpreted as the ecosystem's diversity and evokes the emergence of diversity and evolution (G Harmsworth & Shaun Awatere, 2013). Ecosystems with wairua may have a diverse range of species with good connectivity between populations, ensuring genetic movement in the landscape. Ecological diversity may therefore be expressed as the evolutionary fuel for the emergence of new ecological elements. The more ecological elements there are, the more interactions may occur and the stronger the ecological functions and processes may be. Hence an old-growth forest has more wairua than a monoculture crop. Ecological diversity may generate functional redundancies and greater ecological stability. The biota provides life and wairua to the landscape and the wairua becomes more than the sum of its biotic parts (Marsden, 2003, p. 48). Landscape features may take on a wairua and an essence of their own, which they can then reciprocally bestow on the inhabitants of the ecosystem. The distribution, abundance and diversity of species over time and space may be key indicators of wairua. The resulting community composition and the presence of rare species that create the essence of the ecosystem are another indicator of its unique wairua. Population assessments may be an important assessment tool for wairua.

*Recommended environmental assessment programme for wairua:*

- Map the temporal distributions of species in the landscape, noting changes in species composition over time, using GIS
- Complete a community composition analysis focusing on evenness, distribution and persistence of communities in the landscape
- Identify the presence of focal species that are ecologically important and identify their distribution. I recommend focusing on assessing bird and forest tree biodiversity and the presence of any rare or threatened species in the study site (Bibby, 1999, p. 83). This will involve five-minute bird counts for birds, and permanent 20*20 vegetation NiVS plots (R. B. Allen, 1993).
- Interrogate the LCDB database and identify any land-use changes in the survey area over the last 20 years (the extent of the LCDB data timeline)

## Mauri and Mauriora/Life-force

### Ecological integrity - vitality, strength of the ecosystem

Mauri may be defined as the life-force and the special nature of organisms. Every living and non-living thing including forests, rivers and mountains has mauri (Klein, 2000, p. 109). Mauri can be interpreted as ecological integrity and expressed as ecosystem vibrancy (Forster, 2012, p. 14; Klein, 2000, p. 109). Ecological integrity may be described as a function of structural diversity. The indicators of structural diversity are habitat structure, diversity and spatial distribution. These habitats are likely to support rare species, particularly if those species are sensitive to perturbation. For forest habitats, this habitat diversity may be expressed in a diverse understory and ground cover and a complex tier structure. Forest fragments may generally support less diversity and their greater edge to core ratio means they may experience greater edge effects and greater susceptibility to weed species infestation. Mauri tū may be the process of restoring balance to the environment, the returning of mauri.

The primary indicators of mauri may be the occupancy, connectivity, heterogeneity, representativeness, rarity and structure of ecological habitats. Mapping species distributions can explore and assess the species occupancy. Habitat connectivity and heterogeneity (the variety of habitats in a landscape) can be evaluated by mapping habitats and their spatial characteristics using GIS as a desktop exercise. Databases such as LCDB and LINZ can be used to identify rare and threatened habitats and to assess representativeness. Forest assessments such as FORMAK (Forest Monitoring and Assessment Kit) can describe forest habitat structure.

When it comes to the management of the mauri of an awa, Māori often use the concept of minimum ecological flow. Minimum ecological flow is the minimal flow of water in the awa that will support the ecology (Royal, 2011, p. 7). It is often higher than the minimum flow rate identified by mainstream scientists, which is often modelled on the requirements of one or two species that are usually large fish. A healthy awa with a flow rate above the minimal ecological value will not support algae blooms, will remain below the temperature that will deplete oxygen levels to below life support levels for the most sensitive aquatic organisms and there will be no excess N, P, or faecal coliforms.

*Recommended environmental assessment programme for mauri:*

- Complete a full of 20*20 or FORMAK assessment in several locations throughout the forest or each forest fragment in the study area
- Map the distribution of any rare plant or bird species (Culmsee et al., 2014, p. 313)
- Map the habitat fragments in the study area and map the location of any threatened or rare habitats in the area using LINZ and LCDB databases
- Analyse habitat variability and land use to determine habitat representativeness and heterogeneity, again using LINZ and LCDB databases

## Te Ao Mārama/Biodiversity, the diversity of life

### Species abundance, evenness, richness and biomass

**Kanorau – diversity**

**Koiora – life**

Te ao mārama translates to ‘a world of light and opening’ and encapsulates the flow of energy through the environment (Dymond, 2013, p. 276). In an ecological context, te ao mārama may relate to biodiversity, genetic and morphological variability and biomass. It may be considered the diversity of life in the ecosystem, species abundance, richness and evenness in the landscape. In terms of energy flow, te ao marama may be denoted by organism growth, photosynthesis and respiration and the flow of energy and nutrients through the system. Te ao mārama indicators may therefore include species diversity, distribution, abundance and evenness. It may be the output of energy, the yield of raw materials, food, medicines and genetic and biochemical products. Te ao mārama may be assessed using biodiversity indices as described in Chapter Five and by calculating the biomass of species and doing genetic and morphological analysis.

*Recommended environmental assessment programme for te ao mārama:*

- Conduct five-minute bird counts or slow walk transects to understand bird diversity
- Conduct enough FORMAK or 20*20 vegetation plots to ensure adequate spatial coverage to obtain a full species list. FORMAK plots are recommended as they are less complex and quicker than NiVS plots. There may already be data on the NiVS database, which if accessed can be used
- Conduct five-minute bird counts or transect counts for birds
- Conduct artificial refuge studies for lizards using large refuges to maximise sensitivity
- Conduct pest animal monitoring with tracking cards for small mammals and wax tags for possums. Conduct a faecal pallet count for ungulates
- If an assessment of invertebrate biodiversity is required, live pitfall trapping is recommended and analysis should be limited to one or two taxonomic groups such as ants, beetles, or spiders to keep it manageable
- Biomass of plants can be assessed with dry weight measurements or from tree mass calculations using volume and DBH (diameter and breast height)

## Whakapapa/Genealogical links

### Community composition (richness and abundance), indigenous dominance, identity and belonging

Whakapapa may be described as the genealogical belonging or indigeneity of the denizens of the ecosystem (Chick & Laurence, 2016, pp. 3-4; M. Roberts, Norman, Minhinnick, Wihongi, & Kirkwood, 1995; Te Rire, 2012). Whakapapa may exemplify the link that an organism has to the land and the evolutionary and physical connection to the habitat it is acclimated and adapted to (Chan, Satterfield, & Goldstein, 2012, pp. 8-9). Indigenous species clearly have a strong whakapapa link to the land. However, we should also consider the indigeneity and ecological functions of species that were introduced and are now naturalised (Taura, Van Schravendijk-Goodman, & Clarkson, 2017, p. 8). There are even species that self-introduced before human occupation but relatively recently in geological time, such as the pīwakawaka or fantail (*Rhipidura fuliginosa*), silvereye (*Zosterops lateralis*) and the pūkeko. Introduced pest species that harm ecosystem quality may also be important indicators of whakapapa. Whakapapa may be described in ecological terms as the genetic distribution and variability of indigenous organisms in the landscape. The ecological indicators of whakapapa are indigeneity and the distribution and dominance of the members of the ecological community. It may also be the abundance of pests and non-indigenous species in the environment. Assessing the abundance and distribution of pest species may inform management practices and may provide an understanding of their impact on native species and the ecology.

*Recommended environmental assessment programme of whakapapa:*

- Identify any relevant keystone, cultural keystone, or threatened species and map their distributions and habitats
- Conduct 5MBC or transect monitor for birds for a species list
- Conduct a large refuge study for lizards using large refuges
- Conduct a recce to get a vegetation species list. A recce monitor a reconnaissance monitor as described in the FORMAK method.
- Conduct pest monitoring using chew cards for small mammals, tracking tunnels for rodents and mustelids, faecal pellet counts for ungulates and pest plant infestation mapping
- Calculate indigenous dominance

## Taonga species/Treasured species – Focal species

**Aroha-tānga - care, love and respect for the whenua and the creatures living on it**

**Taonga tuku iho - endangered species management**

Taonga species are generally focal, rare, or culturally important species in an environment (Cragg, 2010, p. 102; Dymond, 2013, p. 117). Taonga species may be either plant or animal and may be keystone, umbrella or ecological engineers, or any other focal species type. Culturally important taonga species may include harakeke because of its resource value, tuna or manuka for their food value, kiwi (*Apteryx spp.*) and kauri (*Agathis australis*) because they are iconic species, or kōkako (*Callaeas wilsoni*) and kākāpō (*Strigops habroptilus*) because of their conservation value. Aotearoa is now a unique mix of indigenous and introduced species and the introduced species appear to be here to stay. I have grouped aroha-tānga and taonga tuku iho along with taonga species as these relate to the love, care and respect we have for our taonga species and their management. We often put specific species management plans in place around taonga species when managing the national population becomes a priority and put them on offshore islands or in sanctuaries. Indicators for this ariā primarily relate to the abundance and distribution of these species rather than overall biodiversity. The distribution of the species spatially and temporally, its abundance and its population size and behavioural dynamics may be the key indicators for taonga species. Abundance may be measured directly and distribution may be assessed by mapping species distribution and the location of breeding sites. Population dynamics may be evaluated with behaviour studies.

*Recommended environmental assessment programme:*

- Identify the relevant focal species, rare species, or culturally important species
- Confirm their presence in the study area and determine indigenous dominance using:
    - 5MBC for birds
    - RECCE for vegetation
    - Appropriate live trapping for invertebrates (live pitfall trapping for ground invertebrates, Malaise trapping for low flying invertebrates, hand searching for litter living invertebrates and rare weta species)
    - Large artificial refuge occupancy for reptiles
- The habitat extent and location of these species should be mapped using GIS. Possible habitat that is currently unoccupied can also be mapped. This will enable the carrying capacity of the study area to be determined
- Map nest/burrow locations and monitor the fate of nests for any focal bird species identified

## Mana atua

### Habitat quality – Ecosystem functions and processes and structural diversity

Mana atua refers to the spiritual influence of the atua. Atua are the spiritual guardians of their respective domains (Douglas, 1984, p. 12; Makey, 2010, p. 56). The domains of the gods are the forests, soils, atmosphere and aquatic ecosystems and the quality of these habitats defines the mana of the atua present in that habitat. (Nelson & Tipa, 2012, p. 5). Tāne Mahuta is the lord of the forests and his children are the birds. Haumia-tiketike is the god of wild foods and Tūmatauenga is the god of cultivated foods. These two Gods can be embodied by soil habitats. Soil is the foundation of healthy wild and domestic food production. Tāwhirimātea is the god of the wind, air and climate. Tinirau is the guardian of fish and Maru is the god of freshwater habitats (Gregory, Wakefield, Harmsworth, Hape, & Heperi, 2015). Mana atua may be considered to be both the power imparted by the atua to the environment and the power they receive from the environment. Mana refers to the power, strength and status that something or someone possesses and the flow is reciprocal.

Mana atua may be interpreted ecologically as the ecological functions and processes that build and support a quality habitat. Manu atua may refer to the strength and quality of the ecological processes and functions that occur in the terrestrial, aquatic and pedological environments. Vital and varied ecological functions denote resilient, quality ecosystems (Dymond, 2013, pp. 275-276; P. Lyver et al., 2017, p. 7). Relevant forest functions may include succession, productivity, growth, the forest's response to seasonal change (phenology), etc., and standing or fallen dead wood may denote carbon sequestration rates. Aquatic ecosystem functional indicators may include water quality (clarity, chemistry and temperature) and hydrology (flow regulation). Riparian habitats that connect the land to the water may be important for water purification, erosion control, flow and temperature regulation and habitat provision. Soil functional indicators may include nutrient cycling, soil fertility, formation, structure, decomposition, humus, and leaf litter depth and habitat provision. Healthy soil may support diverse invertebrate and mycorrhizal assemblages. Tāwhirimātea may be represented by air quality, temperature regulation, gas exchange and climate regulation.

The indicators for mana atua may pertain to assessments of the quality of the environment, including ecosystem service yield, pest species impacts and the status of focal or rare species. Focal species may function as bio-indicators of ecosystem health and therefore can indicate mana atua.

*Recommended mana atua environmental assessment programme for mana atua:*

- Conduct a 20*20 vegetation plot or a FORMAK plot assessment for forest structure and function
- Interrogate the LCDB and map any threatened ecosystems in the catchment and the extent of productive farmed land
- Identify any rare, threatened, or cultural keystone species and map the distribution of these
- Conduct a pest monitor of all pest species
- Map weed incursion
- Conduct a CHI assessment in the stream and get the water quality data from the local government organisation in the area collecting this data
- Interrogate the NiVS database for the carbon sequestration data

## Mahinga kai

### Provisioning services – utility, productivity and yield

Mahinga kai pertains to all food products, wild and domesticated (L. Roberts et al., 2015, p. 2). Mahinga kai demonstrates one primary ecological function, the provisioning of food for people. Ultimately mahinga kai may be considered an ecosystem service because we consume the food resources the ecosystem produces. Mahinga kai provision may depend on the ecosystem's ability to provide abundant high-quality food. The phenology (the study of cyclic and seasonal changes in plants and animals) in the forest may provide information on the timing, quality and yield of forest resources. The fertility, organic component, formation of the soil and the nutrient cycling in the soil may also be key indicators for cultivated food. Other indicators of mahinga kai may be the direct yield of food produced. Mahinga kai may be easily assessed with direct quantification of food productivity, yield, diversity and abundance. The market value of the food produced and spatial analysis of the area of land used for primary production may be proxy indicators of yield and productivity. Pollination may also indicate mahinga kai because the food we consume often requires insect pollination (G. Tipa, 2009, p. 113). Pollination services may be assessed using the market value of crops pollinated by bees.

*Recommended environmental assessment programme of mahinga kai:*

- Focus on the native mahinga kai species and natural forest productivity. Map and locate any important mahinga kai resource species as identified by Māori or local farmers, such as mānuka (*Leptospermum scoparium*) or karaka (*Corynocarpus laevigatus*) stands
- Map any areas that were once used for mahinga kai collection but are not available for this purpose anymore. Compile a species list of mahinga kai species no longer present in the study area
- Map the land use using LCDB and note the area used for livestock farming, dairying, cropping, viticulture, etc.
- Survey the eel (*Anguilla spp.*).and whitebait populations and the health of the eels
- Calculate the market value of food produced in the study area

## Whakawhanaungatanga/Ecosystem services

Provisioning services - ecological relationships, interdependence, reciprocity, interactions and networks

**Iwitanga – Family and community**

**Tau utuutu – Reciprocity, give and take and the ecological flows**

**Koha - gift-giving**

**Te aotūroa - interdependence with nature**

Whakawhanaungatanga concerns connections, relationships and ecological mutualisms. It may be described through ecological networks and interactions that shape the environment around us. It may also be about human interactions with the natural world, what we give to it and what we take from it. Historically Māori have generally respected the natural world and the finely balanced reciprocal relationship we have with it. Whakawhanaungatanga symbolises reciprocal interactions, such as energy and nutrient flows. Indicators of whakawhanaungatanga may be ecological networks and relationships that shape community composition and the ecosystem's ability to provision people with consumable natural resource such as fibre, building materials and medicines. Whakawhanaungatanga may be assessed using food web, predator-prey interactions, trophic level and niche occupancy analysis.

I have grouped several other similar Māori perspectives to describe this ariā, including iwitanga, tau utuutu, koha and te aotūroa in this ariā. Iwitanga refers to family and community. In this context, I have interpreted this to be our relationship with our non-human iwi and our place in the biological community. Tau utuutu represents the reciprocity of our activities in the natural world, the give and take of sustainable management (M. Roberts et al., 1995, p. 11). Koha reflects the gifts the natural world imparts to us and what we give back to the whenua in our care. Te aotūroa espouses our interdependence with the natural world. If the whenua is not healthy then the people may not be healthy.

*Recommended environmental assessment programme of whakawhanaungatanga:*

- Mapping habitats to assess their connectivity, heterogeneity, distribution and core ratios is advised
- Map key species distributions and overlay on habitat maps
- Conduct food web and network interaction analysis of species in the area

  Map areas of influence for disturbance events (flooding, drought and disease incursion). Map the erosion-prone zones, the flood-prone zones and the drought-prone zones, storm surge-prone zones and follow changes over time and the cost of mitigation or repairing damage
- Map the location of all ecosystem products consumed by people that are not food including fuel, fibre, raw materials and any genetic and biochemical resources
- Assess the yield of non-food resources obtained and the market value of these resources

## Toiora/Wellbeing

### Regulating services – resilience and protection

'You get vitamin N (nature) for nature deficit disorder' TM

Toiora may be considered the wellbeing of mind, body and soul. For many Māori, the foundation of wellbeing is a healthy environment (Dymond, 2013, p. 278; L. Roberts et al., 2015). Economic (material), social (mental) and spiritual (emotional) wellbeing may not happen if the environment is not healthy. The wellbeing of the individual therefore rests on the wellbeing of the environment, as discussed in Chapter Five (M. Durie, 1998; G Harmsworth & Shaun Awatere, 2013). The indicators of toiora may be considered the ecosystem services that regulate the flow of nutrients, water, pollutants and energy through the environment to improve the environment and keep us safe, healthy and well. This may include the physical protection we receive from shelterbelts such as reduced wind, noise and pollution levels, or the flood protection and sediment control we receive from riparian vegetation and wetlands. Toiora may be measured by identifying and mapping socially important locations.

*Recommended environmental assessment programme for toiora:*

- Map the legally protected, conservation and recreation areas being managed for societal use
- Map the cultural landscape indicators including recreational areas, culturally important sites, etc.
- Map recreational areas, parks and reserves

## Tangata/Social connections and community participation

**Te oranga - societal participation**

**Ngā manukura - community leadership**

**Te mana whakahaere – autonomy**

**Tino rangatiratanga - self-determination**

**Whanaungatanga – consultation, consensus and respect**

**Tohungatanga – expertise and knowledge**

**Kotahitanga - unity and solidarity**

**Mana whenua - authority over the land and resources**

**Tūrangawaewae – a place to stand**

Tangata refers to human interaction with the natural world. Tangata may be concerned with our social connection to the land. It may be the cultural heritage bestowed by the land and the identity we gain from it. Tangata may be demonstrated in the stories passed on to us, the customs and beliefs we have developed, our social philosophies and social structures and the values that we use to interact with the natural world. We generally prioritise our management based on our social and cultural values, which creates our social landscape. Cultural services included in tangata include the benefits of exercise and quiet spaces to relax or be with loved ones. It may also be the sense of peace we get from being in nature, the spiritual connection and the heritage and identity we receive from natural spaces.Tangata may be assessed by the ability to access special places and the use and presence of culturally developed landscape markers or features, nomenclature and the presence of taniwha, for example. Indicators of Tangata may be the amount of land legally protected and where and how much land is being actively managed. Other indicators are the symbolic representation of our cultural identity, including culturally important sites (wāhi tapu, etc.), the use of special nomenclature and the presence of taniwha or other culturally important entities.

I have grouped all the Māori principles that relate to social oversight of the land together in this ariā (K. Hughey & Booth, 2012, p. 554). Te oranga refers to societal participation such as care groups, citizen scientists and iwi groups. Ngā manukura may be interpreted as the amount of natural resource and land management that is driven by the community rather than landowners, the Crown, or local authorities. Te mana whakahaere and tino rangatiratanga may be described as the amount of autonomy and self-determination afforded to the community to manage their environment and their ability to implement and drive management decisions. Whanaungatanga may be evaluated by the depth of consultation enabled by the parties involved and the equality of any co-management relationships. A key aspect of this may be asking the iwi partner what they see as the management priorities and objectives in the initial planning phase. Tohungatanga may be expressed as the extent to which Indigenous knowledge is engaged. Kotahitanga reflects all sectors of society standing together to achieve our common goals and working as one in a unified manner. Mana whenua may be gauged by the level of Māori authority over the land and resources and the extent of Māori owned land and land where Māori are active and effective co-managers. Finally, for Māori, tūrangawaewae locates us in space and is the source of our rights and our responsibilities.

*Recommended environmental assessment programme:*

- Identify and map the important cultural features (wāhi tapu etc.), nomenclature, legally protected sites, presence and home of taniwha, or other culturally important features
- Map the extent of species management areas and location of land-use changes to identify pressure areas
- Record any historical narratives and location information
- Using GIS, map the extent, distribution and change over time of the management area boundaries and identify the habitats they contain. Interrogate the LCDB to define land use in the catchment and identify any changes over time between the LCDB database iterations
- Collate the iwi management goals and aspirations. Identify their priority areas to see how closely these align to current management practices being undertaken

## Tikanga/Customary practice

**Ritenga – customs and protocols**

**Tohu - instructions, guides, advice, signals and markings, management guidelines and targets**

**Rāhui – restrictions**

**Muru - social deterrent**

**Ture – societal guidelines**

**Tapu and Noa- the sacred and the common. Prioritisation and ranking of management sites and populations**

**Māramataka**

Tikanga reflects our knowledge system and captures kaupapa Māori ecological management practices (Moller, Kitson, & Downs, 2009, p. 251). Tikanga are the rules, management guidelines and deterrents or controls used by Māori to manage the environment (Cragg, 2010, p. 100). They may embody our customary rituals and practices, our ritenga and tohu and they are our knowledge, understanding and interpretation of environmental cues (Faulkner & Faulkner, 2017, p. 6). Tikanga include the rāhui we enact and the social constraints and guidelines, muru and ture, that are imposed on our behaviour and imparted to us by our tipuna. It may involve the values we place on environmental qualities and attributes, making them tapu or noa - sacred or common. Tikanga, therefore, may be assessed by mapping important cultural management boundaries and customary resource acquisition and use locations. Tikanga may be particularly relevant to the customary management of cultural keystone species such as the titi, so mapping the distribution of these species may indicate tikanga. Titi have a very prescriptive management tikanga around them and they are also key (they are ecological engineers) to the biodiversity of the islands on which they live.

*Recommended environmental assessment programme:*

- Identify and map all the cultural management boundaries
- Define all the management targets that exist for both mainstream authorities and iwi management programmes
- Identify iwi management plans and their size and location. Identify historically important areas in the cultural landscape that are not available to iwi or not under iwi management currently. Map the location of new/potential iwi management programmes that the iwi would like to undertake

## Kaitiakitanga/Environmental guardianship and conservation

### Mana tū – obligations and responsibilities

> 'I am the succession plan to Tama Kaimoana for the knowledge of our food resources'
> JM

Kaitiakitanga and mana tū entail humanity's caretaking and guardianship obligations for the ecosystem and natural resources. Kaitiaki may be viewed as the responsibility to nurture and protect that balance. Kaitiakitanga may be whole system management, valuing native species, particularly mahinga kai resources (Forster, 2012, pp. 42-43; Makey, 2010). Landscape features instilled with wairua, such as sentinel maunga or guardian taniwha, may also be kaitiaki of the whenua. Kaitiaki are generally the people with the knowledge of kaitiakitanga. They may have the wisdom of the past that we rely on, embodied in our kaumātua and tohunga and the practices they teach that have been proven over time. Mana tū may be considered alongside kaitiakitanga because it represents the obligations and responsibilities that kaitiakitanga confers. Māori may view resource management as a way to ensure a strong, healthy, resilient tribe and abundant resources (Cragg, 2010, p. 100).

Kaitiakitanga may be defined by the management activities and objectives we may employ to restore or manage species or habitats. Species management usually involves key focal species and rare species, usually large and charismatic ones. Habitat management may be concerned with the rarity, representativeness, structure and morphology of selected sites. Sites are usually managed to improve or preserve indigenous dominance and persistence (ecological sustainability). The indicators of kaitiakitanga include habitat occupancy of rare species, the carrying capacity of habitats for focal species and the genetic and morphological variability of rare species (particularly when inbreeding may be a potential problem). Assessment criteria for kaitiakitanga may include the number of paid and volunteer kaitiaki, the area managed by kaitiaki and the resources available to them, as well as how many man-hours are invested.

*Recommended environmental assessment programme kaitiakitanga:*

- Identify and prioritise key species, habitats and people in the management area
- Map the locations and outcomes of pest plant and animal management programmes
- Map the habitats and locations of key species or habitats in the management area. This will involve 5MBC for birds, large artificial refuges for lizards, weta hotels (presence/absence), or hand searching for rare weta
- With iwi, identify and map important sites, built capital, human capital, legally protected land, taniwha homes, mahinga kai and rongoā areas and the extent and locations of management programmes
- With local authorities and landowners, map the extent of land management parcels

### Mahi/Resource management

**Ki Uta Ki Tai – from the mountains to the sea, integrated catchment management**
**Āwhinatanga – a kaupapa of support and benefit to the community and the environment**
**Manaakitanga – kindness, respect and support**
**Wehi – reverence, conservation and protection**
**Whakapono- acting with trust, honesty and integrity (Kanwar, Kaza, & Bowden, 2016)**
**Kōkiri- going forward and winning, a kaupapa of advocacy and supporting**

Mahi may be determined by the work that we do and the conservation management we practice. It is about caring for threatened species and ecosystems and how we use land sustainably (Bibby, 1999, p. 83). Mahi encapsulates how we prioritise and implement resource management. Mahi may be indicated by the extent of management activities undertaken, where (with whom) the management authority resides and where the management resources are invested. Vegetation cover (restoration planting), and pest management are common management responses. Mahi can also be about the ongoing research, science and planning done and the investment in developing new trapping, pest control and management tools and technology. Tangata may be considered the prioritisation model, kaitiaki the human resource and knowledge and mahi the implementation of management plans. Indicators of mahi are the extent and location of restoration plantings, pest management programmes, monitoring and research programmes and infrastructure development and maintenance. The cultural indicators of mahi may relate to the community, particularly iwi control over and participation in resource management, how authority is exercised and if it is done in a culturally appropriate way.

Several other concepts are analogous to and associated with mahi. Ki uta ki tai – from the mountains to the sea - expresses our integrated catchment management epistemology (L. Roberts et al., 2015, p. 6). Āwhinatanga may be interpreted as human management to support biodiversity. To achieve this, the community should work together to support biodiversity and protect habitats. We do this through manaakitanga with respect, kindness and support for the creatures we share the environment with and for one another. Wehi may be similar to manaakitanga and encapsulates the reverence we have the environment and the necessity we feel to protect and conserve the natural world. Whakapono may be having trust, honesty and integrity in our interactions with the environment and one another. This ariā may define how we support each other and work toward a common objective.

*Recommended environmental assessment programme:*

- Map the location and extent of pest management programmes
- Map the location and extent of restoration planting programmes
- Map the location and extent of monitoring and research programmes
- Map infrastructure
- Note any land-use change pressures

## Conclusion

> Ko ngā mana ko ngā mauri o te whenua kei i raro iho i ngā tikanga a o tātou tūpuna
> The prestige and life force of the land is enhanced beneath the mantle of our ancestral traditions (Garth Harmsworth, 2017)

He Kete Hauora Taiao is an environmental framework that places mātauranga front and centre. It connects Māori ariā to pertinent ecological concepts that define and illustrate them and in this way enables scientific indicators and metrics to be applied to them. He Kete Hauora Taiao is built on the Driver – Pressure – Ariā – Ecological Element – Indicator – Response framework. He Kete Hauora Taiao permits quantitative data collected using scientific methods to be harnessed, expressed and communicated in terms of Māori ariā. Several ecological elements can be used to depict different ariā and have multiple indicators that reflect the ecological response. The ariā, elements and indicators selected will be a reflection of the kaupapa of the user. This means that the definition of the ariā is not fixed; it is flexible and the interpretation can be unique to each user or group of users. Therefore, the framework can be relevant to multiple iwi or hapū using their own interpretations, values and management goals. It can also be used by non-Māori less familiar with the meanings of the ariā. Non-Māori can follow the connections between the Māori ariā and the science outlined in Appendix 1 and 2 and can interpret the ariā in that way without needing to be completely conversant with the meaning of the ariā.

He Kete Hauora Taio may help resource management to move away from relying on relatively discrete scientific indicators towards a more holistic view and in the process, improve scientific understanding of how ecological structures, functions and services are affected by perturbation (W. H. Thomas, 2003, p. 991). Resource managers may also gain an understanding of how management impacts cultural values. In this chapter, I have described the ariā from an ecological perspective and described the ecological elements and indicators that relate to each. I have linked the Māori ariā to the scientific ecological principles and I have linked the ecological principles to tangible metrics. This is the essence of this framework and is where the relationships and links between the ariā and the ecological concepts have been made.

In this chapter, I provided examples of how each ariā can be linked to ecological elements, the scientific indicators that measure them and the tools (metrics) used to do so. Understanding how science quantifies ecological functions enables us to understand how these metrics can be used to effectively measure ecological changes in a way relevant to both Māori and scientific ecological management epistemologies, thereby improving our management and depth of knowledge. The next chapter will explore the ecological elements that generate and define ecological health and the indicators and metrics used to assess ecological health, the E-I and R components of the DPAEIR framework.

# Chapter Whitu –Ngā raranga

# Chapter Seven – Weaving mātauranga and science together

> Meyer (1997) describes a healthy river as "an ecosystem that is sustainable and resilient, maintaining its ecological structure and function over time while continuing to meet societal needs and expectations." (Young et al., 2008, p. 10)

An ecosystem's health may be a product of its persistence and resilience, as expressed by its integrity and quality over time and indicated by its response to natural and anthropogenic pressures (Parrish, Braun, & Unnasch, 2003). An ecosystem's health may therefore be a product of that ecosystem's relative value as assessed by that ecosystem's physical characteristics, biological (individual and taxonomic) composition, structural integrity, functional diversity, the quality of its constituent habitats, the quality and quantity of the processes occurring therein and the quality and quantity of ecosystem services produced. This is depicted in **Figure 9**. I have used the framework in **Figure 9** to organise and structure the ecological elements that will be used to define the ariā.

The ecological elements may be defined as the sum of environmental structures, functions and services (Hernández-Morcillo et al., 2013, p. 438). The ecological structure consists of the abiotic and biotic elements. The abiotic features that generate ecosystem structure are physical properties such as hydrology, temperature, topography, geology, etc. The biotic elements describe biodiversity and community composition within an ecosystem and are a result of geological and climatic history (Hermann et al., 2011, pp. 20-21). The constituents of the ecological structure combine to create ecological integrity (habitat characteristics), and the functional diversity (population dynamics) of an ecosystem. The consequence of an ecosystem's integrity and functional diversity are its ecological functions and processes

(Andreasen, O'neill, Noss, & Slosser, 2001). Ecosystem processes are 'a series of events, reactions or operations…' required for an ecosystem to function (Hermann et al., 2011, p. 7). Ecosystem functions are the capacity of the ecosystem to produce ecosystem services (Hermann et al., 2011, p. 7). Ecosystem services are the outputs of ecosystem processes and functions that benefit life and in particular humanity. Ecosystem services include the production of oxygen, biomass, nutrient and gas cycling and raw materials (food, fibre, medicines and energy) (de Bello et al., 2010, p. 2874).

## E: Elements of ecological organisation

Biodiversity, ecosystem functions and processes and ecosystem service production are 'inherently linked' see **Figure 9** (Cadotte, Carscadden, & Mirotchnick, 2011, p. 1079). These ecological elements are well understood by mainstream ecologists as the constructs of ecological systems and the relationships defining ecological health. This framework was described by L. Roberts et al. (2015, p. 98), however, L. Roberts et al. (2015) described this framework in the context of the mainstream economic value system.

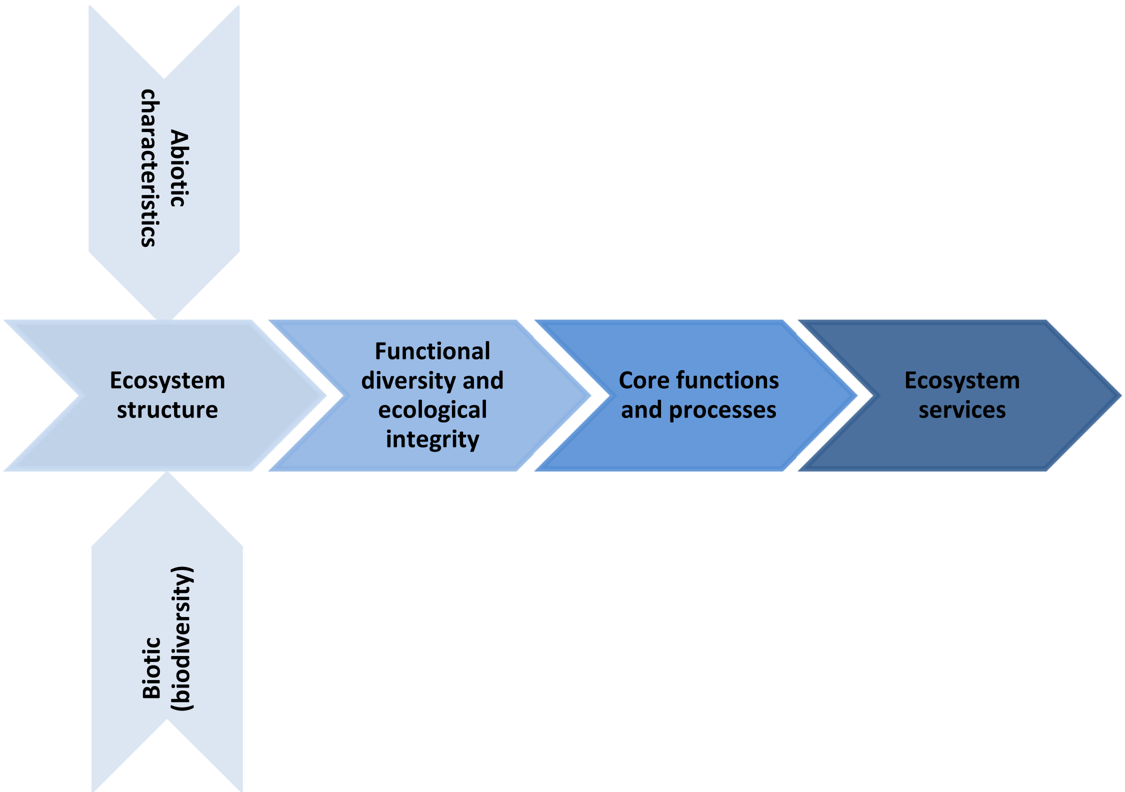
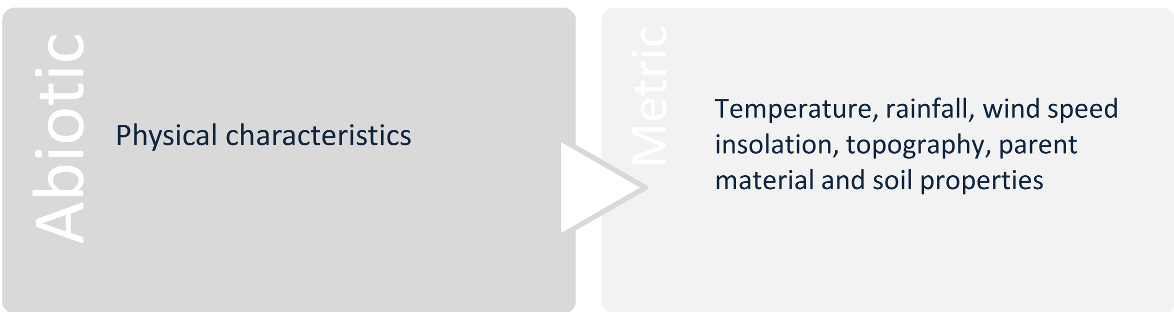


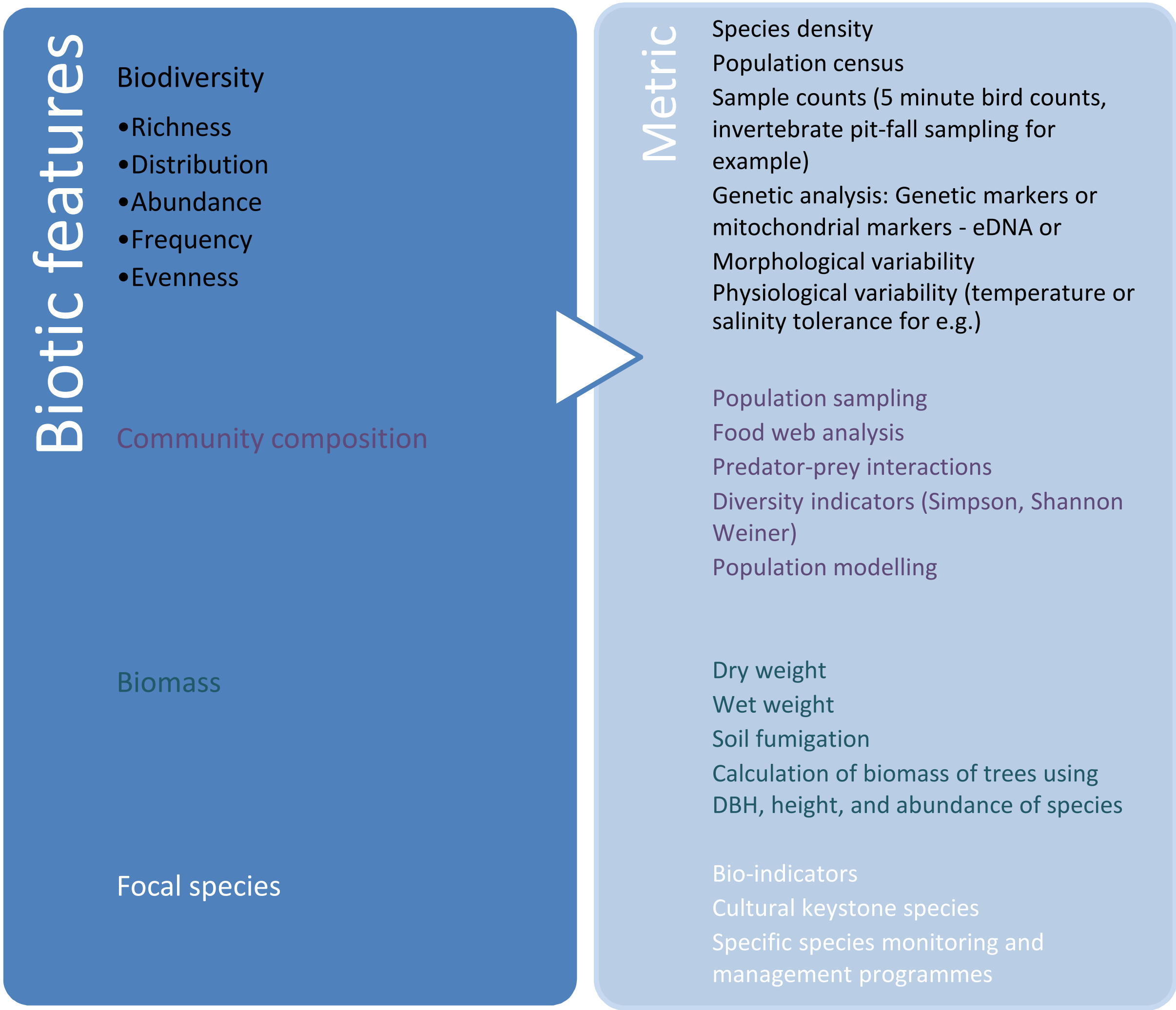
**Figure 9**. Ecological elements: the relationship between ecological structure, ecosystem functions and processes and ecosystem services (adapted from L. Roberts et al., 2015, p. 98). Biotic and abiotic characteristics make up the ecological structure. The ecological structure determines the ecological functions and processes. The processes prescribe the ecosystem services produced.

## Ecosystem structure

The first component in the ecological relationship framework above is Ecological Structure. Ecological Structure consists of the abiotic and biotic properties of the environment, the physical and the biological components (Hernández-Morcillo et al., 2013, p. 438; Johnston et al., 2015). The physical components are the topography, climate, insolation, hydrology, geology, etc. The biotic indicators include biodiversity, biomass, community composition and the presence and biology of focal species, see **Figure 10**. Biodiversity is assessed by counting members of a population or taking a sample count of the population in a specified area or timeframe. Biomass measures the weight or mass of organisms in an ecosystem and is an indicator of growth, photosynthesis and energy conversion. Community composition is a product of the diversity of species in a community, their configuration in a population and their interspecific and intraspecific interactions. Focal species may be important ecologically or culturally and are often the focus of management programmes.

**Figure 10**. The abiotic (physical) and biotic (living) features of ecosystems. The biotic and abiotic features combine to create the structure of the ecosystem.






### Biodiversity

Biodiversity is a product of species abundance, diversity, distribution, richness, evenness, dominance and rarity (Balvanera et al., 2006, p. 1149; Bryan, Raymond, Crossman, & Macdonald, 2010, p. 112). Biodiversity supports redundancy of ecological function, as more than one set of species may provision a functional pathway. Loss of biodiversity has cascading impacts on ecosystem function and services that directly affect society (Balvanera et al., 2014, p. 56). For example, the biodiversity of native wild pollinators is declining globally and commercial honey bees may not be able to compensate for the reduction in wild pollinator services. The resulting shifts in global pollinator networks may impact our food supply (Tylianakis, 2013, p. 1532). Biodiversity is measured using the genetic, behavioural, morphological and physiological diversity of the individuals and species in an ecosystem.

Biodiversity may be directly linked to ecosystem integrity and functional diversity and therefore ecosystem processes/functionality and ultimately economic productivity (Brooks et al., 1998, p. 131; Watkinson & Ormerod, 2001, p. 235).

### Community composition

Assessing community composition involves population modelling. Population modelling involves modelling the fecundity, survival, current population size and the carrying capacity of the land (the amount of land required to support a sustainable population). Such population modelling can inform a variety of important statistics. The Minimum Viable Population (MVP) is the smallest number of individuals that can support a genetically, demographically and stochastically robust, sustainable population. The Ecological Viable Population (EVP) is the smallest population that supports critical ecological functions, processes and relationships. The Harvest Viable Population (HVP) is the level of population abundance that supports recreational or commercial harvest while maintaining critical ecological functions (Tear et al., 2005, p. 838). The ecosystem's carrying capacity, 'K', is the number of individuals that an area of land can support and have the population remain genetically and ecologically viable. These statistics are often important for management and conservation decision-making.

Population modelling can also furnish rarity curves. Rarity curves model the relationship between the economic value of a species (desirability to harvest) and the population size and carrying capacity and can illustrate the threat of decline (risk profile) for that species. Community viability analysis, community sensitivity analysis and network analysis are all novel ways of modelling the strength of ecological interactions and functions that cannot be assessed by focusing on just one species. These analyses simplify complex ecological relationships (Cottee-Jones & Whittaker, 2012, pp. 122-123).

Species lists are the simplest form of biodiversity monitoring. Rapid Biodiversity Assessment uses para-taxonomic units (morphological and functional groups) instead of single species. For example, pollinator diversity and herbivore to carnivore ratios can provide a quick overview of important ecological functions (Obrist & Duelli, 2010, p. 2201). Monitoring biodiversity as a whole, rather than focusing on individual species, may capture more ecological complexity and ecological connections and relationships to better describe ecological health and is likely to be more effective and efficient long-term (Beever, 2006, p. 67). Biodiversity indices provide an 'index of biodiversity' that can be used to measure biodiversity and understand population ecology or compare the similarities between populations. Diversity indices assess species richness and evenness within the community. The three most commonly used diversity indices are described in **Equation 1** below.

The most simple diversity index is species richness or the number of species present (Morris, 2014, p. 3515). The proportional abundance can be incorporated into diversity indices. The Berger-Parker dominance index calculates the proportional abundance of the most abundant species and is the simplest of these indices and it is sensitive to rare species (Morris, 2014, p. 3515; Spanos, Feest, & Petrakis, 2009, p. 58). The Shannon-Wiener and the Simpson's diversity indices calculate richness and abundance and are widely used (S. Buckland et al., 2012, pp. 603-604; Morris, 2014, p. 3515). The Simpson's index is the probability of two randomly selected individuals in a community belonging to the same species and returns an index of '0' if the community contains only one species and '1' when all individuals sampled are all different species. Shannon's index predicts the likelihood of an individual in a community being a member of one species or another based on the entropy the community is experiencing.

Neither of these indices accounts for species that are present but not detected and they may also fail to detect abundance changes if all species are declining at the same rate (S. Buckland et al., 2012, p. 608). Rare species are also difficult to rationalise. Some indices apply weightings to rare species and the Shannon's Evenness Index can provide information on species composition and richness. Simpson's evenness index is the inverse of Simpson's diversity index and is calculated by dividing the Shannon Diversity Index by its maximum (1) (Eurostat, 17/10/2018; Wikkipedia). The Simpson's diversity and evenness indices are sensitive to abundant species (Morris, 2014, p. 3515). The Simpson's index is good at quantifying the difference between sites, while Berger-Parker is the best at differentiating differences resulting from different land uses (Morris, 2014, p. 3522).

**Equation 1.** Shows the three most commonly used diverisity indices.

$$D = Nmax/N$$

### Berger- Parker Index

- Assess the proportional abundance of the most abundant species. Corresponding to a weighted generalised mean
- The total number of individuals in the most abundant species divided by the total number of individuals in all species

$$D = -1 * \sum\left(\left(\frac{n}{N}\right) * ln\left(\frac{n}{N}\right)\right),$$

### Shannon Wiener

- Characterises spp. diversity in a community using abundance and evenness
- -1 multiplied by the sum of the number of individuals in a species divided by the number of species multiplied by the inverse of the number of species and the number of individuals in a species divided by the number of species

$$D = 1 - \left(\frac{\sum n * (n-1)}{N(N-1)}\right)$$

### Simpson Index

- Quantifies the biodiversity of a habitat accounting for spp. richness, abundance, and evenness by calcuating the relative abundance of each species
- Sum the number of individuals of each species multiplied by the number of individuals in each species -1 divided by the total number of species multiplied by the total number of species -1

D= diversity index

n= the number of individuals in a particular species

N= the total number of individuals of all species counted in the sample

Nmax= the total number of species in the most abundant species

## Biomass

Weighing the organic matter of the organisms in a given volume is the simplest measure of biomass and can be done on a small scale. Assessing the change in biomass of forests requires a different approach and can be done by measuring the basal areas of trees. This involves measuring the area covered by every tree in the sample area and calculating the area covered by each species present (Knoepp et al., 2000). There is a calculation for assessing the structural diversity of a forest using diameter at breast height (DHB) and finding the population distribution and skewness (McRoberts, Winter, Chirici, & Lapoint, 2012, p. 301). A natural forest tends to have a reverse J shaped distribution curve with many individuals belonging to a common/abundant species and a small number belonging to an extremely rare or widely distributed species (McRoberts et al., 2012, p. 301).

### Focal Species

Many ecological management programmes revolve around the preservation of a focal species or the habitat for that species. These focal species are species that are important to the ecology or culture of an area. Focal species (or taxa) represent a subset of the community and are a cost-effective and efficient proxy for environmental assessment (Siqueira, Bini, Roque, & Cottenie, 2012, p. 1). There are many ecological concepts relating to focal species and I have outlined them in **Figure 10**. These ecological concepts are not discrete and an umbrella species may also be a keystone species and an ecological engineer. The Keystone species concept was introduced in 1969 by Paine. It describes a species that has a disproportionate influence on the community relative to its abundance and may be critical to the communities' sustainability (Cottee-Jones & Whittaker, 2012, p. 117). A keystone species is a vital component of an ecosystem's function (Cottee-Jones & Whittaker, 2012, p. 118). Elephants are a keystone species on the savannah. Kereru are keystone species that disperse large seeds in the New Zealand forest. Pest species can also be keystone species because of the impact they have on the ecosystem (Cottee-Jones & Whittaker, 2012, p. 120). Focal taxa are groups of species that have similar trophic or niche characteristics, such as a 'guild' (a group of species that exploit the same resource or different resources in similar ways) (McGeogh, 1998, p. 184).

An example of a keystone species which is also an ecological engineer and an umbrella species is the wolf. The re-introduction of the grey wolf (*Canis lupus*) changed the ecosystem function at Yellowstone National Park. Wolf predation caused elk (*Cervus canadensis*) numbers to drop and herds to become more mobile. This resulted in less browse on willows, cottonwoods and aspen, which are now rejuvenating. The willows have stabilised the stream banks, improving the habitat for fish by providing shade and lowering the water temperature. Songbirds and beaver have also increased in these stands. Grizzlies, foxes, magpies and ravens have also benefited. Coyote numbers have dropped by half and they are no longer the top predator. Consequently, the number of voles, mice and small mammals has increased, benefiting the foxes and raptors (Robbins, 2005).

Often focal species are effective indicators of ecological status, such as biodiversity and can be used to extrapolate environmental health over large spatial scales. Indicator species function like gauges, reflecting the abiotic and biotic state of the environment (Billeter et al., 2008, p. 141; Carignan & Villard, 2002, p. 51; Hilty & Merenlender, 2000, p. 186; McGeogh, 1998, pp. 183-184). Bio-indicators reveal changes to habitats, communities, ecosystems, or biodiversity (Rainio & Niemelä, 2003, p. 487). Positive bio-indicators increase when ecological integrity is good and negative bio-indicators increase when they dominate disturbed areas (Carignan & Villard, 2002, pp. 53-54). For example, the higher the biodiversity of invertebrates, the greater the biodiversity and abundance of birds may be (Dugdale & Hutcheson, 1997, p. 15). Using indicator species can reduce the need for intensive sampling when conducting ecological assessments (A. Andersen, Hoffmann, Muller, & Griffiths, 2002, p. 9). New Zealand is often constrained in the use of indicator species because of a lack of national monitoring and paucity of data. We need more long-term data on taxon diversity, ecosystem types, environmental pressures and threat status (Hoare et al., 2010, p. 76). Traditional knowledge may provide important information to identify useful indicator species.

Indicator species are species that are closely linked to ecological functions or processes and their presence may be evidence of that process or function. To be an effective indicator species or taxa, an organism should be taxonomically resolved and have a well-understood (studied) ecology, with clearly defined tolerance levels that are easily correlated to the characteristics of the ecosystem (e.g. range of tolerance of soil pH). The organism should have a rapid, detectable and reliable response to perturbation (Carignan & Villard, 2002, p. 52). Body size, habitat specialisation and ecological compatibility are all predictors of good indicators (Manne & Williams, 2003, p. 296). Ideally, an indicator species should have a wide distribution in the habitat (covering the ecosystem or geographic area of interest), a small home range, limited mobility (not be a migratory species), a small body size, rapid generation time, low population fluctuations, be easily detectable and have a specialised ecological niche in a low or medium trophic level (Carignan & Villard, 2002, p. 52). Small bodied organisms may be affected more by local environmental changes. Specialists may be sensitive to the loss of specific conditions that characterise their niche. Members of high trophic levels are usually top predators with prey population influences, have been subject to human interference pressures and are usually low in number and widely distributed (Hilty & Merenlender, 2000, p. 186).

Indicator species should come from all major functional guilds: producers, herbivores, carnivores and decomposers to ensure the entirety of ecological function is represented (Carignan & Villard, 2002, p. 50).

There are five types of bio-indicators:

- Sentinels - sensitive early warning organisms
- Detectors - species that show a response by changing behaviour, mortality, or population structure
- Exploiters - their presence indicates disturbance or pollution
- Accumulators - organisms that accumulate toxins (often tolerant of pollution)
- Bioassay organisms - can be subjected to laboratory tests on toxin/pollutant levels (McGeogh, 1998, p. 183; Ti Kipa Kepa Brian Morgan, 2010, p. 247)

Invertebrates are good bio-indicators because of their short generation times, high density, high diversity, abundance and sensitivity to environmental changes (Bowie & Frampton, 2004, p. 34). Surveys can compare the faunal composition, abundance, richness, functional group representation, rare species presence and species demography (e.g. size, life cycle stage, etc.). Beetles, spiders, grasshoppers and moths have all been used successfully as bio-indicators (A. N. Andersen, Fisher, Hoffmann, Read, & Richards, 2004, p. 88; Rainio & Niemelä, 2003, p. 492). Large predatory spiders are good indicators of food web linkages, while earthworms are good indicators of decomposition. Bees are often used as bio-indicators because they show a significant response to habitat diversity and are important for our food security. According to JM, one of my interviewees, insects are the primary ecological health indicator. Stink beetles/blue beetles (kehakeha) (*Plocamostethus planiusculus*) are particularly important indicator species.

Invertebrate fauna remains abundant and diverse in a fragmented landscape but with altered community composition and so are ideal for assessing the functional implications of fragmentation (Dodd et al., 2011, p. 83; Rainio & Niemelä, 2003, pp. 487-502). Detritivores dominate in forest fragments and pastures, while herbivores are poorly represented (R. J. Harris & Burns, 2000, p. 57; Hutcheson & Kimberley, 1999, p. 76). More indigenous beetle species were found in forests, although pasture had a higher overall diversity because this habitat contains more introduced species. The forest/pasture margin had the highest diversity of all because the diversity calculation included both pasture and forest species and included all the introduced species found in the pasture. Forest fragments and dispersal corridors are important for preserving the biodiversity of native species that primarily live in forest habitats. (Crisp, Dickinson, & Gibbs, 1998, p. 209; R. J. Harris & Burns, 2000, pp. 57, 62, 63).

The database GLOBENET was developed for beetle data in the Northern Hemisphere (A. N. Andersen et al., 2004, p. 88). Insect species can be hard to differentiate, so it may be better to use entire taxa or functional groups (Dugdale & Hutcheson, 1997, p. 7; Hutcheson & Kimberley, 1999, p. 70; K. S. Williams, 1993, p. 113). The Eco-morphological index (EMI) is a way of using terrestrial invertebrates in a similar way to the MCI aquatic invertebrate index. Like aquatic invertebrates, soil invertebrates have different sensitivities to land management practices. The invertebrates in the selected taxa are scored 1-20 according to their tolerance to different soil types, disturbance and pollution. The scores are added to calculate an index that characterises the terrestrial invertebrate community in a similar way to the Aquatic Macroinvertebrate Index (Parisi et al., 2005, p. 323).

Ants make good bio-indicators because they are widely distributed, easy to sample, respond to environmental variation rapidly and have diverse trophic functions critical to ecological functions (Underwood & Fisher, 2006, p. 167). Ants are sampled using nest mapping, hand collection, litter and soil sampling and pitfall trapping (Lobry de Bruyn, 1999, p. 431). Ants are more biodiverse in forests and are significantly affected by tillage, agrichemicals, microclimate conditions and any reduction in litter and organic matter (Lobry de Bruyn, 1999, p. 428). Ants have been used successfully as bio-indicators on mining site restorations in Australia and in rainforest health assessments by building a strong picture of ant diversity and functional responses to disturbance (A. Andersen et al., 2002, p. 9; A. N. Andersen et al., 2004). Ant biodiversity and distribution, combined with ecological condition and land use, have been used to create a Biodiversity Integrity Index (A. N. Andersen et al., 2004, p. 90).

**Figure 10**. Focal species concepts.

| | |
|---|---|
| Indicator species | • Are statistically significantly associated with habitats or ecological states |
| Keystone species | • Have a disproportionately large impact on ecological function relative to their numerical dominance |
| Ecological engineers | • Have large impacts on the structure of the habitat or ecosystem (e.g. earthworm in soils, Asian elephant in the gap-phase dynamics of tropical forests) |
| Umbrella species | • Are selected for conservation because their ecological requirements encompass those of many other species |
| Link species | • Provide critical links to energy flow in communities (e.g. species that are abundant nodes in food webs transfer energy across trophic levels, key pollinators, etc.) |
| Flagship / Special interest species | • Flagship species such as the kakapo (*Strigops habroptilus*) or the giant panda (*Ailuropoda melanoleuca*) are iconic species that can serve as ambassadors or mascots of conservation programmes |
| Foundation species | • Controls the population size of many species and community dynamics through regulating important ecological processes such as production. Usually are at low trophic levels as opposed to keystone species which may be top predators (Dale & Beyeler, 2001, p. 8) |

The main types of focal species described by ecologists Cottee-Jones and Whittaker (2012, p. 123)

### Cultural keystone species

Cultural keystone species are a type of focal species particularly relevant to Indigenous communities. A species may become a cultural keystone species because it is valued as an important food or medicinal resource or because it has relevance to a religious belief or practice. Communities may begin to identify themselves with that species (Garibaldi & Turner, 2004). Cristancho and Vining (2004, pp. 158-159), listed the following attributes as indicative of a cultural keystone species:

- The origin of the species is tied to the myths, ancestors, or the origin of the culture
- The species is central to cultural knowledge
- The species is indispensable in major rituals
- The species is integral to the basic needs or activities of the community
- The species has significant spiritual or religious value for the culture
- The species exists physically within the community's territory
- The cultural group refers to the species as especially important to them

The value of cultural keystone species as indicators for Indigenous peoples' wellbeing may be tremendous and losing them may have dire social, economic and ecological implications. The identification and assessment of these species should be prioritised (Cristancho & Vining, 2004). For example, if the Letuama people were not able to access their traditional coca *(Erythroxylum spp.)*, related practices' (Cristancho & Vining, 2004, p. 158), currently under threat from non-Indigenous drug dealers and mandated government institutions, their cultural wellbeing may suffer. Coca is a keystone species plant for multiple reasons and understanding its relevance to the community and its function as an indicator species is important for the preservation of the species, the ecology and the culture (Cristancho & Vining, 2004, p. 158). Many cultures have cultural keystone species (see **Table 11** below for examples of important cultural keystone species from around the globe). The social investment in management areas set aside for the preservation or cultivation of taonga species and the resource investment is another important ecological indicator.

> By chewing the coca powder, Indigenous people offer to their Masters of Nature something that pleases them in order to get their permission to extract plants or animals. Their offerings also serve to prevent negative

consequences…..Coca is represented as having at least five critical uses for the Letuama culture, as is demonstrated by the following quotes from the narrative data:

- As CURRENCY for negotiating with nature
- As a DEFENSE from natural threats
- As an ENHANCER of the power of thought
- As MEDIATOR in learning and socialization
- As a PARTNER (anthropomorphism of Coca) (Cristancho & Vining, 2004, pp. 157-158)

**Table 11. Cultural keystone species**.

| Examples of cultural keystone species from around the world |
|---|
| •Laurel (*Laurus nobilis*) in ancient Rome and Greece<br>•Fleur-de-lis (*Iris graminea*) in France<br>•The cow (*Bos taurus*) and hemp (*Cannabis sativa*) in India<br>•The poppy (*Papaver sp.*) in China<br>•Betel (*Piper betle*) in all Asia<br>•Belladonna (*Hippeastrum sp.*), peyote (*Lophophora williamsii*), and the date (*Phoenix dactylifera*) in Central America<br>•Pigs for the Tsembaga of New Guinea<br>•Chilean wine palm (*Jubalea chilensis*) for early Easter Islanders<br>•Ayahuascavine (*Banisteriopsis caapi*) for the Quichua from Ecuador and Peru<br>•Corn (*Zea mays*) for the Maya and the Hopi<br>•*Anadenanthera sp.* for the Yanomamo Indians from Venezuela<br>•The edible red laver seaweed *(Porphyra abbottiae),* western red-cedar (*Thuja plicata*), five species of salmon *(Oncorhynchus spp.)*, cockles (*Clinocardium uttallii*), and abalone *(Haliotis kamtschatkana)* for the Gitga'at, a Tsimshian community in Hartley Bay, British Columbia<br>•Ahakeye or bush plum (*canthium attenuatum)* for the Aboriginals of Australia. The plant supports the emu and bustard which are also important ecological and cultural keystone species |

This table lists a sample of cultural keystone species from cultures around the globe. It is not a definitive list (Cristancho & Vining, 2004, p. 154; Garibaldi & Turner, 2004; Walsh et al., 2013, p. 9).

Cultural keystone species are culture specific keystone species, Māori may identify these as taonga species. Many of our taonga species are wetland species. Wetlands were like the supermarkets of the day and wetlands themselves are taonga for Māori. The importance of wetlands and awa (waterways) to Māori is evident in the close link the tangata whenua historically have to them (Dymond, 2013, p. 196). Some of these taonga species are:

- Kauri (*Agathis australis*)
- Harakeke (NZ flax: *Phormium tenax*)
- Kuta (Bamboo spike sedge)
- Raupō (*Typha orientalis*)
- Mānuka (*Leptospermum scoparium*)
- Tuna (eels: *Anguilla* spp.)
- Sphagnum moss (Dymond, 2013, p. 194)

To New Zealanders, these species form part of our cultural identity. We even call ourselves Kiwis. Many of us carry a memory of our favourite childhood beach framed by the branches of a pohutukawa red with flowers. We all associate Aotearoa with paua (*Haliotis spp*.), kina (*Evechinus chloroticus*), tī kōuka (*Cordyline australis*) and kauri, alongside sheep (*Ovis aries*), pine trees and possums (*Trichosurus vulpecula*). Tuna are a particularly important keystone species culturally and ecologically and feature prominently in Māori traditional knowledge. They are apex predators, feature in many legends and have a commercial value and an intrinsic value as endemic species (L. Roberts et al., 2015, p. 44). Much of this valuable bush lore has been lost as urbanisation of the population has occurred. Privatisation of land prevented access to historic food collection areas and deforestation, agricultural intensification and wetland draining removed and degraded habitats. The result is that many indigenous species are listed as threatened according to the New Zealand Threat classification system (Molloy, 1959) and continued cultural harvesting was deemed untenable by the authorities.

PH, a Rangitāne O Manawatū kaitiaki, identified what he views as some key cultural species for his iwi. These key species include tuna (eel), pātiki (flounder), kātaha (yellow-eyed mullet *Aldrichetta forsteri*), hopu grey mullet (*Mugil cephalus*) and titi (*Ardenna grisea*). Traditional flax harvest in the area has ceased because of the draining of the wetlands. PH said the iwi postulated that this draining occurred naturally during the last sea-level rise event and as the land rose the birds just adapted and flew a bit further. Titi used to nest in the Ruahine ranges and may still nest in the Tararua ranges. Northern Royal Albatross (*Diomedea sanfordi*) historically nested on Ruapehu, hence the name of the Turoa ski field. According to PH, taniwha such as Whangaimokopuna and Peketahi are also important kaitiaki for Manawatū iwi. Pest species are also important to iwi and can become important taonga species. PH's iwi has classified cattle as a pest species under their tikanga. They also use the meat from the pest samba deer that live in a block of land retuned as part of their Treaty settlement and they have effectively substituted eel for deer meat. In this case, a pest has become a resource, however, its environmental damage has not been mitigated and its benefit to the iwi and environmental damage should be carefully managed. Since their introduction, pigs and deer have become a valuable resource for many Māori whanau.

TM, a kaitiaki of Wellington-based Taranaki iwi listed tuatara (*Sphenodon punctatus*), kākāriki (*Cyanoramphus novaezelandiae*), kororā (little blue penguins, *Eudyptula minor*) and the Cook Strait giant weta (*Deinacrida rugosae*) as taonga species for her iwi. Taupata is a taonga plant species. The berries are fed to the sheep and are made into relish, alcohol and syrup. Taonga species all have their own traits that kaitiaki can use to assess the health of the species or the environment. According to TM, and I paraphrase, 'little blue penguins are stoic and will make themselves available to you if they are feeling OK. The kākāriki are playful. If you don't hear or see them playing then something is wrong. The tuatara are meditators. They are gurus and are just chill. If they react they are not happy. Some tuatara are 'rock stars' and like attention but others don't. Weka may be reintroduced to Matiu in the future and taste fantastic'.

## Functional diversity and ecological Integrity

Functional diversity is the equivalent of species diversity but for morphological or behavioural traits or trait categories and is often a better indicator of ecosystem function then species diversity (see **Figure 11**) (Schleuter, Daufresne, Massol, & Argillier, 2010, pp. 469-470). Functional diversity may determine an ecosystem's response to stress or pressures. Functional richness may be gauged by the depth of that functional diversity. Indicators of functional diversity include niche filling, dispersal, food webs, trophic and guild interactions, habitat occupancy, indigenous dominance, population structure and the distribution of resident species. Functional richness may indicate niche space occupation, revealing the condition of vital ecological functions such as pollination and predation (Schleuter et al., 2010, p. 471). Functional diversity is usually positively correlated with species diversity (Schleuter et al., 2010, pp. 470-471). Food web and trophic interaction analysis may be used to measure functional diversity (Andreasen et al., 2001, p. 26). Mapping the spatial distributions and understanding the demographics of species may indicate the habitats functional diversity. Functional richness/diversity is particularly important if the top predators or pollinators are missing from a community.

Ecological integrity may be conceptually related to ecosystem health and an outcome of ecosystem structure (see **Figure 11**). I have considered ecological integrity alongside functional diversity because, although it helps generate ecosystem functions and processes, it is not in itself a function or process. Ecological integrity represents the ecosystem's extent, distribution, complexity, representativeness, richness and composition. The indicators of ecological integrity are described in The Department of Conservation's (DoC) Index of Biological Integrity. DoC defines the integrity of New Zealand's significant natural areas or quality habitats using the following indicators: habitat representativeness, distribution, naturalness, size, shape, buffer size and shape, rarity and long-term viability (M. Davis et al., 2016, p. 18). In summary and including the DoC indicators, the indicators of ecological integrity include the habitat's spatial characteristics (size and shape), the location and connectivity of habitat fragments, habitat rarity, heterogeneity and persistence over time. Ecological integrity may be most effectively assessed by looking at the spatial characteristics of the ecosystems and mapping habitat types, extent and studying their geographic characteristics spatiotemporally. The biggest challenge to ecological integrity may be habitat fragmentation and therefore habitat extent.

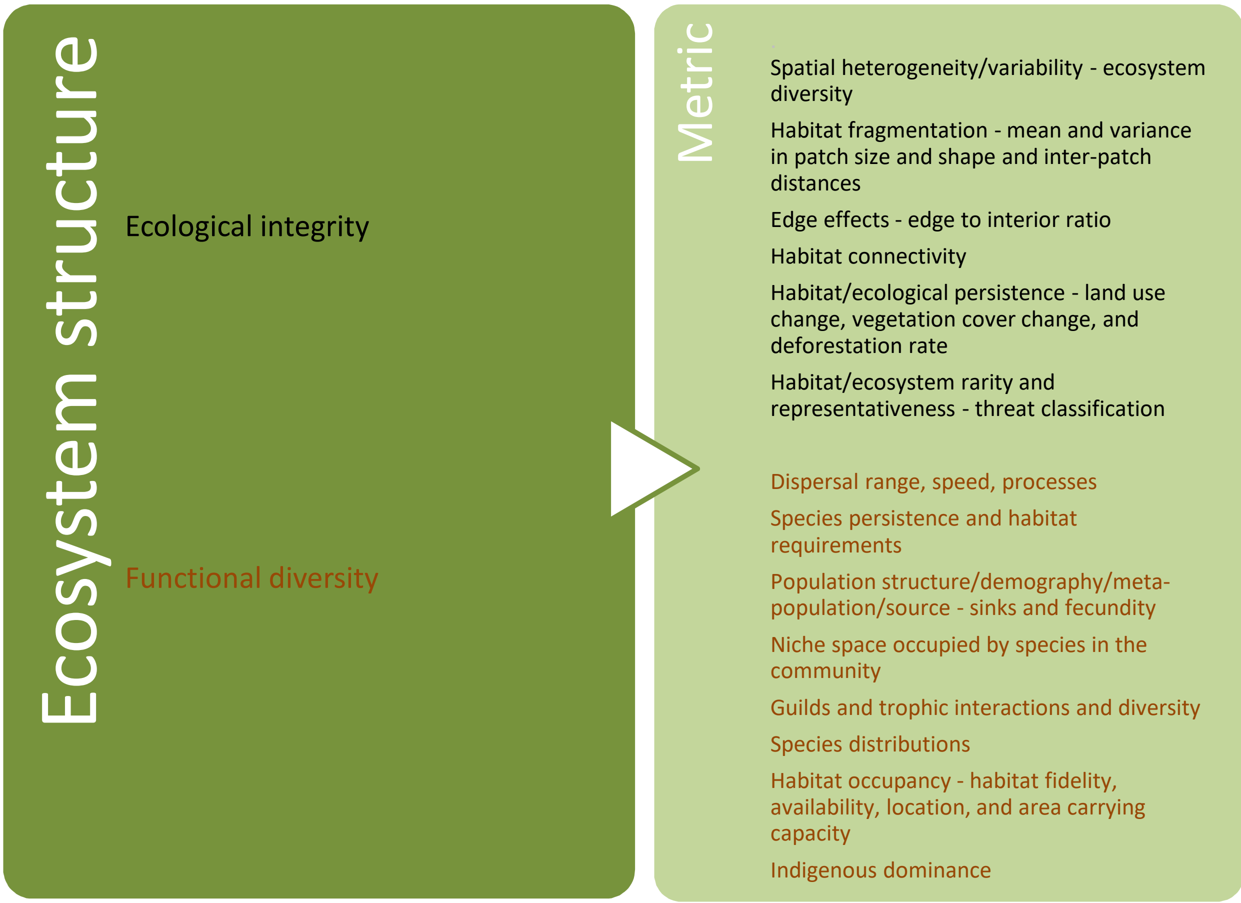



**Figure 11.** Ecosystem structure (created from the biotic and abiotic components) can be described as ecological integrity and functional diversity. The metrics that measure ecological integrity and diversity are on the right. Adapted from Andreasen et al. (2001, p. 26); Carswell et al. (2013, p. 531); Dale and Polasky (2007, p. 228).

## Ecosystem functions and processes

Ecosystem processes include the transfer of energy, cycling of nutrients, gas exchange, primary production, water-cycling and soil formation. Arguably the ultimate and most important ecosystem function is the provisioning of a stable, resilient, quality habitat (Brooks et al., 1998, p. 131). The quality of an ecosystem is often relative to the species within it. A quality habitat for a house sparrow (*Passer domesticus*) will be different than that required for a kokako (*Callaeas spp.*) (Garbisu et al., 2011, p. 2; Toevs et al., 2011, p. 15).

Ecosystem function and process indicators can be divided into the ecosystems they service, terrestrial (forest), aquatic and soil (see **Figure 12**). Since the forest is the domain of Tāne

Mahuta, I have linked forest ecosystem functions and processes to him. I have identified ecological indicators for different ecosystems by the atua that kaitiaki that ecosystem: Tinirau for water, Tāne Mahuta for forests, Haumia tiketike for mahinga kai and rongoā, Tūmatauenga for cultural activity and Tāwhirimatea for the climate and atmosphere. G Harmsworth and Shaun Awatere (2013, p. 4); and G. R. Harmsworth and Pauling (2013) linked departmental atua to ecosystems and I have followed their example. Linking the atua to the ecological habitats was valuable because it introduces Māori cosmology, provides a framework to connect the ecological indicators holistically and inclusively, reflects ecological functions and processes and promotes kaitiakitanga of ecosystems. It also enables relationships to be forged between He Kete Hauora Taiao and the frameworks described in the literature mentioned. Comparing complementary frameworks may also allow data cross-pollination.

The important ecological processes and functions in the domain of Tāne Mahuta include forest structure (canopy height and tier structure), forest regeneration and succession, trophic dynamics, faunal population dynamics and landscape spatiotemporal patterns (dispersal, migration, extinctions including local) (Dale, 1997, p. 291). Tinirau is the God of freshwater habitats and the related ecological functions include the regulating of water chemistry, the removal of pollutants (phosphates, nitrates and faecal coliforms), the provision of suitable, quality habitat for aquatic organisms (supporting aquatic biodiversity), the regulation of water flow and the movement of sediment (water clarity). I have included riparian habitat provision in with aquatic habitat because the extent and composition of the riparian zone impacts the aquatic habitat rather than the terrestrial one. Riparian habitat indicators include the vegetation, providing shading that lowers the water temperature, shelter and food for aquatic organisms, regulation of the hydrology (slows overland water flow), and reducing the sediment load (prevents bank erosion and can prevent the inflow of sediment from the land). The processes and functions occurring in soil ecosystems include regulating soil chemistry and structure (including influencing groundwater hydrology), nutrient cycling, the removal of pollutants (phosphates, nitrates and faecal coliforms), the maintenance of soil fertility (decomposition) and the support of soil biodiversity (micro and macro).

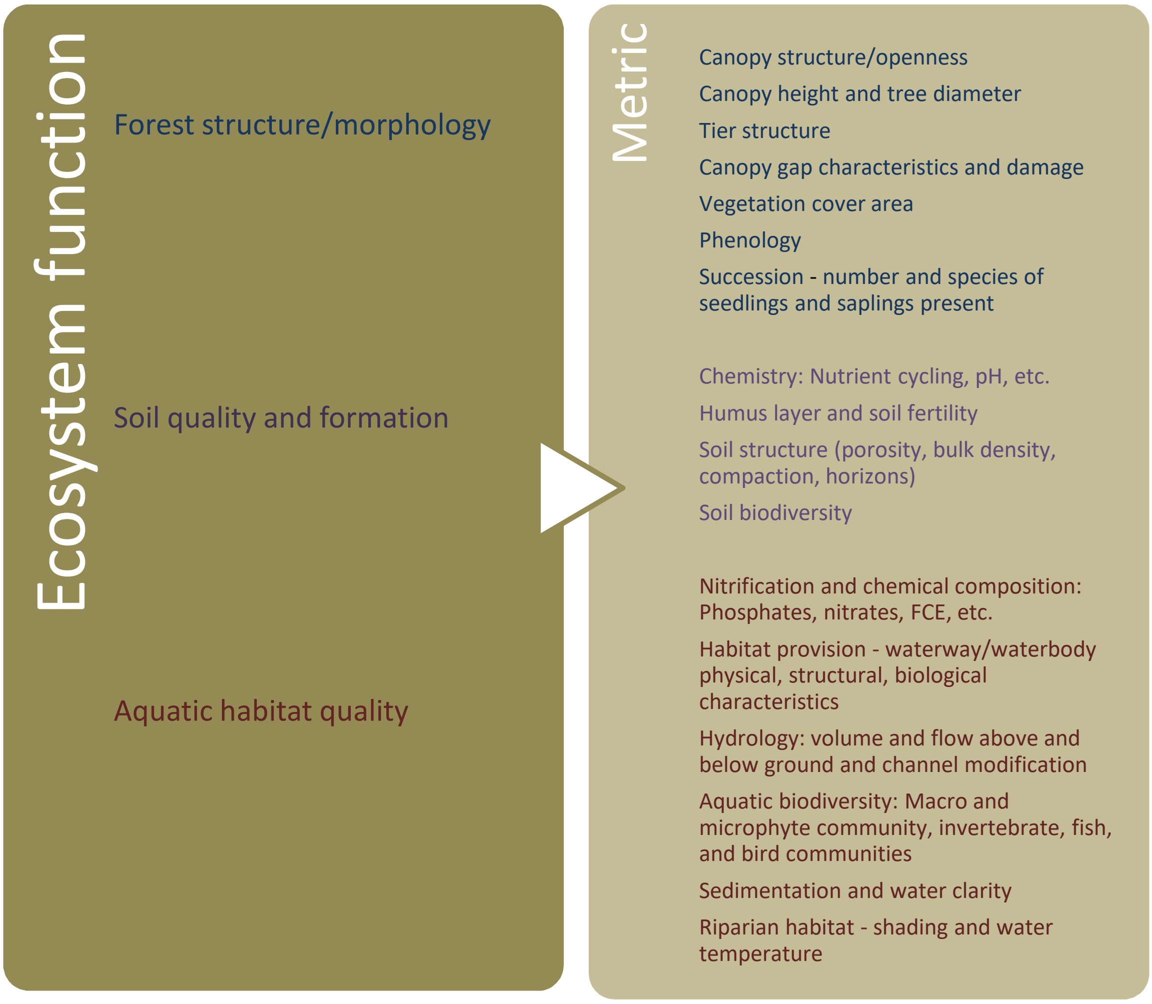



**Figure 12.** Lists the three habitats that form terrestrial ecosystems and the metrics that can be applied to measure the functions and processes occurring in each.

### Ecosystem services

The definition of Ecosystem service/s (ES) is a set/s of ecosystem functions that humans derive benefit from (Hermann et al., 2011, p. 7). ES are generated in all habitats, from forests to deserts and even urban street trees, parks, lawns, etc. (Bolund & Hunhammar, 1999, p. 293). ES connect human welfare to ecosystems (Costanza, 2008, p. 350; Fisher & Kerry Turner, 2008, pp. 1167-1168). Who benefits, by how much and what happens to their benefits over time are all important issues for overall societal welfare. The economic value of an ecosystem and its services is often employed as an assessment framework for resource management. ES that are stored in ecosystems are defined as ecosystem stock (Geijzendorffer & Roche, 2013, p. 149). Ecosystem hotspots produce and export benefits and tend to be biodiversity hotspots with high species richness and diversity (Egoh, Reyers, Rouget, Bode, & Richardson, 2009, p. 553). The value of ecosystem services is multiple and cumulative and transcends geopolitical and physical boundaries (Albert, Von Haaren, Othengrafen, Krätzig, & Saathoff, 2015, p. 3). For example, when valuing the water of a stream for salmon (*Salmo* spp. and *Oncorhynchus* spp.), the value of the salmon to the grizzlies (*Ursus arctos* ssp.) may also be important (S. Farber et al., 2006, pp. 124-125). In this section, I will explore ecosystem services and how they are used in resource management and to value the environment economically.

There are four categories of ecosystem services: Supporting, Provisioning, Regulating and Cultural (see **Figure 13**) (de Bello et al., 2010, p. 2881). Supporting services underpin basic ecosystem functions that support life, providing the necessities of life and the physical matrix on which life depends. Supporting services support the other ecosystem service categories (Golubiewski, 2012, p. 9). Therefore, I view supporting services as analogous to the ecosystem functions and processes described earlier and outlined previously and I have treated them as such. Provisioning services are products obtained from the ecosystem. Regulating services regulate ecosystem processes, such as water flow and nutrient cycling. Cultural services are humanity's non-material benefits, such as recreational, spiritual and aesthetic pleasure, derived from the ecosystem (Ash, 2010, p. XI; de Bello et al., 2010, p. 2881). Ecosystem services are usually viewed from an anthropocentric standpoint and mostly include the goods and services that satisfy human needs, either directly or indirectly (Hermann et al., 2011, p. 7; van Oudenhoven, Petz, Alkemade, Hein, & de Groot, 2012, p. 113).

Provisioning ecosystem services produce humanity's raw materials and form our natural capital stock of food, wood, fibre, bio-chemicals, biocontrol and genetic capital. This is the best-understood group of ecosystem services because the products have a market value (Ghaley, Sandhu, & Porter, 2015). Regulating services regulate the processes and functions engendered by the supporting services. Regulating services maintain the equilibrium, rate and intensity of ecological processes, removing pollution and mitigating the impact of pressures and disturbances. For example, good vegetation cover and riparian strips improve water quality by reducing contaminants such as E-Coli, filtering excess nutrients, reducing water speed and physically stabilising the soils (Dymond, Serezat, Ausseil, & Muirhead, 2016, p. 1897; McAlpine & Wotton, 2009, pp. 12, 17). Another example is forests. Forests improve air quality and can remove 15 tonnes per hectare or more of particulates from the atmosphere per year (Bolund & Hunhammar, 1999, pp. 295-296). Forests provide a habitat for beneficial insects, providing natural biocontrol and pollination services (Kadykalo, 2013, p. 76; McAlpine & Wotton, 2009, pp. 24,27). Forests also provide carbon sequestration. The sequestration rate is a function of tree density, the volume of carbon stored (biomass), metabolic rate and leaf area (A. Dawson, 2010, p. 60).

Cultural ES relate to socio-cultural wellbeing and spiritual fulfilment (Häyhä & Franzese, 2014, p. 126). Cultural ES may provide a sense of belonging and identity. They may locate us politically, geographically, economically and physically, defining where we live and socialise and providing us with our heritage, identity and learning opportunities (Bryan et al., 2010, p. 115; Hernández-Morcillo et al., 2013, p. 435; Wiersum, 1997, p. 8). Identifying the location and value of Cultural ES and mapping them may help identify risk areas and help define management and monitoring priorities (W. Allen et al., 2009, p. 1; Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013, p. 118). It is difficult to quantify socioecological systems and therefore they are hard to value and integrate into planning and management (K. Chan, M. A. et al., 2012, p. 744). Cultural ES valuations are usually based on social preference (Felipe-Lucia, Comín, & Escalera-Reyes, 2015, p. 308).

Cultural ecosystem services may define our cultural landscape and our wellbeing. Our cultural landscape links our social values and perceptions to the landscape and its features. Cultural landscapes spatially depict our relationships with the land, our cultural identity, historic use of the land and our special places (spiritual or cultural). It defines how we manage and use the land for food production and housing and how we meet our recreational, spiritual, emotional, educational and therapeutic requirements (G. Brown & Weber, 2012, p. 318). Our cultural landscapes depict our values, perceptions, heritage and the legacy we leave for the future environmentally, economically, culturally and socially (G. Brown & Weber, 2012, p. 318). For example, PH, a Rangitāne O Manawatū kaitiaki, has identified and mapped more than 700 culturally important sites covering 440,000 ha of land using GIS. One of these sites, Motu O Poutoa, is a wāhi tapu and for 800 years was an important defensive site. It was abandoned in 1925 after a fire and in 1975, six meters were taken off the top for a bridge onramp. From the top you could once see the entire rohe.

## Ecosystem services

### Supporting

Soil formation
Life support/gas exchange
Nutrient cycling
Primary production
- Photosynthesis
- Biomass

Water cycling
- Evapotranspiration
- Precipitation

Habitat provision
- Shape
- Size
- Connectivity
- Legal protection
- Quality

### Provisioning
(materials, nutrition, and energy)

Food - crop yield
Fibre
Fuel
Raw materials
Genetic resources
Biochemical resources
Freshwater (volume)

### Regulating
(flow, physical environment, biotic environment)

Air quality & Pollution control
Particle removal
Climate & CO2 sequestration
Temperature regulation
Soil quality
- Soil fertility
- Soil bulk density
- Soil nutrients

Water (storage and flow)
Infiltration rate
Erosion control
Water purification/waste treatment
Disease regulation
Biocontrol
Pollination
Natural hazards disturbance regulation

### Cultural
(symbolic, intellectual, and experiential)

Spiritual/inspirational
Heritage
Identity
Belonging
Recreation and tourism
Aesthetic
Wellbeing
- Noise reduction

Education
Information
Knowledge systems
Existence

**Figure 13.** Shows ecosystem service categories of supporting (supporting the other classes of ecosystem services), provisioning (providing food, energy and raw materials), regulating (regulating environmental processes), and cultural (social, spiritual and wellbeing) (De Groot, Wilson, & Boumans, 2002, p. 395; Dymond, 2013, p. 75; Haines-Young & Potschin, 2011, pp. 1-6).

Below are the Indicators for provisioning, regulating and cultural ecosystem services and the metrics that may be used to measure them. Cultural services and their indicators, are particularly important for Indigenous people. I have sub-grouped indicators for ecosystem services into two groups (see **Figure 14** and **Figure 15**). I have combined provisioning and regulating indicators in one box and the cultural indicators in a separate box. This was done to reflect the extent and importance of cultural indicators in He Kete Hauora Taiao. Social/cultural indicators are a function of societal wellbeing as well as ecological health (D. King et al., 2008, p. 385). The cultural ecosystem services indicators can themselves be divided into two groups; cultural landscape indicators and socioeconomic indicators. The cultural landscape indicators include recreational use, culturally important sites and the use of Māori place names (nomenclature) among others. The socioeconomic indicators consisting of built and human capital, tenure, management and social boundaries, etc.

Bundling ES can help identify groupings with similar drivers, making management more effective. The trade-off is a reduced assessment complexity (E. M. Bennett, Peterson, & Gordon, 2009, p. 1401; Deal, Cochran, & LaRocco, 2012, p. 74). Provisioning and regulating services can be aggregated into six 'services' and four 'goods' listed below (see **Table 12**). Bundling ES effectively condenses multiple concurrent ecosystem functions and processes into a single index (Hermann et al., 2011, p. 21). The ES goods can be easily valued on the market. The services not so easily.

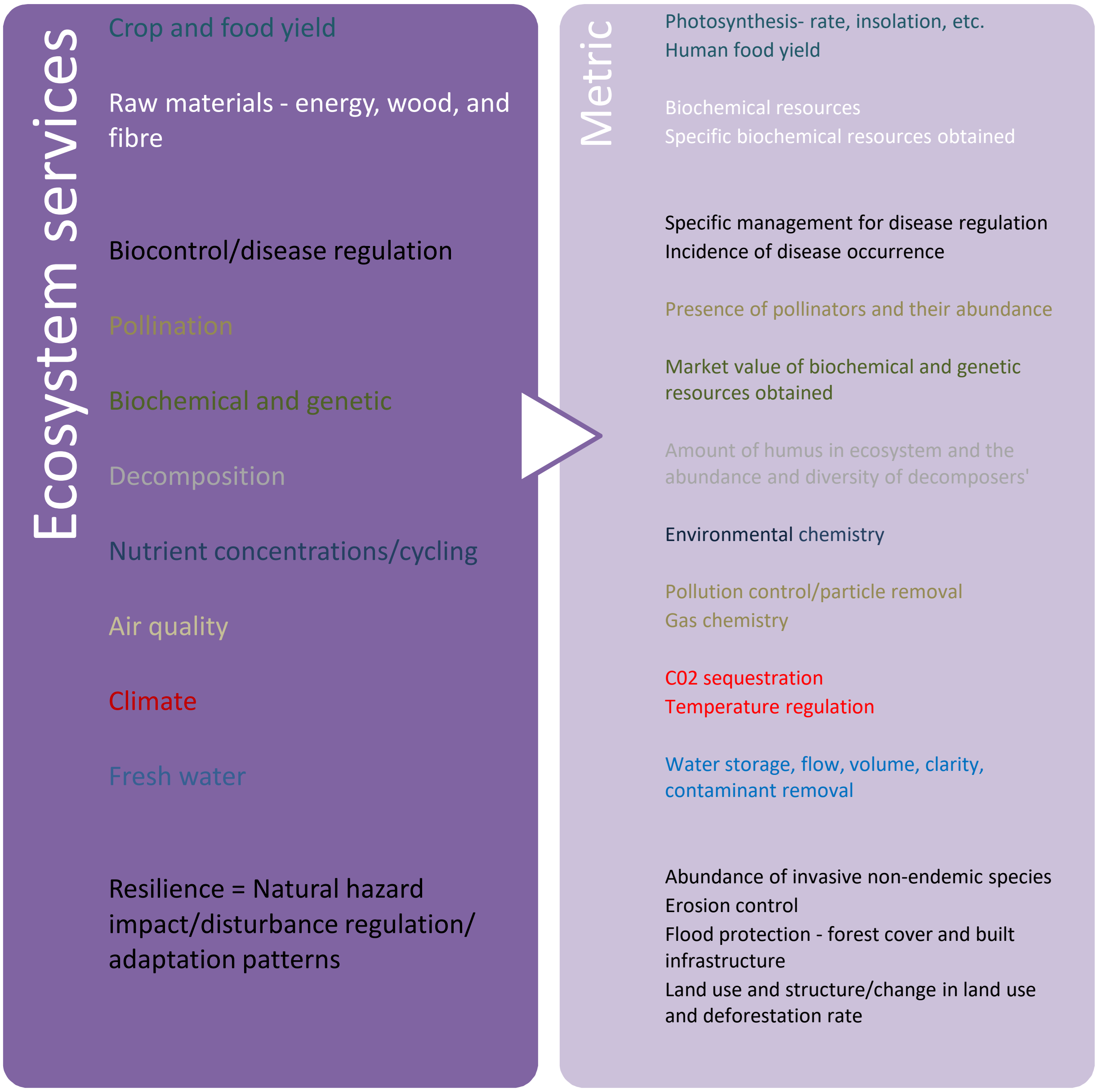



**Figure 14**. Describes the indicators for provisioning and regulating ecosystem and the metrics used to measure them.

**Figure 15** Describes the cultural ecosystem services and the metrics used to measure them.

**Social/ Cultural**

- Spiritual
- Heritage
- Identity
- Belonging
- Recreation and tourism
- Inspiration
- Aesthetic
- Wellbeing - e.g. noise reduction
- Education
- Information
- Knowledge systems
- Importance/value (e.g. cultural)

**Metric**

- Amount and importance of nomenclature relating to the area, site, or biota
- Built capital (infrastructure)
- Legal Protection area/type and rate
- Number of special sites identified
- Number of visitors
- Cultural importance
- Number of artworks depicting the site
- Number of stories or tails relating to sites
- Number of taniwha in the area
- Number of people working in the area
- Number of research investigations undertaken in the area
- Medicinal plants located in the area
- Amount of noise reduction achieved
- Historical reference to the area
- Amount of cultural knowledge relating to the place
- The number and identity of people with connections to the land

**Services:**

- Soil formation
- Gas regulation
- Climate regulation
- Nutrient cycling
- Disturbance regulation
- Waste assimilation

**Goods**

- Water
- Harvested organic mater
- Mined ores
- Extracted fossil fuel (Boumans et al., 2002, p. 532)

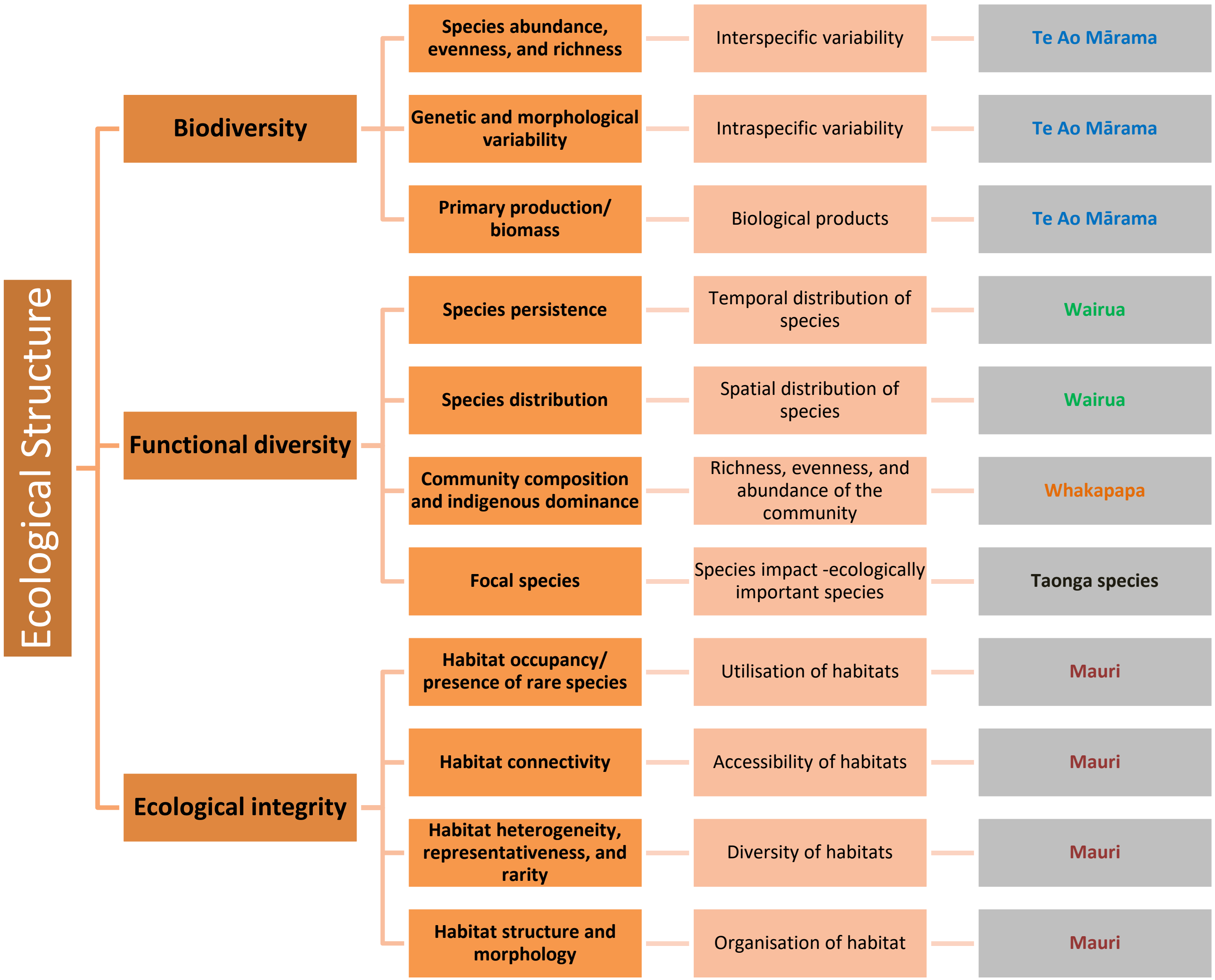
**Table 12.** Lists the seven ways ecosystem services and the four ways ecological goods can be bundled.

## Linking ariā and ecological elements

The ariā are linked to the ecological scientific indicators through ecological concepts. The ariā have been illustrated in the figures below. **Figure 16** shows the āria linkages to ecological structure. **Figure 17** shows the āria linkages to ecological functions and processes. **Figure 18** shows the āria linkages to eco-services. The ariā have been linked to the ecological elements that they best characterise. These ecological concepts have then been broken down into their constituent indicators and the metrics used to assess them.

The first set of ecological elements relate to ecological structure. Ecological structure may be a product of biodiversity, ecological integrity and functional diversity. Biodiversity may be a function of the biological, genetic and morphological diversity and abundance. Ecological integrity may refer to the spatial arrangement of habitats and ecosystems in the landscape, the way species occupy and move through landscapes, the diversity of habitats in the landscape and the physical structure of the available habitats. Functional diversity may be defined as the spatial and temporal distribution of species in the landscape, the composition of the community created by the movement of species over time and space and the presence of focal species or rare species. The second ecological concept represents ecological functions and processes occurring in the forests, waterways, atmosphere and soils. These functions and processes are the natural cycles of nutrients, gasses and hydrology, which generate and maintain the integrity of the habitats in the landscape. The third set of ecological concepts are ecological services. Ecological services provide the things we consume, the things that regulate our environment, protecting us and the things that provide our cultural and social wellbeing.

**Figure 16.** The ecological concepts that constitute Ecological Structure are Biodiversity, Functional Diversity and Ecological Integrity. These three ecological functions are shown along with the indicators that define them. The pale orange boxes contain a brief description of the ecological principle represented by the indicator. The grey boxes show the ariā that could best characterise the ecological indicator and therefore define the ecological concept.



Ecological Structure
Biodiversity
Functional diversity
Ecological integrity
Species abundance, evenness, and richness
Interspecific variability
Te Ao Mārama
Genetic and morphological variability
Intraspecific variability
Te Ao Mārama
Primary production/ biomass
Biological products
Te Ao Mārama
Species persistence
Temporal distribution of species
Wairua
Species distribution
Spatial distribution of species
Wairua
Community composition and indigenous dominance
Richness, evenness, and abundance of the community
Whakapapa
Focal species
Species impact -ecologically important species
Taonga species
Habitat occupancy/ presence of rare species
Utilisation of habitats
Mauri
Habitat connectivity
Accessibility of habitats
Mauri
Habitat heterogeneity, representativeness, and rarity
Diversity of habitats
Mauri
Habitat structure and morphology
Organisation of habitat
Mauri

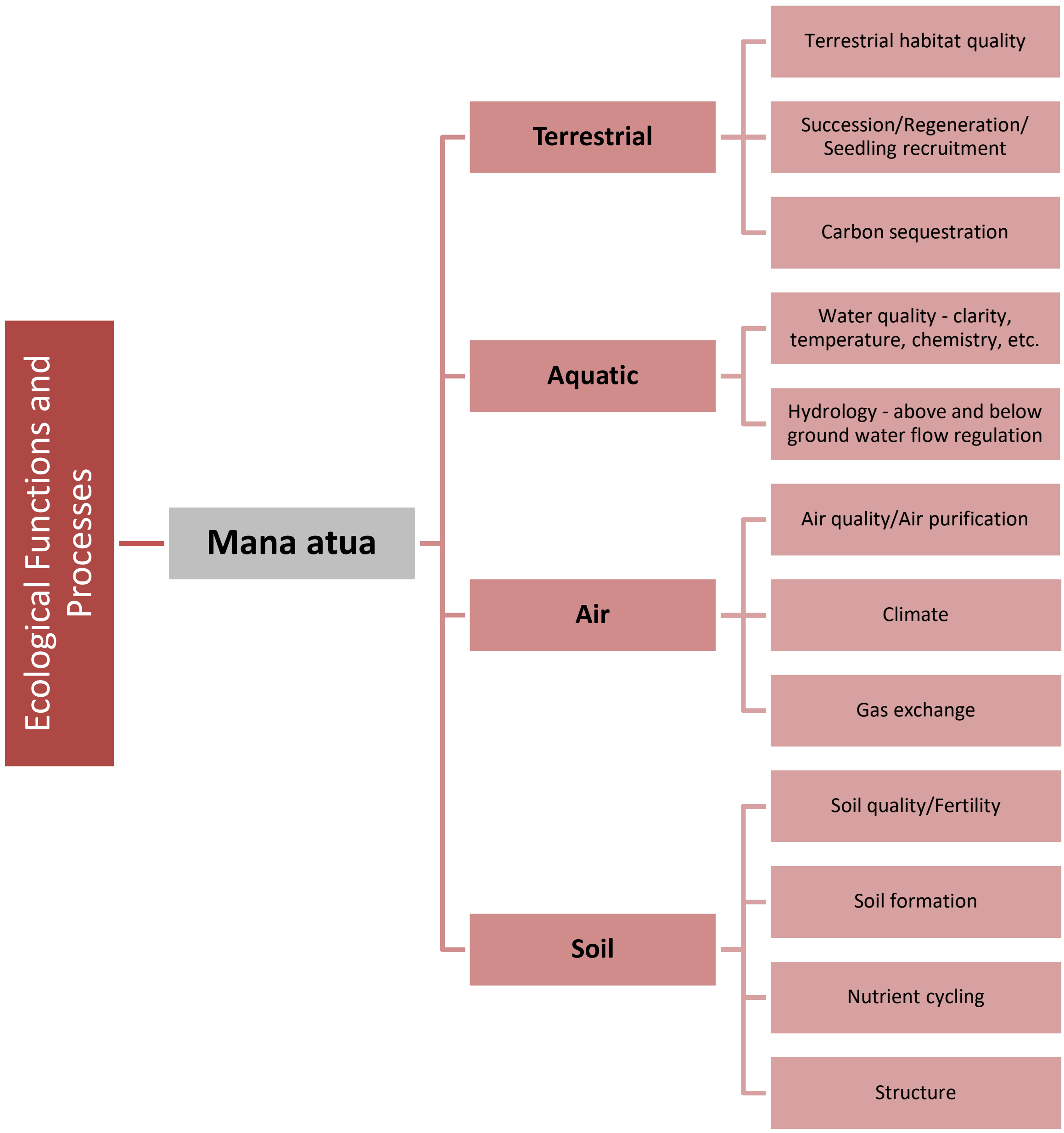



**Figure 17.** The ecological concepts that constitute Ecological Functions and Processes. Ecological functions and processes represent habitat quality and supporting ecological services. The primary processes and functions that occur in terrestrial and aquatic habitats, in the soil and in the atmosphere are shown on the right. Mana atua may be the ariā that best characterises Ecological

function and for convenience and clarity has been placed just to the right of the ecological concept in the grey box.

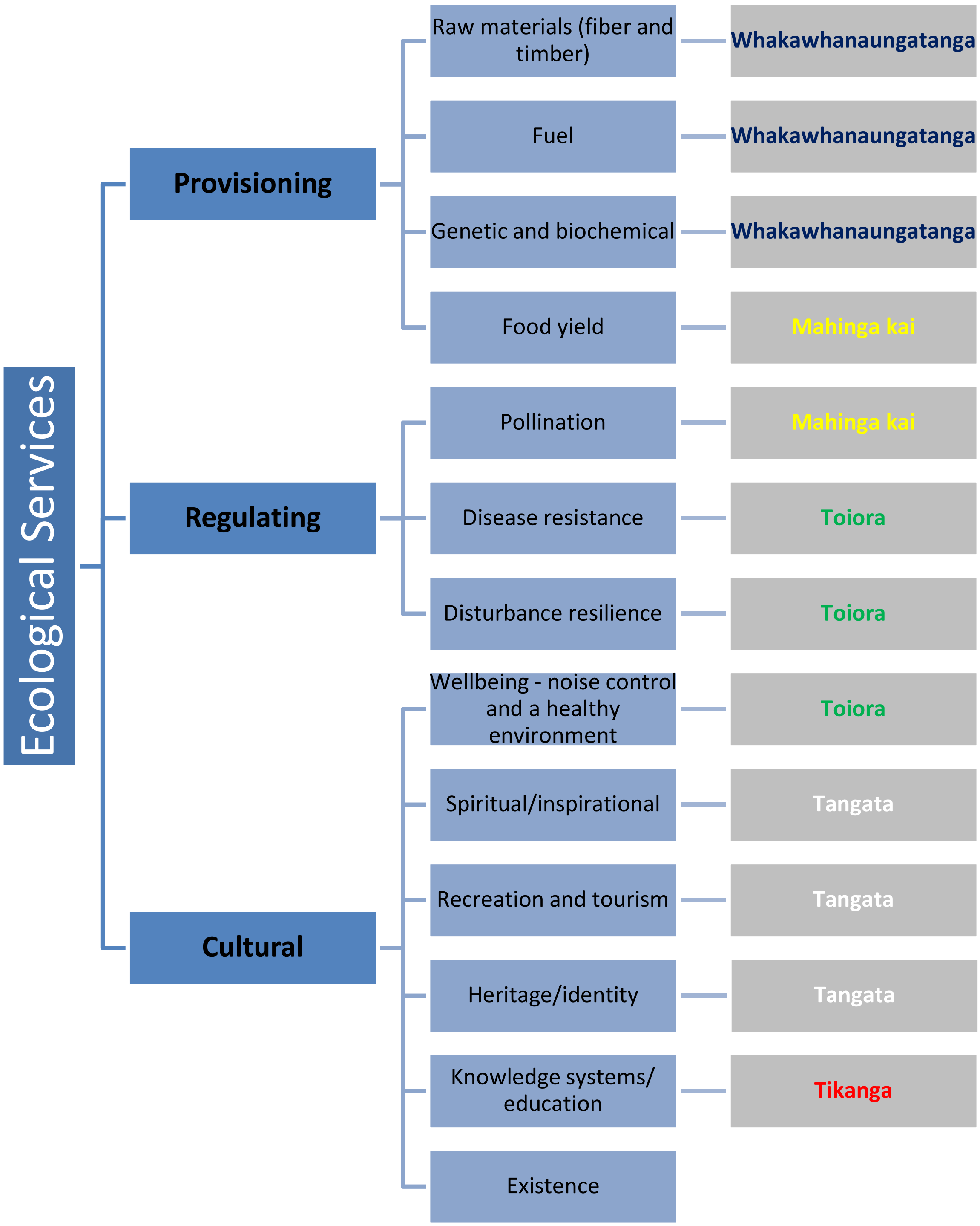


**Figure 18.** The ecological concepts that constitute Ecological Services. Ecological services provision humans with ecological products, regulate our environment for our safety and security and provide humans with social and cultural wellbeing. These three groups of ecological services are shown along with the indicators that define them. The grey boxes show the ariā that could best characterise each ecological indicator and therefore define the ecological concept.

## I – R: Indicator and response

'Talk to the bugs….they'll tell the truth.' JM

Ecological indicators may be measured by scientific metrics that assess the ecological response. Scientific methods and metrics quantify the response. Examples of metrics that measure indicators and assess the response of an aquatic ecosystem included assessing the stream invertebrate community composition using the macro-invertebrate index, riparian bird diversity and abundance using five-minute bird counts,  the biomass of periphyton and toxic algae in the water, or the water's clarity, sediment load and chemistry. The degree of change in the state of the environment signalled by the indicator is termed the ecological response. The response determines the degree and direction (trend) in which the environment is changing. The response is often used as a management performance gauge (Dymond, Begue, & Loseen, 2001, p. 163; G Harmsworth & Tipa, 2006).

At the end of this thesis is a set of appendices. These appendices detail the connections and links I have made between MEK and TEK to create He Kete Hauora Taiao. Appendix one has two spreadsheets that present a matrix of the Māori ariā and the ecological indicators that may define the ariā. The green cells show where there is a strong connection between the indicator and the ariā. The yellow indicates a reasonable connection. A resource manager can use this matrix to see which ecological indicators can be used to measure an ariā they are interested in, or it can be used to see which ecological indicators can express an ariā. Appendix two is a second set of spreadsheets containing the list of ecological elements, their indicators and the metrics used to measure them. The green cells are the most relevant to the ecological elements and the yellow cells are less relevant. I have depicted the ecological concepts and their indicators in the same framework I have used to describe the ecological structure in **Figure 9**. They have been presented by grouping them as ecosystem structure, ecosystem functions and processes and ecosystem service indicators.

## Conclusion

> The herders' personal experiences and collective social memory help in understanding rangeland quality trend and causative socio-economic events. The knowledge of Borana herders has thus shown that rangeland quality is a dynamic process of environmental changes, which cannot be understood with one-time ecological assessments. Herders' knowledge can play a complementary role to the conventional ecological research methods of rangeland quality assessment and monitoring and this knowledge may provide a basis for encouraging local communities in range rehabilitation (Dabasso et al., 2012, p. 12)

In the previous chapter, I described the Māori ariā, what they mean to Māori in an ecological context and what mainstream ecological elements relate to them. In this chapter, I have linked these to the most important ecological elements relevant to each ariā. In this chapter, I have described how biodiversity and physical attributes create ecological resilience, which fuel the ecological processes and functions that in turn generate ecosystem services benefiting humanity. I have unpacked ecological structure (biodiversity, community composition, biomass, focal species, ecological integrity and functional diversity), ecological process and functions and ecosystem services. It is the quantification of these ecological components that form the basis of any ecological assessment. Resilient and functional ecosystems have integrity and provide quality habitat and abundant, high-quality ecosystem services that are consumed by humans and other organisms, creating a feedback loop. The metrics employed by mainstream science take these ecological functions, break them down into constituent parts and measure those parts to quantify them, often by using a monetary valuation framework.

Biodiversity assessments in Aotearoa are often done using bird counts, vegetation plots and pest animal activity indices. The diversity of birds is usually the foremost indicator because birds are an important vertebrate group in Aotearoa. He Kete Hauora Taiao may give context to these commonly used indicators by linking them to Māori ariā and concurrently provide a method of applying quantitative data to ariā. In this chapter, ecological elements have been linked to ariā to help kaitiaki construct an appropriate ecological assessment framework using the ariā that are most important to them. This chapter may demonstrate to scientists the quantitative metrics that can be related through ecological principles to the Māori ariā. The inclusion of Māori knowledge and values may enhance and support resource management by expanding and enriching our perception of ecological states. This may help us understand what is considered important and a priority to manage (K. F. D. Hughey et al., 2004, pp. 90-91).

Environmental State Assessment Tool (ESAT) has been constructed to support He Kete Hauora Taiao. ESAT allows each user to apply a Māori ariā to a dataset and weight that data in relation to its relevance to ariā. How ESAT can be used as a management tool and the benefit it can provide to understanding our environment and natural resources will be the focus of the next chapter. ESAT is an Excel™ platform database that holds mainstream science datasets. The datasets can have a weighting applied according to its relevance to Māori ariā. I have tested ESAT using two case studies one is a short tailed bat colony in the Waikato, the other is a remnant kahikatea forest in the Wairarapa. The case studies will illustrate how the concepts in the He Kete Hauora Taiao framework change the outlook for ecological health when applied to scientific metrics and how the perception of ecosystem outcomes and prospects change when different ariā weightings are applied.

# Ūpoko Waru – Te whaiao

# Chapter Eight – Shedding light using ESAT

> To truly restore these landscapes, we must also begin to re-story them, to make them the lessons of our legends, festivals and seasonal rites. (Nabhan, 1991, p. 4)

For the He Kete Hauora Taiao framework to be beneficial, valuable, engaged with and employed in resource management programmes, a way to translate it into a physical resource management tool is required. Bringing He Kete Hauora Taiao to life, making it tangible and giving it a practical application, necessitates physically linking ariā to scientific data. A tool that achieves this may help non-Māori interpret ariā and embed Māori perspectives in the resource management decision-making processes. In this way, cross paradigm knowledge communication, interpretation and dissemination may be facilitated. The Environmental State Assessment Tool (ESAT) was created to fulfil this objective. ESAT is an extension and addition to He Kete Hauora Taiao. Exploring the development, function and application of ESAT is beyond the scope and parameters of this thesis but will be the subject of a published paper/s at a later date. ESAT will be employed in a National Science Challenge – New Zealand's Biological Heritage project 'Tools to support landscape scale control of invasive invertebrates'. The research team will use ESAT as a tool to measure the impact ecologically and socially of gene silencing and gene driving technology to control wasps. ESAT will be briefly discussed now to give the reader an understanding of how He Kete Hauora Taiao can be interpreted as a physical resource management tool and to illustrate how such a tool might change how resource management outcomes are informed, implemented and evaluated.

A research assistant was funded through the National Science Challenge NZ, Scion NZ, Landcare NZ, Greater Wellington Regional Council, Horizons Regional Council and Environment Southland to build ESAT according to my specifications, requirements and design briefs. In its current iteration, ESAT is an Excel™ workbook template, however, it is built in a format that will support conversion into a database platform and ultimately a website with an application portal in the future if desired. I refer to ESAT as a database because it holds and manipulates data, although currently, it is not technically a database. Databases store data in tables rather than cells and databases can assign and enforce relationships between tables and between records within tables. Jeff Foley designed and built ESAT following discussion and direction from myself. The discussions were intended to ensure that ESAT kept to the intent and will be a tool that supports and implements He Kete Hauora Taiao. I provided the Māori ecological indicators/ariā and described how they should be linked to the scientific metrics. However, Jeff was given latitude to design the user interface and architectural features of ESAT.

ESAT consists of eight Excel™ worksheets. There is one Induction page, one Prospects page, five Workings pages and a Reference page. The Induction page holds the metadata for the project, such as the project's name, a brief description of the type and characteristics of the habitat, the geographic location of the project, the project goal/s and details of the stakeholders. The Workings pages each hold a dataset consisting of eight data series. The datasets on each Workings page contain data relating to a particular aspect of ecology. For example, one Workings page may hold the dataset relating to bird biodiversity and consist of the data series relating to five-minute bird counts, direct population counts of a particular species, nesting success figures, etc. Another Workings page may hold the dataset relating to vegetation monitoring such as FORMAC monitoring data, canopy height and the diameter at breast height of the large emergent trees, or data from 20*20 plots. Yet another Workings page may hold the dataset for invertebrate monitoring such as pitfall trap results and weta house occupancy. Finally and importantly, the Prospects page provides an overall model of the health of the ecosystem derived from indexes generated from the data in the workings pages.

The data series entered are combined and converted into a ratio of the ideal health transition value defined for that data series. When each ESAT project is set up, each data series to be included in the dataset is described. The process of describing the data includes identifying any associated management target values or levels and establishing the range of values unique to each data series that would describe a good (healthy), tolerable, neutral, poor and fatal outcome for the ecological feature described by the data. In some instances these levels will be well known, for example, possum and rat tracking targets are well-established management targets. In other instances, particularly in regard to the health outcome levels, ecological managers may need to estimate the levels that will be used in the ESAT modelling. These statistics may be changed over the life of the project as over time a greater understanding of the scientific data and how it relates to the ecological health is gained. The point of doing this is that the data can then be transformed into the same comparable ratio of ecological health. Once the data series in each workings page has been translated into a health index they can be combined into an overall health index for the dataset. Each data series is fed into an index for the dataset and each dataset index is then combined into an index for the project. In this way, models are generated for each data series, data set and the entire project. The trajectory of the ecological health models in ESAT reflect the outcomes of the management objectives, the data provided and the ariā (values) applied.

As explored in previous chapters, the ariā can be described and quantified by the ecological features that characterise, describe and define them using the ecological science metrics that are used to measure changes in those ecological features. For example, if the mana whenua view wairua as a key ecological indicator we may wish to use wairua as the indicator of ecological health applied to the data in ESAT. Wairua may be interpreted as representative of the distribution and stability of the ecological communities because wairua is what makes ecosystems unique and imbues them with life and identity. Mana whenua may suggest that the wairua of this forest fragment is now diminished because many of the birds that use to live there are now gone. Given this, ecologists may suggest bird abundance and diversity be used as the ecological features to measure the change in wairua. Bird diversity and abundance may be assessed by evaluating the diversity of the indigenous birds, the presence and number of threatened bird species and the nest locations of these species in the forest fragment. Five-minute bird counts, population census of rare birds and nest mapping using GIS may then be the metrics used to measure the response to management changes. Therefore, in this instance bird diversity, the number of threatened birds present and their nest location are used to quantify wairua.

The models generated by ESAT may be used to assess the effectiveness of different management strategies to meet different management goals as well as the influence of different value structures on management outcomes. Ariā reflecting the resource management values, either Māori or non-Māori, are applied and the data weighted according to its influence on the ariā. Applying different weights to data according to the ariā may effectively change the management value ontology. Changing the weighting settings of the data series in relation to the applied ariā may change the slope or shape of the modelled curve, revealing the influence of a management goal on a dataset and its relationship to established targets, as well as the overall ecological health of the ecological feature being measured. Different ariā can be applied to each data series in the workings pages and again to the overall project outcome modelled on the prospects page. This can be done in real-time to track actual progress, to understand how the data would behave in the future under a given management regime, or to explore the effect of viewing the data through a different value lens.

Using ESAT in this way may help identify which management values would achieve the best ecological health outcomes and identify the areas in which active management would have the greatest influence. The data can be explored by changing the ariā and the associated weightings settings and this may help define which of our activities generates the largest bang for buck ecologically and economically and inform management prioritisation and cost/benefit analysis assessments. How the Māori perspective/s are interpreted and applied is objective and requires ecologists to consider how the ecological concepts they are familiar with relate to Māori ecological concepts and value systems. Ideally, the ariā that will be used to prescribe the data will be informed by the mana whenua of the land in question. The ariā (ecological perspectives) are currently derived from mātauranga Māori, but they could be replaced with the ecological and cultural perspectives of a different societal or Indigenous group. Applying culturally different ecological values or indicators and weighting the data accordingly may produce different ecological outcome models in ESAT that could enlighten us as to how different cultures interact with their environment.

Case studies may best illustrate how ESAT functions, enable scientific data to be viewed through the lens of ariā and can be a tool to explore management outcomes. ESAT was used to explore and model the data from an actual short-tailed bat colony (*Mystacina tuberculata*) in a small block of forest on private land in the Waikato. One noteworthy finding was that if the total number of bats counted (population size) was taken as the metric of health, the colony appeared stable and near the ideal ecological health targets. However, upon applying the perspective of mauri and giving more importance to and increasing the weightings applied to the bat health data (average weight and length of the bats and the number of lice they carried) the outcome was changed and the model suggested colony health was declining toward critical levels. In this instance, the health of bats in the bat colony best represented mauri if mauri is characterised by the ecological vitality and strength of the ecology. ESAT may become a valuable resource management tool that enables the user to see the data through a Māori perspective and ascertain what happens to the overall health of the ecosystem if the perspective (value system) and weighting settings are changed to fit different management objectives. ESAT can therefore function as a decision support tool or a planning and development tool.

ESAT effectively uncovers trends that would otherwise be hidden and relating scientific data to ariā (ecological value system) can provide a deeper understanding and context to the data. ESAT can be used to manage specific species such as in the bat case study, but ESAT can also be applied to site management. The next example explores the application of ESAT to the Tauherenīkau forest fragments. Tauherenīkau forest fragments have some of the last remaining stands of kahikatea (*Dacrycarpus dacrydioides*) and tōtara (*Podocarpus totara*) in the Wairarapa and contain some historically and biologically important specimens. Tauherenīkau covers 55ha split over seven forest fragments of various sizes (see **Figure 19**). Tauherenīkau is a showcase for lowland podocarp broadleaf forest; this is a highly threatened ecosystem type and therefore ranks as a high priority for integrated pest management (McCarthy, 2018, p. 4). The significant bush blocks have been legally protected and covenanted under QEII National Trust. The stakeholders involved are GWRC, the Wairarapa Racing Club, QEII National Trust, the Lowlands Trust and the Donald, Hornabrook, Lysaght, Murry, Monk and Farrier families (McCarthy, 2018, p. 6).

Tauherenīkau is home to two threatened species, the large-leaved milk tree (*Streblus banksia*) and the New Zealand pipit (*Anthus novaezeelandiae*) and a regionally rare mistletoe

(*Korthalsella lindsayi*). The forest remnants are frequented by kereru, tui and korimako (Bellbird *Anthornis melanura*) who all use the site to feed. The Donald block contains large emergent kahikatea that are thought to be over 1,000 years old (McCarthy, 2018, p. 7). Other canopy trees are tōtara, tawa (*Beilschmiedia tawa*), karaka (*Corynocarpus laevigatus*), titoki (*Alectryon excelsus*) and matai (*Prumnopitys taxifolia)*. There is an understorey of māhoe (*Melicytus ramiflorus*), kanono (*Coprosma grandifolia*), karamu (*Coprosma robusta*), hinau (*Elaeocarpus dentatus*), porokaiwhiri / pigeonwood (*Hedycarya arborea*), titoki (*Alectryon excelsus*) and pukatea (*Laurelia novae-zelandiae*). Manatu or ribbonwood (*Plagianthus regius*) can be found in some blocks. Understorey species include ferns, kawakawa (*Macropiper excelsum*) and supplejack (*Ripogonum scandens*).

The greatest threat to the biodiversity in Tauherenīkau comes from pest plants and animals. Weeds now constitute important structural and ecological components of the forest, affecting the bulk of the reserve. Weed management has focused on removing *Tradescantia fluminensis*, sycamore (*Acer pseudoplantaus)*, poplar (*Populus spp.*), willow (*Salix alba*) and some climbers. Tree Lucerne (*Chamaecytisus paimensis)* forms a monoculture on the river edge and sycamore are invading the racecourse and Donald block (see **Figure 19**). The management activities at this site revolve around pest animal and weed control and some revegetation. The aim of the pest control (weed and animal) is to limit the impact of invasive species, maintain biodiversity and facilitate ecosystem functions.

Greater Wellington Regional Council (GWRC) has helped manage this site for its significant biodiversity value for the last 20 years and has extensive monitoring datasets. GWRC has conducted rodent, bird and weed monitoring in Tauherenīkau from January 2005 to August 2013, ceasing when the monitoring programme was restructured (unpublished data, Greater Wellington Regional Council). The monitoring informed the small mammal pest management programme and verified that the current baiting regime successfully maintained rats below the 10% target level. Research suggested that a 10% rat tracking index would support populations of small insectivorous birds (Moylan, Bancroft, & Lambie, 2010). A weed monitor using a methodology adapted from the FORMAK vegetation monitor (Handford, 2019) and the Department of Conservation’s weed monitoring manual (Department of Conservation, 2008) was undertaken in 2008 and 2009 to determine the outcome of weed control activities.

Monitoring of four plots (two control and two treatment plots) on the river edge tracked the initial removal of *Tradescantia* and sycamores and their replacement with grass and tree lucerne (Moylan et al., 2010). In 2009, a FORMAK vegetation monitor was conducted in the racecourse/Donald block (Moylan, 2009).

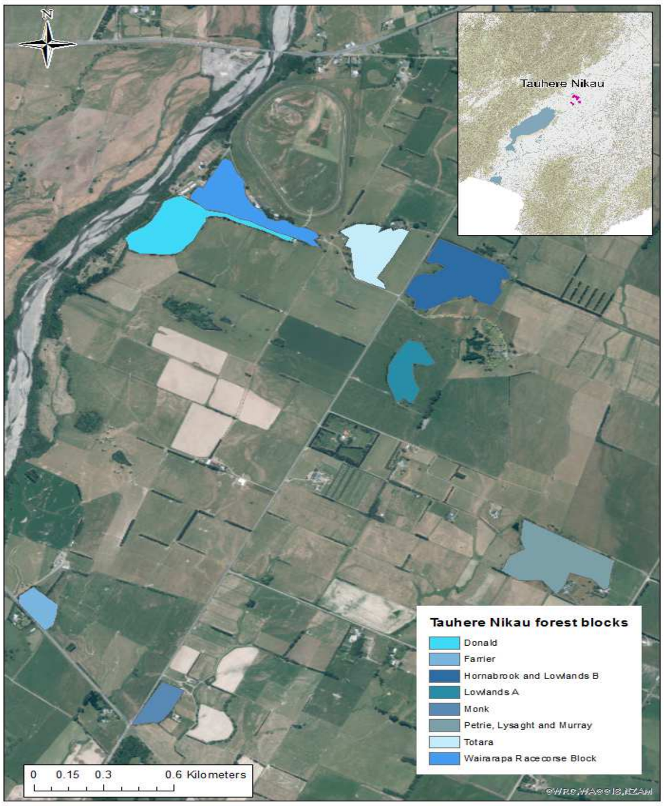
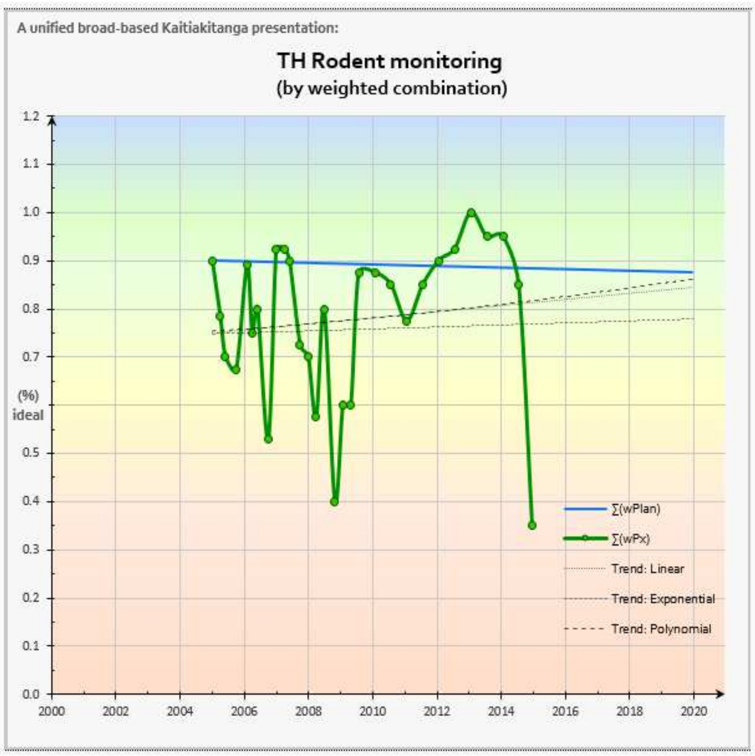



**Figure 19**. Map of Tauherenīkau forest blocks. Map created by author using ArcMap 10.1. Inset shows the generalised location of Tauherenīkau.

**Figure 20** below is an example of how the rodent monitoring data is visualised in ESAT. The plot below shows the rat tracking index data series. The tracking index is an index of activity and not a direct population count. The chart shows how data is plotted in ESAT (green line), how ESAT models data trend lines (linear, exponential and polynomial), how the data models appear and are visualised in relation to the target ecosystem health levels (background shading), and how the data is compared to the management target level (blue line). The blue line is a plot of the ratio of the actual data to the target. If the blue line is flat the data is meeting the target. If the line is not horizontal the slope of the line reveals the degree and direction that the data and therefore management is diverging from the target. All the data is plotted as a ratio of the prescribed ideal health value enabling different data series to be represented similarly and therefore be directly comparable. The ecological health levels prescribed by the user are translated into the shading from red (bad) to green (good), as a ratio of the actual data to the prescribed ecological health level. The goal is to get the data into the green.

**Figure 20.** Close up of main (unified view) chart in Workings 1 of Tauherenīkau. The rat tracking index is weighted at 100 and the mouse tracking index was weighted at 25, because mice are generally not managed and will therefore not be as influential on the perspective of kaitiakitanga. The combined, weighted data series view through the perspective of kaitiakitanga shows that the management of rodents is improving the health of the ecosystem.




ESAT takes all the datasets and turns them into weighted indices, then combines and plots them modelling the overall prospects for the health (long-term integrity and functionality) of the ecosystem. The overall ecological health prospects model is then itself viewed through another Māori perspective. Each dataset, in this case, small mammal monitoring, vegetation monitoring, bird monitoring and weed monitoring can be weighted independently according to their contribution to the ariā being applied to the project as a whole and fed into the overall project model. In this case the ariā was set as wairua and the associated weighting settings produced a model that appears to show that, over time, the ecological health prospects for the Tauherenīkau reserve are rapidly declining (see **Figure 21)**. This analysis reveals the critical state of the reserve.

Looking at the rodent monitoring alone does not show that the overall health of the ecosystem has a poor prognosis. In fact, each management activity taken individually appears to successfully meet the management targets set and the modelled trend lines show positive ecological health outcomes. It may be concluded that the current management regime controls rodents and weeds but is failing to preserve the biodiversity in the reserve. This analysis also revealed that controlling rats has a significant impact on the biodiversity and sustainability of the reserve. Reducing the weighting of the rat monitoring data produced a large divergence away from the ideal health outcome.

**Figure 21.** The Prospects page for Tuherenīkau. The chart shows the outcome of combining all weighted data series in each dataset and the modelled data trajectory viewed through the perspective of wairua. The overarching perspective applied is wairua and all the datasets contribute 100% to the perspective. The individual dataset weightings can be seen in the green panel down the left-hand side. The view shows a poor outlook for the forest block using the data available when viewed through this set of perspectives and weighted in this configuration.

*He Kete Hauora Taiao*

## *Tauherenikau*

| 01 Jan. 2000 | 16 Dec. 2019 | 01 Jan. 2020 |
|---|---|---|
| Start | Now | End |

Refresh | Delete | Load | Save

Auto. 0 | Locked | Locked | Save 1

**Status** ↘ Incomplete specification – Project analyst: Please at least provide a name and contact phone number.

| Workings | | | Weighting (%) | |
|---|---|---|---|---|
| Count | | Sample (series name) | $W_{Gxn}$ | Unified |
| Gp1 TH Rodent monitoring | 1 | Rat tracking index | 100 | 26.7 |
| | 2 | Mouse tracking index | 25 | 6.7 |
| | 3 | | 0 | 0.0 |
| | 4 | | 0 | 0.0 |
| | 5 | | 0 | 0.0 |
| | 6 | | 0 | 0.0 |
| | 7 | | 0 | 0.0 |
| | 8 | | 0 | 0.0 |
| Gp2 Tauherenikau Weed Monitoring | 1 | Average diverstiy weed control | 100 | 8.3 |
| | 2 | Average diversity no weed control | 0 | 0.0 |
| | 3 | Average density weed control | 100 | 8.3 |
| | 4 | Average density no weed control | 0 | 0.0 |
| | 5 | Average saplings weed control | 100 | 8.3 |
| | 6 | Average saplings no weed control | 0 | 0.0 |
| | 7 | Average seedlings weed control | 100 | 8.3 |
| | 8 | Average seedlings no weed control | 0 | 0.0 |
| Gp3 Bird monitoring | 1 | Fantail | 100 | 8.3 |
| | 2 | Greywarbler | 100 | 8.3 |
| | 3 | Tui | 100 | 8.3 |
| | 4 | Kereru | 100 | 8.3 |
| | 5 | | 0 | 0.0 |
| | 6 | | 0 | 0.0 |
| | 7 | | 0 | 0.0 |
| | 8 | | 0 | 0.0 |
| Gp4 | 1 | | 0 | 0.0 |
| | 2 | | 0 | 0.0 |
| | 3 | | 0 | 0.0 |
| | 4 | | 0 | 0.0 |
| | 5 | | 0 | 0.0 |
| | 6 | | 0 | 0.0 |
| | 7 | | 0 | 0.0 |
| | 8 | | 0 | 0.0 |
| Gp5 | 1 | | 0 | 0.0 |
| | 2 | | 0 | 0.0 |
| | 3 | | 0 | 0.0 |
| | 4 | | 0 | 0.0 |
| | 5 | | 0 | 0.0 |
| | 6 | | 0 | 0.0 |
| | 7 | | 0 | 0.0 |
| | 8 | | 0 | 0.0 |
| | | | Sum | 100.0 |

### Analyst

| | | | |
|---|---|---|---|
| Name | Sar Moylan | Ref. | TH |
| Org. (Iwi) | GWRC | | |
| Date | | m. | |

**Unified broad-based perspective** Wairua Index 1

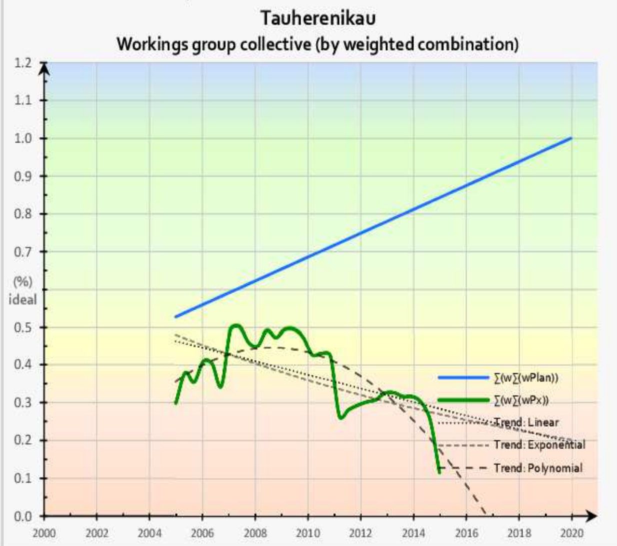
**Rationale**

Spirit: Essence, identity, origins, soul.

The rat and mouse tracking index the vegetation plots that have received weed control and the four tounga species reflect the overall wairua of the site equally

| Workings group perspective | | Unified group weighting | $W_{Gx}$(%) |
|---|---|---|---|
| 1 | Kaitiakitanga | | 100 |
| 2 | Mahi | | 100 |
| 3 | Taonga species | | 100 |
| 4 | | | 0 |
| 5 | | | 0 |

A unified broad-based Wairua presentation:




**Notes**

1
2
3
4
5

## Conclusion

ESAT can be used to assess and interpret scientific data through a Māori perspective. The Māori perspectives can be defined based on the MEK and ERM linkages in the He Kete Hauora Taiao framework explored in the previous chapters. Each user can load their own set of perspectives and perspective weightings to the same data and save their settings, share the outputs, or try a completely new set of perspectives and settings. This lets individual users tailor their view of the scientific data based on different management goals and/or ecological priorities. Each user can use Māori perspectives to interpret the scientific data in any way they wish. ESAT requires the user to apply a Māori perspective to any scientific data loaded, however, how the Māori perspective/s are interpreted and applied is subjective. This requires ecologists to consider how the ecological concepts they are familiar with relate to Māori ecological concepts. Aligning perspectives and weightings to the values and goals of mana whenua would be recommended in co-management situations. The perspectives are currently derived from mātauranga Māori, but they could be replaced with the ecological and cultural perspectives of any Indigenous culture. ESAT could be an internationally applied tool that removes or explores cultural differences by using quantifiable scientific data as the common language.

This chapter described how ESAT functions and explored how the view of environmental health can change depending on which perspectives are applied and how the datasets and data series are weighted. The data can be explored to discover which of the datasets (indicators) are responsible for the largest negative influences on the long-term ecological prospects for the ecosystem when viewed through a particular perspective. This can enable managers to identify what aspects of the management programme need reviewing. The next chapter is the concluding chapter and will sum up this thesis, present my key findings and propose possible future research opportunities. I will review my research questions and consider if they have been answered sufficiently. I will analyse the process of constructing He Kete Hauora Taiao and consider if there were any aspects of the process that could have been done better and which worked well.

# Ūpoko Iwa – Kupu whakatepe

# Chapter Nine - Conclusion

Whatungarongaro te tangata, toitū te whenu.

People come and go, but the land endures (Garth Harmsworth, 2017)

Māori have a whakapapa connecting us to the whenua and a self-imposed obligation of kaitiakitanga. Whakapapa connects us to the land and bestows our identity on us and it connects us by heritage to the land (C. Raymond & Brown, 2011, pp. 653, 655). Kaitiakitanga describes our obligation to care for the land conferred into our care by our tūpuna. It is time to work together to look after Papa-tua-nuku. After all, if she dies so do we. We may need her more than she needs us. To date, mainstream resource management may not have achieved sustainable ecological outcomes. Under the current regime, it appears that waterways have become increasingly polluted, the seas increasingly empty and the forests increasingly quiet. It is probably high time to revitalise and restore some of the vast and effective knowledge and practices employed by the first nations over the globe. If we don't, our future is not assured. We simply cannot continue to do what we are currently doing. It has been generally unsustainable; natural resources are not infinite.

Our experiences, perceptions, values, economics, cultures, relationships, institutions, ethics and values all drive our resource management decisions, shaping our prioritisation and resource investment decisions. However, resource management is arguably primarily about human relationship management. Successful, sustainable management generally requires the sanction and cooperation of the entire community and it is implemented by and for the community (Binoy & Radhakrishna, 2013, p. 758; Potschin & Haines-Young, 2013, p. 1055; Stevenson, 2006, p. 169). Sustainable resource management should be tied to its social context. Sustainable resource management is conferred inter-generationally, is specific to the location and culture and is linked to the outcomes for the land and the wellbeing of the people (Dawoe et al., 2012, p. 96; Wario et al., 2015, pp. 732-734). Neglecting social values may have serious social consequences, undermining biodiversity and impeding ecological management (K. Chan, M. A. et al., 2012). Good resource management should be appropriate for the land and it should improve the quality of life and bring self-reliance and equality for the people living on it (Rigby et al., 2001, p. 468).

The framework and tool I have created provide a way for Māori ecological knowledge to be employed in mainstream resource management. It may help fulfil the Tiriti O Waitangi obligations of the local authorities toward Māori and enable true co-management. It may also allow understanding and the cross-pollination of knowledge between Māori, mainstream resource managers and ecological scientists and in this way greatly expand the depth and breadth of our cumulative knowledge base. It may enable new understanding and cognition of our knowledge of the natural world and innovative new thinking. But most importantly, it may enable Māori to kaitiaki the whenua as our tipuna demand and help decolonise mātauranga Māori. Combining the two knowledge systems with two-eyed seeing may enable us to benefit from more than one worldview, more than one contextual framework and more than one way of conducting natural resource management. Ultimately, this should improve our natural resource management efficacy and build understanding, respect and acceptance between different cultures.

I would suggest that most people in this country would agree that Māori culture and activities are an important part of our national identity and many of us have a visceral connection to the land and environment (Ministry for Culture and Heritage, 2009, p. 7). Co-management, where we are partner kaitiaki for this whenua, may provide the best protection for the children of Tane. For this to happen, kaupapa Māori and mātauranga Māori may need to be prioritised and this will depend on building trust between the two groups. Without trust, there may be no respect and acceptance and without these, there may be no true co-management where both partners are on equal footing. To build trust, walls of prejudice, ignorance and misunderstanding should be dismantled. The history of colonisation means that it should be the dominant partner that takes the first and largest steps and actively cedes power. Each partner does not have to completely understand, accept, or agree with the other, but there should be tolerance and respect. Indigenous knowledge comes from a place of significant disadvantage and may require a large investment of will and resources if it is to catch up.

## From kosmos to praxis

There is, in general, a growing momentum for Territorial Authorities (local and regional councils) to build a functional relationship with Treaty partners involving co-management. This impetus has come from legislation, Treaty settlement processes and the need to stem biodiversity loss. This has resulted in the formulation of council co-management policies, iwi resource management plans and the desire from scientists and mainstream resource managers to understand and access mātauranga Māori. This has inspired many attempts to create environmental assessment frameworks engaging both mātauranga Māori and mainstream science. I have created He kete Hauora Taiao, a new ecological assessment framework that situates mātauranga at its core and supports Māori ecological knowledge with ecological science. I have used ngā kete e toru (the three baskets of knowledge) and the Greek kosmos – corpus – praxis complex as the frameworks to explore the intersection between Māori ecological knowledge and ecological science. These conceptual frameworks consider the spiritual and cosmological beliefs and respective bodies of knowledge, cultural processes and paradigms (tools and tikanga) that shape our interactions and relationship with our environment. The dual paradigms are interpreted in the context of resource management practises, prioritisation models, planning, evaluation methodologies and desired management outcomes. Creating He kete Hauora Taiao involved translating Māori and mainstream science cosmologies.

He kete Hauora Taiao was constructed on the Driver - Pressure – Ariā – Ecological Element – Indicator – Response (DPAEIR) framework. The DPAEIR framework is a modified version of the Driver – Pressure – State – Indicator – Response (DPSIR) framework, which is the OECD's state of the environment reporting framework (Victoria Ann Froude, 2011, pp. 107-108; G Harmsworth & Tipa, 2006; K. F. D. Hughey et al., 2004, p. 85). Māori ariā or perspectives have been substituted at the 'state' level of the framework. The ariā define the way that Māori perceive, evaluate and interact with the natural world. They are Māori ecological indicators, describing ecological states. A new level, Ecological Elements, has been inserted between State and Indicator in the OCD's DPSIR framework. Ecological Elements are ecological concepts and features that define the ecological structure (abiotic and biotic), ecological functions and processes and ecological services. The Māori ariā have been interpreted using their constituent Ecological Elements. Ecological Elements have indicators that describe the ecological response. Indicator and Response are the final two elements of the DPAEIR framework. The ecological responses and indicators have well-established quantification methods and tools associated with them.

He Kete Hauora Taiao may bridge the gap between mātauranga Māori and mainstream science. It links ecological science methodologies and data collection to the Māori ecological science and the perspectives that drive Māori ecological management. In general, both knowledge worldviews come from a foundation of observation and testing and use the same habits of mind to seek a universal truth (Barnhardt, 2005, p. 10). Western science has evolved from a reductionist/hypothetico deductive paradigm that emerged primarily from Mediterranean cultures (Ens et al., 2015, p. 136). Ecological science may find the underlying mechanisms of ecological function and provide theories that can be applied universally and the tools with which to do so, while Indigenous knowledge is in general a holistic, metaphysical knowledge system immersed in social, cultural and landscape value context (Aikenhead & Ogawa, 2007, p. 558; G. Brown & Raymond, 2007; Dewalt, 1994).

A strength of the He Kete Hauora Taiao framework may be that it does not prescribe the interpretation of the Māori ariā. Each iwi, institution, or person using the framework can interpret the ariā in any way that suits them. I have tried to link the relevant ecological principles to each ariā. This means that the ariā may be interpreted using several different ecological principles and each principle has a variety of indicators for its constituent components. The user/s can therefore apply any number of scientific principles and indicators to the ariā that they value. This enables the scientific data to be seen through a Māori lens. It enables a more holistic examination of the scientific data and affords it a social and ecological health context. The pH of the water or average DBH of the native trees may be given meaning with respect to ecological health and social wellbeing.

Defining Māori ariā in the context of their associated ecological element in this framework enables them to be linked to qualitative scientific metrics. For example, the ariā of mauri could be explored using the ecological element of biodiversity and biodiversity may be assessed by counting plant or animal abundance and performing diversity index calculations. The assessment indicators selected to communicate and illustrate the critical ariā may create the most appropriate monitoring programme for the kaitiaki agenda. In addition, the mana of the knowledge may be protected if research is undertaken using kaupapa Māori research principles. He Kete Hauora Taiao may bring social indicators into an ecological assessment framework. People are an integral part of the environment but may be absent from scientific assessments. I wanted to bring social indicators into ecological assessments and I wanted to go further than just mahinga kai and important cultural sites. When I began this research, I was asked by my manager if I would be interested in investigating the intersection between mātauranga Māori and mainstream science. I did not perceive there to be an intersection between science and mātauranga Māori. For me, science was more like a subset of mātauranga Māori.

Given more time and resources, it would have been good to better depict the connections between the ariā and the ecological elements better. Access to R- software may have been useful to better visualise the connections between the ariā and the ecological elements. The relationships between the ariā and the ecological elements are complex and difficult to illustrate without using specialised software. I settled for portraying the connections as a matrix, but given time, a better way may have emerged. A relationship tree may have been a better option, however, given the sheer number of connections and features involved, the resulting tree would have been extremely complicated. It was also difficult to visualise the strength of connections. This was done using the colour coding in the matrix. In the end, a matrix worked well as a way to represent the connections and the strength of those connections.

Applying He Kete Hauora Taiao framework in a practical context required the development of a database that allowed scientific data to be linked to mātauranga Māori perspectives. I had the Environmental State Assessment Tool - ESAT - created for this purpose. ESAT is a database that allows scientific data to be linked to different Māori perspectives. A weighting can be applied to the datasets depending on the strength of the association between the Māori perspective and the data. For example, rodent monitoring data may have a high weighting if kaitiaki is the perspective applied, because rodent control is a key management objective. However, if mana atua is the perspective applied, FORMAK vegetation data that measures forest succession will probably have a higher weighting.

## Into the future

When I first envisioned ESAT, I imagined more of a planning tool. ESAT was envisioned as a way to help resources managers construct a monitoring programme based on the ariā they are interested in. What it evolved into proved much more useful. ESAT became a tool for holding, manipulating, analysing and presenting data through a Māori perspective. He Kete Hauora Taiao became is framework for linking Māori ecological knowledge and ecological science and ESAT became the tool enabling the application of Māori ecological concepts to ecological science. The next phase of ESAT development would be to convert the Excel™ template into a database platform. That will increase its functionality, enable bulk data import and not limit the number of datasets in each project. Long-term, ESAT could become an open access web page with portal access and a supporting application accessible to iwi and other resource managers.

As a spreadsheet application, ESAT's capacity is limited. Currently, only five datasets with eight data series each can be inputted. This restriction can be removed if ESAT is converted into a database platform. Conversion to a database would make the number of datasets and series that can be entered infinite and enable data mining from other databases. Obtaining funding to have ESAT converted into a database in the near future is a necessity to ensure that ESAT is functional and practical for widespread (even international) applications. This is important if it is to be employed and more widely engaged with. The more it is used, the better it will function as a resource management tool. The more data available and the more experience managers gain with it, the better managers will become with interpreting the outcomes of management activities.

Expanding ESAT's application is a priority. Employing He Kete Hauora Taiao in actual natural resource co-management scenarios may be an important next step. Embedding ESAT in local government will begin with my own organisation, Greater Wellington Regional Council. I have already had staff from other departments at Greater Wellington Regional Council express an interest in using ESAT as a way of linking riparian vegetation data to water quality to improve īnanga diversity and abundance in local waterways. The two Crown Research Institutes and the three Regional Councils and their treaty partners who supported me financially will get a copy of this PhD and a copy of ESAT. The PhD will explain how and why He Kete Hauora Taiao functions and ESAT will enable real-life application of the He Kete Hauora Taiao epistemology. Training and support will be provided. This will position ESAT in local government and Crown Research Institutes and establish it as a regularly used, effective and familiar tool.

In the future, ESAT could be adapted for use by other first nations. The ariā can be replaced with a new set derived from other cultures. A new set of cultural indicators can easily be reinterpreted as ecological elements. Another avenue for future application of ESAT is as part of Post-Doctoral Research programmes and there is scope and interest in this. I am aware of two research projects that could be supported by ESAT and have indicated an interest in pursuing this collaboration. The first is providing data on the biodiversity and cultural impacts of wasps in New Zealand. The second is using ESAT to assess the effectiveness of restoring biodiversity to recently returned iwi land that has been retired from farming. Both of these projects could springboard the use of ESAT in many more research programmes.

In the near future, there will be at least two research papers forthcoming. The first will discuss the use of ESAT as a management tool using a case study. This paper will explore how ESAT may be used in an actual natural resource management context, what using ESAT can do to further our understanding of natural resource management, how traditional ecological management values and indicators can be applied to real ecological data and how ESAT may provide a holistic and vastly border way of analysing the data that improves biodiversity outcomes. The second paper will be a joint paper with other Indigenous scientists that will explore our positionality as Indigenous scientists and how we navigate the divide between our indigenous knowledge and our mainstream science training and education.

## Whakakapinga – concluding remarks

> In Māori society, land may be given or taken but you are never alienated from it and "ownership" was only ever temporary (Douglas, 1984, p. 81)

I have thoroughly enjoyed researching and producing He Kete Hauora Taiao. To me, it seemed instinctual to link the Māori ariā to ecological principles and apply context to quantitative ecological and value/s to ariā. I was able to apply quantifiable scientific methodologies to Māori ecological principles. In so doing, I hope I have strengthened both mātauranga Māori and mainstream scientific knowledge. In my view, Māori knowledge provides the context or meaning and science provides the understanding of our observations of the natural world. He Kete Hauora Taiao helps embed mātauranga Māori in mainstream ecology and resource management, decolonising it and normalising it. Using He Kete Hauora Taiao obligates scientists to view quantitative data through a Māori knowledge system and perhaps in the process of familiarisation, gain a deeper understanding and respect for mātauranga Māori. Having the perspective of a Māori scientist enabled me to see the connections between the two paradigms. In the end, it seemed so simple to connect the mātauranga and ecological science in the way I did and made me wonder why it is only being done now. It is a rewarding space to navigate.

Ngā mihi

Tēnā koutou katoa

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# Appendices

## Appendix 1: The Māori perspectives and how they link to ecological science perspectives

The ecological concepts are listed on the right alongside the ecological indicators. The Māori ecological concepts or ariā are listed along the top. The matrix shows the strength of the relationship and relevance of the ariā to the ecological indicators. Green shows a strong association and amber a moderate association. The indicators can be expressed in more than one ariā. The first panel shows the concepts and indicators associated with the ecological structure. The second panel shows the concepts and indicators associated with ecological functions and processes. The third panel shows the ecological indicators associated with ecosystem services.

| Māori perspectives – ariā and Ecological structure indicators | | Wairua | Mauri - Mauriora | Whakapapa | Kaitiakitanga | Te Ao Marama | Mana atua | Whakawhanaunga - Iwitanga - Tau utuutu - Koha - Te Aotūroa | Mahinga kai | Taonga species - Aroha tānga - Taonga tuku iho | Tangata - Te Oranga - Ngā Manukura - Te Mana Whakahaere - Tino rangatiratanga - Whanaungatanga - Tohungatanga - Kotahitanga - Mana whenua - Tūrangawaewae | Toiora | Mahi - Ki uta ki tai - Āwhinatanga - Manaakitanga - Whakapono - Kōkiri - Māriu Tu | Tikanga - customary practices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abiotic factors | | | | | | | | | | | | | | |
| Biodiversity | Biodiversity: Species richness, abundance, frequency, rareness, evenness, density - biodiversity indices | | | | | | | | | | | | | |
| | Genetic diversity - morphological, physiological and behavioural diversity | | | | | | | | | | | | | |
| | Biomass | | | | | | | | | | | | | |
| | Focal species: Monitoring of important species including cultural key stone species | | | | | | | | | | | | | |
| | Focal species: Bio-Indicators | | | | | | | | | | | | | |
| | Focal species: Pest species infestation abundance, location and distribution | | | | | | | | | | | | | |
| | Presence of rare threatened spp. - birds, invertebrates, reptiles or plants | | | | | | | | | | | | | |
| Functional diversity | Population persistence and habitat requirements - minimum viable population size, temporal changes and habitat requirements | | | | | | | | | | | | | |
| | Dispersal range, speed, direction and constraints | | | | | | | | | | | | | |
| | Habitat occupancy: Fidelity, availability, location, area and carrying capacity | | | | | | | | | | | | | |
| | Functional diversity: Occupancy of niches, presence of predators, presence of guilds | | | | | | | | | | | | | |
| | Indigenous dominance | | | | | | | | | | | | | |
| | Species distributions and actual and potential | | | | | | | | | | | | | |
| | Population structure: Demographics, sex ratio, meta population data, sources and sinks, life history and reproductive strategies, adult mortality and fecundity | | | | | | | | | | | | | |
| Ecological integrity | Spatial heterogeneity and variability. Ecosystem diversity | | | | | | | | | | | | | |
| | Fragmentation: Mean and Variance in inter-patch size | | | | | | | | | | | | | |
| | Fragmentation: Mean and Variance in inter-patch distance | | | | | | | | | | | | | |
| | Ratio of edge to core | | | | | | | | | | | | | |
| | Connectivity: Corridors and stepping stones | | | | | | | | | | | | | |
| | Habitat/ecological persistence - land use change, vegetation cover change and deforestation rate | | | | | | | | | | | | | |
| | Habitat/ecosystem rarity and representativeness - threat classification | | | | | | | | | | | | | |

| Māori perspectives – aria<br>and<br>Ecological function and process indicators | | Wairua | Mauri - Mauriora | Whakapapa | Kaitiakitanga | Te Ao Marama | Mana atua | Whakawhanaunga - Iwitanga - Tau utuutu - Koha - Te Aotūroa | Mahinga kai | Taonga species - Aroha tānga - Taonga tuku iho | Tangata - Te Oranga - Ngā Manukura - Te Mana Whakahaere - Tino rangatiratanga - Whanaungatanga - Tohungatanga - Kotahitanga - Mana whenua - Tūrangawaewae | Toiora | Mahi - Ki uta ki tai - Āwhinatanga - Manaakitanga - Whakapono - Kōkiri - Māriu Tu | Tikanga - customary practices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem functions and processes | **Forest (Tane Mahuta ): Vegetation cover and type** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta ): Canopy structure, openness, gap characteristics and damage** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta): Tier Structure** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta): Forest height and tree diameter** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta): Succession** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta): Phenology** | | | | | | | | | | | | | |
| | **Forest (Tane Mahuta): Growth - leaf area and structure** | | | | | | | | | | | | | |
| | **Aquatic ecosystems (Tinirua): Fish and invertebrate diversity, distribution, and abundance and habitat quality. Macro and macrophyte diversity, distribution and abundance** | | | | | | | | | | | | | |
| | **Aquatic ecosystem: Riparian habitat provision, water shading and temperature regulation** | | | | | | | | | | | | | |
| | **Aquatic ecosystem: Flow regulation water storage, precipitation, and channel modification** | | | | | | | | | | | | | |
| | **Aquatic ecosystem: Erosion - zone extent and sediment load** | | | | | | | | | | | | | |
| | **Aquatic ecosystem: Waterway and wetland habitat provision, water clarification and storage** | | | | | | | | | | | | | |
| | **Aquatic ecosystems including wetlands (Maru): Water quality - nitrification, clarity and contamination** | | | | | | | | | | | | | |
| | **Soil (one one ): Fertility, nutrient cycling, chemistry** | | | | | | | | | | | | | |
| | **Soil (one one ): Structure- porosity, compaction, mineral composition, bulk density etc.** | | | | | | | | | | | | | |
| | **Soil (one one ): Organic matter and humus layer depth** | | | | | | | | | | | | | |
| | **Soil (one one ): Biodiversity of macro/micro biome** | | | | | | | | | | | | | |
| | **Decomposition** | | | | | | | | | | | | | |
| | **Air (Tāwhiri mātia): Quality- particulate pollution, gas chemistry and temperature regulation** | | | | | | | | | | | | | |
| | **Air (Tāwhiri mātia): Co2 Sequestration and Air. Carbon accounting** | | | | | | | | | | | | | |

| Māori perspectives – ariā and Ecological service indicators | | Wairua | Mauri - Mauriora | Whakapapa | Kaitiakitanga | Te Ao Marama | Mana atua | Whakawhanaunga - Iwitanga - Tau utuutu - Koha - Te Aotūroa | Mahinga kai | Taonga species - Aroha tānga - Taonga tuku iho | Tangata - Te Oranga - Ngā Manukura - Te Mana Whakahaere - Tino rangatiratanga - Whanaungatanga - Tohungatanga - Kotahitanga - Mana whenua - Tūrangawaewae | Toiora | Mahi - Ki uta ki tai - Āwhinatanga - Manaakitanga - Whakapono - Kōkiri - Māriu Tu | Tikanga - customary practices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Provisioning services | Primary production - raw materials and fuel | | | | | | | | | | | | | |
| | Biochemical and genetic | | | | | | | | | | | | | |
| | Primary production - food production | | | | | | | | | | | | | |
| Regulating services | Pollination: Pollination of bees, reptile, birds, and other pollinating inverts | | | | | | | | | | | | | |
| | Nutrient concentrations and cycling | | | | | | | | | | | | | |
| | Biocontrol: infestation and disease incidence, abundance and release sites | | | | | | | | | | | | | |
| | Resilience: Invasive species abundance, erosion, flood protection, land use and deforestation rate | | | | | | | | | | | | | |
| Cultural and Social: Cultural landscape and management | Nomenclature | | | | | | | | | | | | | |
| | Built capital - inventory of built structures | | | | | | | | | | | | | |
| | Human capital - inventory of community structure and support | | | | | | | | | | | | | |
| | Culturally important sites - location and number of culturally important sites such as wāhi tapu | | | | | | | | | | | | | |
| | Number of visitors and destinations | | | | | | | | | | | | | |
| | Inspiration - art and cultural sites. Stories | | | | | | | | | | | | | |
| | Taniwha - location of sites | | | | | | | | | | | | | |
| | Education - location of research and study sites | | | | | | | | | | | | | |
| | Historically important sites - location and use | | | | | | | | | | | | | |
| | Mana whenua - identity and location | | | | | | | | | | | | | |
| | Wellbeing - sense of connection and spiritual wellbeing. Recreational use | | | | | | | | | | | | | |
| | Medicinal plants - location of harvest areas | | | | | | | | | | | | | |
| | Legal protection - location and extent of area | | | | | | | | | | | | | |
| | Extent of land use change. Location of at risk/ pressure areas | | | | | | | | | | | | | |
| | Extent and location of management areas | | | | | | | | | | | | | |
| | Extent and location of monitoring programmes | | | | | | | | | | | | | |
| | Extent and location of Iwi managed land | | | | | | | | | | | | | |
| | Extent of co-managed land | | | | | | | | | | | | | |
| | Extent of pest management areas (plant and animal) | | | | | | | | | | | | | |
| | Access: Location of important social and cultural values and barriers to access | | | | | | | | | | | | | |
| | Human food provision. Mahinga kai (Haumai tikitike and Rongo) | | | | | | | | | | | | | |

## Appendix 2: Ecological concepts, their indicators and the tools used to assess them

The ecological concepts are listed on the right alongside the ecological indicators. The tools and assessment methodologies used to measure the ecological response to change are listed along the top. The matrix shows the strength of the relationship between the ecological concepts and the tools that can be used to quantify them. Green shows a strong association and amber is a moderate association. The first panel shows the concepts and indicators associated with the ecological structure. The second panel shows the concepts and indicators associated with ecological functions and processes. The third panel shows the ecological indicators associated with ecosystem services. Green represents a very strong connection; yellow is a weaker connection.

| Metrics for Ecological structure indicators | | Direct counts - inventory | Temperature, rainfall, climate (wind), insolation, topography, rock type. | Chemical attributes / pH | Hummus depth, dry/ wet matter weight. | Soil structural attributes: Bulk density, compaction, type, parent material | Assessment of subsoil invertebrate fauna. Earthworm count | Air: Particulate sampling. Smell. Days with airborne particulates over limit | DNA analysis: Mitochondrial or cellular DNA markers. Soil fumigation | Photographic analysis: Photo points, electronic area cover/ density analysis and camera traps | GIS mapping and LiDAR: Species distribution, habitat, territory and nest mapping. Mapping of disturbance extent (human or natural) | Database interrogation: e.g. LCDB, LENZ or NIVS. Species and habitat threat classification databases. Modelling | Bird population counts: 5MBC, slow walk transects. Netting. Tagging (including radio tagging) | Mammal population counts: Tracking tunnels, Possum RTC, small mammal interference devices, faecal pallet counts. Trapping, hunting effort and bait take. Night spotlight counts. Tagging (including radio tagging) | Reptile population counts: Artificial refuges and pitfall traps. Tagging (including radio tagging) | Invertebrate population counts: Trapping (pitfall and other traps for flying insects). Beating. Hand Searching. Spotlighting night count. Tagging (including radio tagging) | Other animal population counts: Bats - sonar and roost. Frogs | Vegetation cover assessments: Canopy, ground and understory | Vegetation: Volume - DBH (Diameter at breast height) and density | Seedling and sapling abundance and density | FORMAK/ RECCE or 20 8 20 (NIVS) vegetation plots | Phenology | Yield / growth rate. photosynthesis rate. Leaf physiology structure and area. Dry and weight | Market value | Cost of damage/ mitigation | Aquatic: Chemical analysis of water, pollution and contaminants present - smell of water | Aquatic: Vegetation cover - riparian, macrophytes and peryphyton | Aquatic: Fish - abundance, diversity, health of tuna and other fish species (electro fishing) and netting. Whitebait catch | Aquatic: Invertebrates (MCI) | Aquatic: Sedimentation (clarity disk) | Aquatic: Hydrology - Channel structure, water volume (flow meter), sound and tone of water | Aquatic: Mapping- GIS mapping of modified zones, recharge zones, vegetation cover, erosion zones and land use change in catchment | Cultural Health Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abiotic factors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Biodiversity | Biodiversity: Species richness, abundance, frequency, rareness, evenness, density - biodiversity indices | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Genetic diversity - morphological, physiological and behavioural diversity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Biomass | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Focal species: Monitoring of important species including cultural key stone species | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Focal species: Bio-Indicators | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Focal species: Pest species infestation abundance, location and distribution | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Presence of rare threatened spp. - birds, invertebrates, reptiles or plants | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Functional diversity | Population persistence and habitat requirements - minimum viable population size, temporal changes and habitat requirements | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dispersal range, speed, direction and constraints | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Habitat occupancy: Fidelity, availability, location, area and carrying capacity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Functional diversity: Occupancy of niches, presence of predators, presence of guilds | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Indigenous dominance | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Species distributions and actual and potential | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Population structure: Demographics, sex ratio, meta population data, sources and sinks, life history and reproductive strategies, adult mortality and fecundity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ecological integrity | Spatial heterogeneity and variability. Ecosystem diversity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Fragmentation: Mean and Variance in inter-patch size | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Fragmentation: Mean and Variance in inter-patch distance | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ratio of edge to core | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Connectivity: Corridors and stepping stones | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Habitat/ecological persistence - land use change, vegetation cover change and deforestation rate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Habitat/ecosystem rarity and representativeness - threat classification | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Metrics for Ecological function and process indicators | | Direct counts - inventory | Temperature, rainfall, climate (wind), insolation, topography, rock type. | Chemical attributes / pH | Hummus depth, dry/ wet matter weight. | Soil structural attributes: Bulk density, compaction, type, parent material | Assessment of subsoil invertebrate fauna. Earthworm count | Air: Particulate sampling. Smell. Days with airborne particulates over limit | DNA analysis: Mitochondrial or cellular DNA markers. Soil fumigation | Photographic analysis: Photo points, electronic area cover/ density analysis and camera traps | GIS mapping and LiDAR: Species distribution, habitat, territory and nest mapping. Mapping of disturbance extent (human or natural) | Database interrogation: e.g. LCDB, LENZ or NIVS. Species and habitat threat classification databases. Modelling | Bird population counts: 5MBC, slow walk transects. Netting. Tagging (including radio tagging) | Mammal population counts: Tracking tunnels, Possum RTC, small mammal interference devices, faecal pallet counts. Trapping, hunting effort and bait take. Night spotlight counts. Tagging (including radio tagging) | Reptile population counts: Artificial refuges and pitfall traps. Tagging (including radio tagging) | Invertebrate population counts: Trapping (pitfall and other traps for flying insects). Beating. Hand Searching. Spotlighting night count. Tagging (including radio tagging) | Other animal population counts: Bats - sonar and roost. Frogs | Vegetation cover assessments: Canopy, ground and understory | Vegetation: Volume - DBH (Diameter at breast height) and density | Seedling and sapling abundance and density | FORMAK/ RECCE or 20 8 20 (NIVS) vegetation plots | Phenology | Yield / growth rate. photosynthesis rate. Leaf physiology structure and area. Dry and weight | Market value | Cost of damage/ mitigation | Aquatic: Chemical analysis of water, pollution and contaminants present - smell of water | Aquatic: Vegetation cover - riparian, macrophytes and peryphyton | Aquatic: Fish - abundance, diversity, health of tuna and other fish species (electro fishing) and netting. Whitebait catch | Aquatic: Invertebrates (MCI) | Aquatic: Sedimentation (clarity disk) | Aquatic: Hydrology - Channel structure, water volume (flow meter), sound and tone of water | Aquatic: Mapping- GIS mapping of modified zones, recharge zones, vegetation cover, erosion zones and land use change in catchment | Cultural Health Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem function | Forest (Tane Mahuta): Vegetation cover and type | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Canopy structure, openness, gap characteristics and damage | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Tier Structure | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Forest height and tree diameter | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Succession | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Phenology | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Forest (Tane Mahuta): Growth - leaf area and structure | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystems: Fish and invertebrate diversity, distribution, and abundance and habitat quality. Macro and macrophyte diversity, distribution and abundance | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystem: Riparian habitat provision, water shading and temperature regulation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystem: Flow regulation water storage, precipitation, and channel modification | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystem: Erosion - zone extent and sediment load | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystem: Waterway and wetland habitat provision, water clarification and storage | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Aquatic ecosystem: Water quality - nitrification, clarity and contamination | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Soil (one one ): Fertility, nutrient cycling, chemistry | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Soil (one one ): Structure- porosity, compaction, mineral composition, bulk density etc. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Soil (one one ): Organic matter and humus layer depth | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Soil (one one ): Biodiversity of macro/micro biome | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Decomposition | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Air (Tāwhiri mātia): Quality- particulate pollution, gas chemistry and temperature regulation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Air (Tāwhiri mātia): Co2 Sequestration and Air. Carbon accounting | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# Metrics for Ecological service indicators

| Metrics for Ecological service indicators | Provisioning services | | | Regulating services | | | | Cultural and Social: Cultural landscape and management | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary production - photosynthesis | Primary production - raw materials | Pollination: Pollination of bees, reptile, birds, and other pollinating inverts | Nutrient concentrations and cycling | Biochemical and genetic | Biocontrol: infestation and disease incidence, abundance and release sites | Resilience: Invasive species abundance, erosion, flood protection, land use and deforestation rate | Nomenclature | Built capital - inventory of built structures | Human capital - inventory of community structure and support | Legal protection - location and extent of area | Culturally important sites - location and number of culturally important sites such as wāhi tapu | Number of visitors and destinations | Inspiration - art and cultural sites. Stories | Taniwha - location of sites | Education - location of research and study sites | Historically important sites - location and use | Mana whenua - identity and location | Wellbeing - sense of connection and spiritual wellbeing. Recreational use | Medicinal plants - location of harvest areas | Extent of land use change. Location of at risk/pressure areas | Extent and location of management areas | Extent and location of monitoring programmes | Extent and location of iwi managed land | Extent of co-managed land | Extent of pest management areas (plant and animal) | Access: Location of important social and cultural values and barriers to access | Human food provision. Mahinga kai (Haumai tikitike and Rongo) |
| Direct counts - inventory | | orange | | | | green | green | green | green | green | green | green | green | green | green | green | green | green | | orange | | green | green | green | green | green | green | green |
| Temperature, rainfall, climate (wind), insolation, topography, rock type. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chemical attributes / pH | | | | orange | | | | | | | | | | | | | | | | | | | | | | | | |
| Hummus depth, dry/ wet matter weight. | | | | green | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil structural attributes: Bulk density, compaction, type, parent material | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Assessment of subsoil invertebrate fauna. Earthworm count | | | | orange | | | | | | | | | | | | | | | | | | | | | | | | |
| Air: Particulate sampling. Smell. Days with airborne particulates over limit | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DNA analysis: Mitochondrial or cellular DNA markers. Soil fumigation | | | orange | | green | | | | | | | | | | | | | | | | | | | | | | | |
| Photographic analysis: Photo points, electronic area cover/ density analysis and camera traps | | orange | | | | orange | green | | | | | | | | | | | | | | | | | | | | | |
| GIS mapping and LiDAR: Species distribution, habitat, territory and nest mapping. Mapping of disturbance extent (human or natural) | | green | | | | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | green | orange |
| Database interrogation: e.g. LCDB, LENZ or NIVS. Species and habitat threat classification databases. Modelling | | | | | | | orange | | | | | | | | | | | | | | | | | | | | | |
| Bird population counts: 5MBC, slow walk transects. Netting. Tagging (including radio tagging) | | | green | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mammal population counts: Tracking tunnels, Possum RTC, small mammal interference devices, faecal pallet counts. Trapping, hunting effort and bait take. Night spotlight counts. Tagging (including radio tagging) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reptile population counts: Artificial refuges and pitfall traps. Tagging (including radio tagging) | | | orange | | | | | | | | | | | | | | | | | | | | | | | | | |
| Invertebrate population counts: Trapping (pitfall and other traps for flying insects). Beating. Hand Searching. Spotlighting night count. Tagging (including radio tagging) | | | green | | | green | | | | | | | | | | | | | | | | | | | | | | |
| Other animal population counts: Bats - sonar and roost. Frogs | | | orange | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vegetation cover assessments: Canopy, ground and understory | | | | | | | | | | | | | | | | | | | | orange | | | | | | | | |
| Vegetation: Volume - DBH (Diameter at breast height) and density | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Seedling and sapling abundance and density | | | | | | | | | | | | | | | | | | | | green | | | | | | | | orange |
| FORMAK/ RECCE or 20 8 20 (NIVS) vegetation plots | | orange | | orange | | green | | | | | | | | | | | | | | orange | | | | | | | | orange |
| Phenology | orange | | orange | | | | | | | | | | | | | | | | | green | | | | | | | | orange |
| Yield / growth rate. photosynthesis rate. Leaf physiology structure and area. Dry and weight | green | green | orange | | | | | | | | | | | | | | | | | green | | | | | | | | green |
| Market value | green | green | | | green | | | | orange | orange | orange | | green | | | | | | green | green | green | green | green | orange | orange | green | | green |
| Cost of damage/ mitigation | | | green | | | green | green | | | | | | | | | | | | | | green | | | | | | | |
| Aquatic: Chemical analysis of water, pollution and contaminants present - smell of water | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Vegetation cover - riparian, macrophytes and peryphyton | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Fish - abundance, diversity, health of tuna and other fish species (electro fishing) and netting. Whitebait catch | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Invertebrates (MCI) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Sedimentation (clarity disk) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Hydrology - Channel structure, water volume (flow meter), sound and tone of water | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aquatic: Mapping- GIS mapping of modified zones, recharge zones, vegetation cover, erosion zones and land use change in catchment | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cultural Health Index | | | | | | | | | | | | | | | | | | | | | | | | | | | | |