A review of the funding and prioritisation of environmental research in New Zealand

December 2020

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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Contents

Pellaea rotundifolia

Overview

Twelve months ago I reviewed the adequacy of environmental reporting in Aotearoa New Zealand. What I uncovered was a system that was passive and opportunistic. Beneath the impressive machinery of report production, I found a lack of consistency in the way we monitor the state of things, and in many important domains, an outright absence of data. I summarised our efforts as "cobbling together what we have to hand, trying to solicit the willing engagement of a wide range of stakeholders and putting the hat around to try to plug some of the many gaps."[1]

The gaps I identified weren't just on the monitoring and reporting side. There are also knowledge gaps. That is less surprising – there will always be things we don't know. The question I confronted was whether we were well set up to fill those gaps. My provisional conclusion was as follows:

> "I am not confident that there is a coherent basis for our national investment in environmental science. I am particularly concerned that there is no mechanism that links the ongoing demand environmental reporting makes for an understanding of complex ecological processes that evolve over decades, and a science funding system that is constantly searching for innovation, impact and linkages to the ever-changing demands of business and society."[2]

For that reason I recommended that the Minister for the Environment and the Minister of Research, Science and Innovation ask their officials to advise on how to better link New Zealand's environmental reporting system with the science system to ensure that key knowledge gaps are incrementally closed.[3]

I am now offering my own advice on how that might occur. To provide it, I first needed to understand what environmental research gets funded, and why. In particular, I needed to establish the extent to which publicly funded environmental research is prioritised to address the most important environmental challenges facing Aotearoa New Zealand.

Trying to find out how much we spend on environmental research, what gets funded and its links with policy priorities proved more difficult than I expected. The links between that research investment and ongoing environmental monitoring and reporting are similarly unclear.

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[1] PCE, 2019a, p.3.
[2] PCE, 2019a, p.6.
[3] PCE, 2019a, p.87.

I discovered no shortage of high-level strategic statements supposed to inform research. But the way environmental research is funded is fragmented, and no single agency is responsible for ensuring that our investment in environmental research spans the range of knowledge gaps that need to be filled.

The evidence base assembled for this report can be simply stated – although it was not simple to assemble.

First, what do we spend on environmental research? No agency could say – because there is no agency charged with prioritising and guiding it. The answer depends on your definition, but a narrow definition puts the level of investment at about $427 million per year. A broader definition puts the number at anything up to $516 million. Chapter two navigates the myriad funding 'pots' that exist and the contribution that each makes to environmental research.

I want to be clear that I have no comment to make about the adequacy of that investment – that was not the purpose of this review. Whatever estimate you choose, it is not a small sum so we need to be sure that it is being spent on the things that matter. I have no reason to believe that it isn't, or that there are not important gaps that will require more investment. But without ownership of this investment by an accountable agency, it would be hard to make the case for more.

There is one exception to my reluctance to express an opinion on the adequacy of the environmental research investment and that is in respect of collections and databases. These are vital research tools and have obvious links to environmental monitoring. Chapter three is devoted to them. It is clear from my enquiries that the absence of an overview and the focus of the current funding system has seen these tools neglected, with researchers being left to cobble together piecemeal solutions to move them forward. I am not the first to comment on this problem. Reviews by Royal Society Te Apārangi and Ministry of Business, Innovation and Employment have failed to move this particular corner of environmental research forward.

Chapter four identifies what long-run strategic priorities exist for environmental research and how they are reflected in the allocation of research funds. There is no shortage of strategic documents to have showered down over the last decade or so. Given the investment of official and ministerial time in developing them, one could reasonably expect that, to the extent they say anything tangible about environmental research priorities, those priorities should be visible in the research funding decisions being taken by key agencies, pre-eminently MBIE.

However, an examination of the criteria governing the allocation of funds under the various funding pots provides no line of sight with the stated priorities for environmental research on current, medium- or long-term issues that are preoccupying those who seek to manage New Zealand's environment.

In my view there should be a strong link between the priorities the Government articulates and where the funding is allocated. That is difficult to achieve if government funding for environmental research comes from multiple funding mechanisms. Central government needs to speak with one voice and it should do that through a regularly updated **environmental research strategy** led by the Ministry for the Environment. This is not a particularly radical suggestion – the bones of such a strategy were put together as recently as 2017 in the Conservation and Environment Science Roadmap.

This strategy should be 'owned' by the Ministry for the Environment, with input from a wide variety of agencies, iwi and interest groups.

Chapter five spells out how such a research strategy should guide the funding of environmental research that supports the public good and informs the environmental reporting system.

The funding system needs to be attuned to the particular characteristics of environmental research. Much of this research involves the patient interpretation and understanding of environmental changes that unfold over decades. It doesn't all need to be novel or innovative – although those qualities may well be in evidence. It is often through meticulous, continuous work that real, perennially applicable discoveries are made. These can, in turn, serve to upend long-held assumptions about ecosystem function, and spawn new ideas and directions.

But this all happens over a long time horizon with implications not just for the selection and funding of research goals, but also for the maintenance of the research workforce and for the collections and databases on which future research must rely.

To recognise this, I am proposing that **public resources for environmental research should be ringfenced** (in much the same way that we ringfence health research funds) and explicitly linked to the proposed environmental research strategy.

Those **funds should be allocated by people familiar with what environmental research entails**, according to **criteria that fit the sort of research required** to understand our highly dynamic New Zealand environment. Allocation should **integrate mātauranga Māori** in a way that allows both mātauranga and science to prosper.

How funds are allocated is the engine room of any system. I propose two institutional models that could achieve what is needed.

The first proposes no new entities and seeks to promote change through altering the roles of key government agencies and the skills available to them. The second option seeks to **embed the necessary expert skills within an Environmental Research Council** – a dedicated funding agency. In my view, the latter option is to be preferred. It will be easier to assemble the specialist skills required and accountability will be clearer.

Under both options it is proposed that **all institutions with relevant expertise should be able to access the available funds** whether they are negotiated or contestable. The emphasis should be on **collaboration**, thereby providing a strong incentive for research institutions independent of central government, such as tertiary institutions and independent research organisations, to align their work with the proposed environmental research strategy.

Simon Upton

Parliamentary Commissioner for the Environment

Hymenophyllum nephrophyllum

Tirohanga whānui

Tekau mā rua marama i mua i arotake au i te tika o te pūrongorongo taiao i Aotearoa. Ko tāku i kite ai he pūnaha hāngū, tūpono noa hoki. I raro i pūrere o te whakaputa pūrongo, i kite au i te kore ōritetanga i te aroturukitanga o te āhua o ngā mea, ā, i roto i ngā wāhi hira, he kore raraunga. I whakarāpopoto pēnei au i ā mātou mahi "he kohikohi i ngā mea kei a mātou, e whakamātau ana ki te tono i te whai wāhi pai ki te whānuitanga o ngā hunga whaipānga me te tuku i te pōtae ki te puru i ētahi o ngā tiriwā maha."[1]

Ehara i te mea ko ngā āputa i kite au kei te taha o te aroturuki me te pūrongorongo anake. He āputa mātauranga hoki. Ehara tērā i te mea ohorere – he mea kāore tātou i te mōhio i ngā wā katoa. Ko te pātai kei mua i a au mēnā e tika ana tā mātou whakaritenga ki te whakakī i ēnei āputa. E pēnei ana taku whakataunga tārewa e whai ake nei:

> "Kāore au i te ngākau titikaha he pūtake mārama mō tō tātou whakangao ki te pūtaiao taiao. E tino māharahara ana au kāore he pūrere e tūhono ana i te hiahia haere tonu a te pūrongorongo taiao mō te māramatanga o ngā hātepe mātai hauropi tuatini kua whanake i ngā tekau tau me te pūnaha pūtea pūtaiao e rite tonu ana te rapu mō te auahatanga, whakaaweawe me ngā tūhono ki ngā pōrearea e panoni tonu ana o te pakihi me te hapori."[2]

Koinā te take i tūtohu au ki te Minita mō te Taiao me te Minita mō te Rangahau, Pūtaiao me te Auaha ki te pātai ki ā rātou āpiha ki te tohutohu me pēhea e pai ake ai te tūhono i te pūnaha pūrongorongo taiao o Aotearoa ki te pūnaha pūtaiao kia whakatūturu e kapia ana ngā āputa mātauranga ā tōna wā.[3]

Nāianei e tuku ana au i taku kupu āwhina mō te ara hei whakatutuki i taua kaupapa. Ki te pēnā, i hiahia au ki te mārama i te tuatahi he aha te rangahaua taiao e whai pūtea ana, ā, he aha ai. Otirā, i hiahia au ki te mōhio ki te whānuitanga o te hāngai o te rangahau taiao ki te urupare i ngā wero taiao matua kei mua kei te aroaro o Aotearoa.

He uaua ake te kite e hia te pūtea e whakapaua ana ki te rangahau taiao, he aha e whai pūtea ana me ōna tūhono ki ngā kaupapahere matua. Kāore hoki i te mārama ngā tūhono i waenganui i te whakangao rangahau me te aroturuki taiao me te pūrongorongo e haere tonu ana.

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[1] PCE, 2019, p.3.
[2] PCE, 2019, p.6.
[3] PCE, 2019, p.87.

He maha rawa ngā tauākītanga rautaki tūhāhā e whakamōhio ana pea i te rangahau. Engari e marara ana te tuku pūtea mō te rangahau taiao, ā, kāore e noho haepapa ana te tari kāwanatanga kotahi ki te whakatūturu ko tā mātou whakangao ki te rangahau taiao e kapi ana i te whānuitanga o ngā āputa mātauranga me whakakī.

He ngāwari te whakaatu i te pūtake taunakitanga i kohia ai mō tēnei pūrongo – engari kāore e ngāwari ana te kohi.

Tuatahi, he aha te nui o te pūtea e whakapaua ana ki te rangahau taiao? Kāore e taea e tētahi tari kāwanatanga te kī – nā te mea kāore he tari kāwanatanga e noho haepapa ana ki te whakarite i tēnei hei kaupapa matua, ā, hei ārahin hoki. Ko te whakautu e hāngai ana ki ō ake whakamāramatanga, engari e ai ki te whakamāramatanga whāiti ko te taumata whakangao ko te $427 miriona ia tau. E ai ki te whakamāramatanga whānui ake ka eke pea ki te $516 miriona. Ka whakatere te upoko tuarua i ngā 'tahua' pūtea huhua me te tāpaetanga o tēnā, o tēnā ki te rangahau taiao.

E pīrangi ana au kia tino mārama kāore au i te kōrero mō te tika o taua whakangao – ehara tērā i te kaupapa o tēnei arotake. Ahakoa he aha te whakatau tata e kōwhiria ana, ehara i te pūtea iti nā reira e tika ana kia whakatūturu e whakapaua ana ki ngā kaupapa matua. Kāore e kore e whakapaua ana ki ngā kaupapa matua, ā, tērā he āputa me kapi ki te whakangao. Engari, ki te kore e noho haepapa ana tētahi tari kāwanatanga, he uaua ki te tohe mō ētahi atu pūtea.

Kāore au e hiahia ana ki te whakaatu i taku whakaaro mō te tika o te whakangao rangahau taiao hāunga ngā kohinga me ngā raraunga. He taputapu rangahau hira ēnei, ā, he hononga mārama ki te aroturuki taiao. Koinā te kaupapa o te upoko tuatoru. Nā taku rangahau e mārama ana nā te kore tirohanga whānui me te arotahi o te pūnaha pūtea onāianei kua whakahapatia ēnei taputapu, ā, kāore e taea e ngā kairangahau te whakakotahi i ngā whakatikatika kia ahu whakamua. Ehara au i te tangata tuatahi ki te kōrero mō tēnei raruraru. Kāore i taea e ngā arotake a Te Apārangi me Hīkina Whakatutuki te neke whakamua i tēnei kokonga o te rangahau taiao.

Ka tautuhi te upoko tuawhā i ngā kaupapa matua rautaki karioi mō te rangahau taiao, ā, he pēhea e whakaatahia ana i roto i te tohatohatanga o ngā pūtea rangahau. Kāore e ārikarika ngā tuhinga rautaki kua tatū mai i te tekau tau kua pahure ake nei. Nā te whakangao o te whakapaunga kaha o ngā āpiha me ngā minita ki te whakawhanake i aua mea, tērā e pōhēhētia, ki te whānuitanga o te kōrero whaikiko mō ngā kaupapa matua rangahau taiao, e kitea ana aua kaupapa matua i roto i ngā whakataunga pūtea rangahau a ngā tari kāwanatanga matua, otirā, ko Hīkina Whakatutuki.

Heoi anō, ki te āta tirohia ngā paearu e pā ana ki te tohatohatanga o ngā pūtea i raro i ngā tahua pūtea huhua, kāore he hononga mārama ki ngā kaupapa matua mō te rangahau taiao kua kōrerotia mō ngā take onāianei, ākuanei, haere ake nei rānei e whakaarohia ana e rātou mā e whakahaere ana i te taiao o Aotearoa.

Ki ōku nei whakaaro he mea nui kia noho te hononga kaha i waenganui i ngā kawatau e whakahuatia ana me te wāhi e tohaina ai te pūtea. He uaua ki te whakatutuki mēnā e puta mai ana i ngā pūrere tuku pūtea huhua. Kia kotahi anake te reo nō te kāwanatanga, ā, me mahi pēnā mā te **rautaki rangahau taiao** e whakahoungia ana, ā, e ārahina ana e te Manatū Taiao. Ehara tēnei i te marohi hou – ko ngā wheua o te rautaki pēnei i hangaia i te tau 2017 i roto i te Mahere Huarahi mō te Pūtaiao Whāomoomo me te Taiao.

Me noho tēnei rautaki i raro i te 'mana' o te Manatū Taiao, me te whakaurunga o ngā kōrero mai i te huhua o ngā tari kāwanatanga, iwi, me ngā rōpū whaipānga.

E whakahua ana te upoko tuarima me pēhea te rautaki rangahau e ārahi i te tuku pūtea ki te rangahau taiao e tautoko ana i te painga tūmatanui, ā, e whaimōhio ai te pūnaha pūrongorongo taiao.

Me hāngai te pūnaha pūtea ki ngā āhuatanga motuhake o te rangahau taiao. Ko te nuinga o tēnei rangahau e pā ana ki te āta whakamārama me te mōhiotanga ki ngā panonitanga taiao e puta mai ana i roto i ngā tekau tau. Ehara i te mea me whakahou, me auaha hoki – engari, ka kitea pea aua āhuatanga. Mā te mahi tūpato e haere tonu ana, e puta mai ai ngā kitenga tūturu e hāngai ana haere ake nei. Waihoki, ka āhei ēnei te tautoko ki te whakahē i ngā pōhēhētanga wā roa mō te mahinga pūnaha hauropi, me te whakaputa i ngā whakaaro me ngā ahunga hou.

Engari ka mahia tēnei i te wā roa kia tae atu ki te pae tawhiti me ngā pānga mō te kōwhiringa me te tuku pūtea mō ngā whāinga rangahau, engari mō te whakapūmau tonu anō hoki o te rāngai rangahau me ngā kohinga, me ngā raraunga e whakawhirinakitia ai e te rangahau ā muri ake nei.

Hei whakatinana i tēnei, e marohi ana au **me karapoti ngā rauemi tūmatanui mō te rangahau taiao** (pērā i te karapotitanga o ngā pūtea rangahau hauora) me te āta tūhono ki te rautaki rangahau taiao e marohitia ana.

Me tohatoha ngā tāngata e matatau ana ki te āhuatanga o te rangahau taiao i ēnei pūtea, e ai ki **te paearu tika mō taua tūmomo rangahau e hiahiatia ana** ki te tino mārama ki tō tātou taiao hurihuri i Aotearoa. **Me pāhekoheko te mātauranga Māori** kia puāwai tahi te mātauranga me te pūtaiao.

Ko te tohatoha o ngā pūtea te tino pūrere o te pūnaha. E marohi ana au i ngā tauira whakanōhanga e rua hei whakatutuki i ngā mea e hiahiatia ana.

Ko te marohi tuatahi kāore he rōpū hou, ā, e rapu ana ki te whakarewa i te panoni mā te whakarerekē i ngā mahi o ngā tari kāwanatanga matua me ngā pūkenga e wātea ana ki a rātou. E rapu ana te kōwhiringa tuarua ki **te whakapūmau i ngā pūkenga mātanga e hiahiatia ana i roto i te kaunihera rangahau taiao** – he tari kāwanatanga tuku pūtea motuhake. Ki a au, he pai ake te kōwhiringa tuarua. He ngāwari ake ki te whakaemi mai i ngā pūkenga mātanga e hiahiatia ana, ā, e mārama ake ana te noho haepapa.

I raro i ngā kōwhiringa e rua e marohitia ana **ko ngā whakanōhanga me te mātanga hāngai me āhei te whiwhi ki ngā pūtea e wātea ana** ahakoa he mea whiriwhiri, he mea whakataetae rānei. Me whakanui i **te mahi tahi**, nā reira e tuku ana i te whakapoapoa kaha ki ngā whakanōhanga rangahau e tū motuhake ana ki te kāwanatanga, pērā i ngā whare wānanga me ngā rōpū rangahau motuhake ki te tīaroaro i ā rātou mahi ki te rautaki rangahau taiao e marohitia ana.

Simon Upton

Te Kaitiaki Taiao a te Whare Pāremata

Hymenophyllum multifidum

1 Introduction

Objectives and scope of this review

This review aims to determine the dimensions of publicly funded environmental research in New Zealand – what gets funded and why. In particular, it seeks to establish the extent to which publicly funded environmental research is prioritised to address the environmental challenges that central and local government agencies are grappling with, and whether the current funding system could be improved.

It has its roots in my November 2019 review of the Environmental Reporting Act 2015.[1] Only robust evidence-based information can help to define a clear and objective picture of the state of the environment. One finding of my review was the paucity of data and lack of robust processes for developing and maintaining databases and infrastructure needed to support environmental reporting.

Meaningful and trustworthy environmental reports need robust science-based data that can only be obtained through consistent monitoring, reliable databases and well-focused environmental research. Without research we may not be able to generate new knowledge or make sense of the data that we collect. High-quality data collection and management of it are, in turn, necessary to identify questions that require research. More generally, research and science that enable us to understand the way our physical environment works and how it is changing provide vital information that can inform decisions made by government policymakers and private stakeholders.

Trying to find out why we do the environmental research we do and the extent to which it informs these decisions has not proved easy. Public funding for environmental research is fragmented, its links with policy priorities are not always obvious and its contribution to ongoing environmental monitoring and reporting is uneven. This is despite several strategies having been developed by ministries and government departments – but for which uptake and implementation is lacking.[2]

[1] PCE, 2019a. For a copy of my review see the PCE website (https://www.pce.parliament.nz/media/196940/focusing-aotearoa-new-zealand-s-environmental-reporting-system.pdf).

[2] Examples include MBIE (2015), MfE and DOC (2017) and MPI (2017).

Local and central government strategies, roadmaps and policy statements, as well as research organisations' statements of intent were examined to provide guidance on where environmental research and science efforts are currently focused.

A detailed stocktake of public spending on environmental research by central and local government agencies was also undertaken to quantify the amount of public-good environmental research funded in New Zealand, map where those funds are spent and determine the extent of any linkages to the many strategy documents.

Finally, key stakeholders in environmental research, including central government agencies (ministries and departments), Crown Research Institutes (CRIs), tertiary institutions, regional councils and unitary authorities were consulted to hear their views on how environmental research in New Zealand is strategized, prioritised and funded; its relevance to society's needs; and whether the results of that research are contributing to the environmental challenges that New Zealand faces.[3]

Source: Pauline SALLET, Flickr

Figure 1.1: Robust policies and decision making based on quality data and research are needed to ensure that places like Blue Spring, Waihou River, are protected for generations to come.

[3] Throughout this report "regional councils" also includes unitary authorities.

What does environmental research include?

For a stocktake of environmental research to make sense, clear definitions of *the environment, environmental science* and *environmental research* are needed.

What is meant by *the environment* is very much context-dependent. There is a continuum between two extreme notions of the environment: at the one end is an encompassing, all-inclusive definition that comprises all natural and anthropogenic phenomena, organisms and features from the stratosphere to the Earth's core – a vision not dissimilar to te ao Māori. At the other end is a more circumscribed definition of the *natural* environment that is limited to the non-urban land and water environment at the surface of the Earth, including the immediate geological subsurface and atmosphere.

The Organisation for Economic Co-operation and Development (OECD) provides a definition of environment as: "the totality of all the external conditions affecting the life, development and survival of an organism", which is closer to an all-encompassing definition than a restrictive one.[4]

Adding the word *science* or *research* after *environmental* adds a further level of complexity.[5] The term *environmental science* remains a somewhat loose concept that lends itself to a variety of definitions. For example, it can refer to:

- an understanding of natural biogeochemical processes; or, more broadly,
- the development of evidence-based practices to mitigate the impact of anthropogenic activity on the natural environment; or, more broadly still,
- the application of natural and social sciences, to provide integrated, quantitative and interdisciplinary approaches to the study of environmental systems and the development of solutions to environmental problems.[6]

Environmental research aims to provide new knowledge needed to understand environmental problems and solve them.[7] Environmental research needs and overlaps with many scientific domains such as agriculture, health, or natural hazards. It also requires an ever-increasing input from social science, urban and landscape development, construction and transport to understand human relationships with, and perceptions of, the environment, and to enable the development of evidence-based policies. Environmental research in the New Zealand context must also embrace mātauranga Māori at the heart of its enterprise.

Environmental research fundamentally relies on the acquisition and management of data, knowledge and the curation of heritage, cultural, scientific and natural collections.

The interrelationships between environmental research and the economy have also increased significantly in recent decades, as phenomena such as climate change have forced a recognition that our economic and social systems rely on functioning ecosystems.

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[4] OECD, 2008, p.176.

[5] Sandhu, 1977.

[6] Modified from Wikipedia (see https://en.wikipedia.org/wiki/Environmental_science).

[7] Sandhu (1977) proposes the following definition for environmental research: "scientific activity undertaken with the primary aim of maintaining, restoring, or improving the environment, or for predicting changes in the environment", p.483.

Fortunately, this review did not have to philosophise about the boundaries of environmental research in a vacuum. In 2017, the Ministry for the Environment (MfE) and Department of Conservation (DOC) developed a Conservation and Environment Science Roadmap (CESR) that described environmental research as covering: (1) the condition of environmental assets; (2) the environmental impacts of activities; (3) environmental risks; (4) the characterisation and management of natural capital; and (5) sustainability, especially through indigenous relationships and knowledge.[8]

The Australian and New Zealand Standard Research Classification

To achieve a detailed quantitative assessment of spending on environmental science, we use the Socio-Economic Objectives (SEO) of the Australian and New Zealand Standard Research Classification (ANZSRC).[9] ANZSRC is used to measure and analyse research and development undertaken in Australia and New Zealand.[10] Using such a classification system inevitably imports a prefabricated definition of environmental research that at the margin will exclude investigations that a more inclusive definition might embrace. On the other hand, it provides a common template for reporting and a basis for comparison.

The ANZSRC is a four-level hierarchical classification descending through sectors, divisions, groups and SEOs.[11] The environment sector covers:

> "R&D [research and development] directed towards the study and improvement of the physical environment, both of pristine and degraded or altered conditions. Such improvements may have wider benefits, but these are not the principal objectives of the R&D. It includes studies of the environmental impact of socio-economic activities as well as R&D for the development of social and economic environmental policies."[12]

There are several individual SEOs or groups that are not in the environment sector but which nevertheless relate to environmental science. For instance, all divisions have an environmentally sustainable group (e.g. Environmentally Sustainable Animal Production, Environmentally Sustainable Construction), which has been added to our list of relevant SEOs. Other groups or codes relevant to environmental science have been selected too, for example Environmental Health or Hydrogen-based Energy Systems.

In total, 277 SEOs from 44 ANZSRC groups that relate to environment research were identified.[13] Because few organisations collect information at the level of individual SEOs, attempting to collect a total figure for environmental research expenditure at this level is not possible.

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[8] MfE and DOC, 2017.

[9] See Pink and Bascand (2008) and https://www.abs.gov.au/Ausstats/abs@.nsf/Latestproducts/CF7ADB06FA2DFD69CA2574180004CB82?opendocument.

[10] Note that the ANZSRC was updated in July 2020. For the purpose of this investigation, the most significant change in the new classification is the separation of the Environment division into Environmental management and Environmental policy, climate change and natural hazards. We have not used the new classification here. See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/research-and-data/anzsrc/.

[11] The sectors are identified by a letter, while divisions, groups and objectives are each assigned two digits so that any SEO is identified by a unique six-digit code. The 2008 ANZSRC SEO classification has five sectors, 17 divisions, 119 groups and 847 objectives. The environment sector has one division (Environment) and 15 groups (including one group for SEOs not classified elsewhere).

[12] See https://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/C9F5D1A8043677CFCA257418000525FE?opendocument.

[13] See Appendix 1.

To produce a more accessible overview and to simplify our analysis, we combined the 277 SEOs into the 11 **classes** shown in Table 1.1. Seven classes relate to the environment sector and provide a way to generate a conservative estimate of environmental research expenditures. We refer to this as our *narrow* definition. Four extra classes of environmentally related SEOs were generated from other sectors. We refer to the 11 classes together as our *broad* definition.

Funding agencies were asked to map their spending to these 11 classes if at all possible.

Table 1.1: The 11 classes generated from 44 ANZSRC groups used for this review.

Parliamentary Commissioner for the Environment Socio-Economic Objective classes	
Narrow definition	• Air and climate • Biodiversity and pest control • Ecosystem management and rehabilitation • Land and water • Natural hazards • Standards, policy and evaluation • Other environment
Broad definition	• Production and primary products • Energy and resources • Health and social • Sustainable economy

Note: See Appendix 1 for ANZSRC groups within each class. Narrow definition based on the 15 ANZSRC groups from the Environment sector (2008 ANZSRC SEO code 96) plus relevant groups from Expanding Knowledge sector (2008 ANZSRC SEO code 97). Classes in the broad definition only include ANZSRC groups or categories that are relevant to the environment.

Beyond the broad areas of research that these aggregations of SEOs represent, there is a common practice of describing research as applied or non-applied. This is not necessarily helpful. Thinking about research as applied or not-yet-applied might be a more accurate way to describe its proximity to the knowledge in question being used.

Nevertheless, there is a tendency to classify research science on a continuum from blue-skies to applied. The Ministry of Business, Innovation and Employment (MBIE) uses a three-horizon classification – H1) leverage proven ideas; H2) develop emerging ideas; H3) generate new ideas – that roughly matches the ANZSRC definitions of pure and strategic basic research, applied research and experimental development.[14]

[14] See https://www.abs.gov.au/ausstats/abs@.nsf/Products/1297.0~2008~Main+Features~Chapter+2,Type+of+Activity?OpenDocument.

Our ability to track environmental research expenditure over time across these horizons using SEOs is limited. This is because widespread classification has only recently started to occur. The motivation for this has been the rollout of the New Zealand Research Information System, developed by MBIE to standardise reporting, including wider use of the ANZSRC system across various funding mechanisms.[15]

For example, Endeavour Fund programmes and Smart Ideas have been coded by SEO since their inception in 2016, while the Strategic Science Investment Fund (SSIF) and National Science Challenges (NSCs) only started to be coded for the 2018/19 financial year. The Marsden Fund administered by Royal Society Te Apārangi (RSNZ) is in the process of being classified using SEO, having only been classified by the ANZSRC Field of Research in the past.[16]

One challenge for all public investment in research – and one that environmental research does not escape – is the need to strike a balance between the three horizons across the many funding mechanisms that exist to reflect national priorities and to acknowledge the infrastructure necessary to support all three horizons. Where multiple funding sources are in play, national overarching strategies are needed not only to set the priorities for the field of research (in this case the environment) but also to drive the allocation of resources across all three horizons.

[15] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/research-and-data/nzris/background/.
[16] See https://www.royalsociety.org.nz/assets/2020_EOI-Guidelines_FS-STD-v5.pdf, p.21.

2

Gleichenia dicarpa

The New Zealand environmental research landscape

Policymakers and taxpayers alike are entitled to know how much public money is spent on environmental research, and to what end. This chapter examines how much publicly funded research is devoted to the environment in total, how that is apportioned between different funding agencies and, to the extent possible, the socioeconomic outcomes to which it contributes.

Public research expenditure on environmental science

At a national level, gross expenditure on research and development has been increasing in New Zealand, from $2,161 million in 2008 to $3,894 million in 2018.[1] In 2018 the government sector made up 20 per cent of expenditure, higher education (25 per cent) and the business sector (55 per cent) accounted for the remainder.[2]

These data come from the research and development survey run biennially by Stats NZ to provide an overview of the research and development landscape in New Zealand. Survey results are also used by international organisations such as the OECD.

When compared with OECD countries or the seven countries of the Small Advanced Economies Initiative, New Zealand's investment on research and development is low.[3] For example, in 2018 New Zealand's gross expenditure on research and development was 1.4 per cent of its GDP, compared with the OECD average of 2.4 per cent.[4] This relatively low overall investment is explained in part by the low level of business expenditure on research and development.[5]

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[1] Figures quoted in this report are not inflation adjusted. Calendar years are cited as e.g. "2018"; financial years are cited as e.g. "2017/18".

[2] Stats NZ, 2019.

[3] MBIE, 2018b, p.60; OECD, 2020. The Small Advanced Economies Initiative is a collaboration of small nations that face similar challenges and opportunities in an increasingly interconnected and competitive global economy. Small advanced economies are Denmark, Finland, Ireland, Israel, New Zealand, Singapore and Switzerland. See https://smalladvancedeconomies.org/.

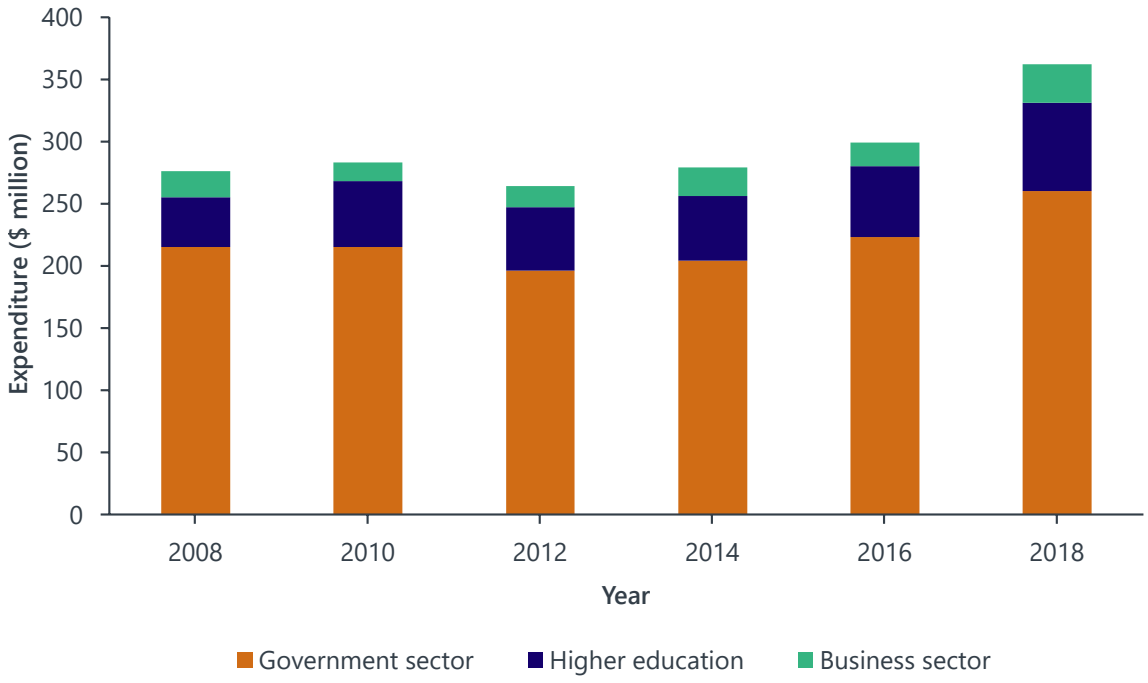
[4] OECD, 2020. GERD is defined as the gross expenditure (current and capital) on research and development carried out by all resident companies, research institutes, university and government laboratories, etc. in a country. It includes research and development funded from abroad but excludes domestic funds for research and development performed outside the domestic economy.

[5] MBIE, 2018b, p.25.

When broken down by the purpose that ultimately benefits from research and development, total expenditure on environmental research for New Zealand in 2018 was $362 million (or nine per cent of gross expenditure). The environment ranked fifth in terms of expenditure, behind primary industries, manufacturing, health and information and communication services.

At $260 million, the government sector accounted for 72 per cent of the total expenditure on environmental research in 2018. Higher education (20 per cent) and business (nine per cent) made up the remainder (Figure 2.1).[6]

The Government is, therefore, the largest investor in environmental research in New Zealand. The environment makes up 33 per cent of its gross expenditure on research and development. This is unsurprising, as an understanding of the environment, its inherent processes, the threats posed by natural systems and the means to mitigate them constitute classic public goods that are the natural domain of central government.[7]



Source: Stats NZ, 2019

Figure 2.1: Results from Stats NZ research and development survey 2019 showing the amount of environmental research by sector over time.

Who funds what?

While national level statistics give an indication of the quantum of research and development in New Zealand, and the broad purpose to which that funding is put, they do not tell us who is making the funding decisions and how those decision are being made. Furthermore, categorisation is at a very broad level. There is no way of knowing what types or domains of environmental research are being funded. To do this, questions need to be asked of the organisations that are allocating the funding.

[6] Stats NZ, 2019. Note, numbers do not add to 100% due to rounding.

[7] MBIE, 2015. p.44.

Central government funding for environmental research is provided by Parliament under a range of different Vote appropriations. The bulk of environmental research undertaken in New Zealand is funded though Vote Science and Innovation. A non-negligible part of the funding is also provided through Vote Environment, Vote Conservation, Vote Agriculture, Biosecurity, Fisheries and Food Safety, Vote Tertiary Education and to a lesser extent Vote Health and Vote Arts, Culture and Heritage.

The central government agencies that fund environmental research include MBIE, MfE, the Ministry for Primary Industries (MPI) and DOC. MfE, MPI and DOC also conduct their own environmental research. A significant contribution from regional councils and unitary authorities must also be added to this central government contribution to environmental research.

An attempt has been made to assemble as complete a figure as possible of the total expenditure from central and regional government agencies and the tertiary education sector on environmental research. The exercise is fraught with difficulties because the system is not designed to report in this way.[8]

The contributions of the private sector and philanthropic organisations to environmental research have not been assessed. Their expenditures on research and development may at times focus on the environment but they are not directly dependent on any public strategy, prioritisation or funding. The private sector contribution remains relatively small, with $46 million spent on environmental research and development in 2019 (which represents 1.9 per cent of the approximately $2,400 million that the business sector spent on research and development in New Zealand).[9]

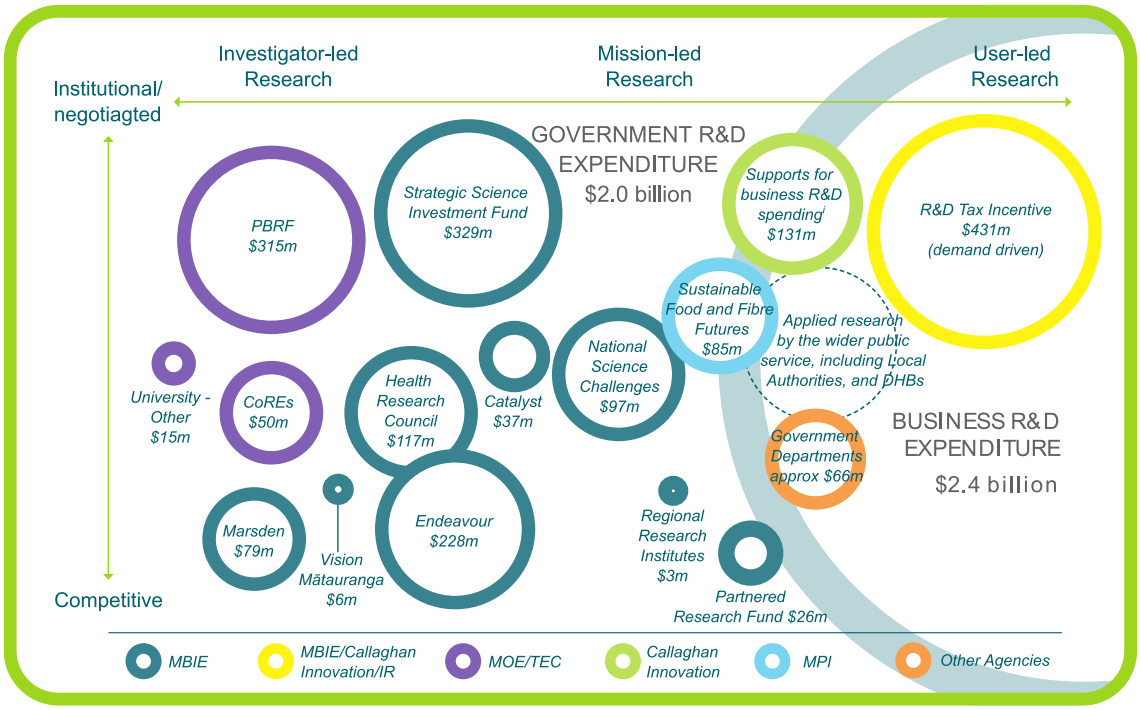
Most people associate the expenditure of science money not with the departmental appropriations from which it emanates but from the names given to the various funding 'pots'. Figure 2.2 illustrates the size and 'ownership' of these different funding mechanisms in relation to two axes: the extent to which the fund is contestable or negotiated, and the location of the fund along a continuum from investigator-led research to user-led research. Each pot has its own requirements and it is these that need to be addressed to reach any conclusions about the way funds are prioritised or linked to national strategic environmental goals.

The following sections outline the basis on which funds are managed and attempts to identify the fraction of each fund that is allocated to environmental research.

Using a broad definition of environmental science (see chapter one) we estimate that a total of $373 million was spent by central government agencies on environmental research in 2018/19 – the only year for which such comprehensive mapping has been possible. A conservative estimate of $286 million was generated using a narrow definition of environmental research. To this, the contribution of Tertiary Education Commission (TEC) funds, such as the Performance-Based Research Fund (PBRF), and that of regional councils should be added. When added, total investment in environmental research ranged from $427 million (narrowly defined) to $516 million (broadly defined).

[8] However, the development of the New Zealand Research Information System represents a promising initiative to make this type of assessment easier when fully implemented.

[9] Stats NZ, 2020.



Source: MBIE

Notes:

i Delivered by Callaghan Innovations, including R&D grants, services and repayable loans.

ii Dollar amounts represent appropriations used in the GBOARD calculation. GBOARD = Government Budget outlays and appropriations on R&D. Business R&D Expenditure from Business R&D survey.

iii R&D = research and development, PBRF = Performance-Based Research Fund, CoREs = Centres of Research Excellence.

Figure 2.2: Distribution of central government investment in all research and development disciplines based on the 2021/22 financial year.[10] The size of the bubbles is proportional to the per-year general funding commitments. The horizontal axis positions the funds on a continuum from investigator-led research (mostly fundamental, new knowledge or H3 type of research), to mission-led research (H2, applied, problem solving), to user-led research (H1, applied, operational). The vertical axis places the funds on a continuum from negotiated to competitive.

[10]MBIE, pers. comm., November 2020.

Funds managed by central government agencies

Ministry of Business, Innovation and Employment

MBIE is responsible for Vote Science and Innovation, which totalled $1,192 million in the 2019/20 financial year, and is the largest source of government funding for science in New Zealand. This appropriation is also the largest source of funds for environmental science.

The bulk of these funds is distributed through the SSIF (25 per cent), the Endeavour Fund (19 per cent), and the NSCs (eight per cent). Another 19 per cent is distributed through research and development Growth Grants, Targeted Business Research and Development Funding, and repayable grants for start-ups to co-fund private businesses for investment, research and development projects, and fund students to work in businesses active in research and development.[11]

The different funds are managed over different time frames, ranging from three to ten years, and with different allocation regimes. SSIF platforms receive between $12 million and $220 million over seven years, while the smallest and largest Endeavour research programmes are both funded for five years, receiving $1.7 million and $19 million respectively (see Table 2.1). In 2017/18 the SSIF Infrastructure fund provided approximately $50 million.[12]

Endeavour Fund

The Endeavour Fund invests approximately $250 million every year into two open, contestable mechanisms: **Research Programmes** and **Smart Ideas**. Policy objectives, investment signals, funding targets and the amounts of money available for the Endeavour Fund are published every year in the Endeavour Fund Investment Plan and Gazette Notice. The key word characterising the Endeavour Fund is that it aims to *transform* New Zealand.

Fierce competition to access the fund has resulted in a success rate of approximately 17 per cent for the entire fund.[13] In 2019, the Endeavour round invested $241 million over five years through 49 Smart Ideas and 22 Research Programmes.[14] MBIE's target was to allocate 25 per cent of its Endeavour Fund to the environmental research objective (with 70 per cent going to economic and five per cent to society).[15] However, using data supplied by MBIE, the estimated contribution of the Endeavour Fund to environmental research announced in 2019 ranged from $92 million (38 per cent) using our narrow definition, to $119 million (49 per cent) using our broad definition.

The Research Programme mechanism invests in ambitious and highly collaborative projects of three to five years' duration with high potential in areas of future value, growth or critical need for New Zealand.[16] In principle, the amount that can be invested in any one project is not capped. In 2020, the Endeavour Fund invested a total of $39 million per year in 17 research programmes. Since 2016, individual research programmes received $8.3 million on average, with the largest individual programmes receiving $19 million over five years (see Table 2.1).

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[11] Growth Grant funding was replaced by the R&D Tax Incentive in March 2020.

[12] MBIE, 2017, p.20.

[13] In 2020, there was a success rate of 13% because only research programmes were open for bidding.

[14] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/success-stories/.

[15] MBIE, 2018a, p.8.

[16] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/.

Table 2.1: Range of funding allocated by MBIE contestable and SSIF funding mechanisms.[i]

Total allocation	Minimum ($ million)	Maximum ($ million)	Maximum duration (years)
SSIF platforms[ii]	12.2	220	7
Endeavour Research Programmes	1.7	18.8	5
Endeavour Smart Ideas	0.5	1	3
National Science Challenges[iii]	47.9	106	10

Notes:

i. The table shows the broad extent of the funds under MBIE's different funding mechanisms. The table does not include funding provided through the SSIF Infrastructure fund, which provides approximately $50.5 million.

ii. All platforms except the NZ Leather and Shoe Research Association. Note that the funds indicated are not necessarily 100 per cent toward environmental research; while most platforms are funded for seven years, some only receive fund for three, four or five years.

iii. These are the amounts received for the two tranches of funding (2013–2019 and 2020–2024) by any one challenge.

The Endeavour Fund uses two criteria to assess research project proposals: **excellence** and **impact**. Proposals must also align with the investment signals in the Investment Plan set out in the Gazette Notice.[17] The assessment process requires that proposals pass the excellence criterion before being assessed for impact. In 2020, the Endeavour Programme call for proposals required proposals to select one of two impact categories: (1) protect and add value, or (2) transform. MBIE believes that the outcome from Endeavour funding is therefore excellence *with* impact.[18]

The Smart Ideas investment mechanism focuses on testing promising research ideas. It encourages a substantial element of scientific or technical risk in the research. The aim is to support the development of new ideas and bolster innovation. In 2019, MBIE invested a total of $49 million in 49 Smart Ideas projects.[19] Smart Ideas projects are funded for a maximum of $1 million spread over three years and involve a smaller team than the Research Programmes. The indicative total investment for all Smart Ideas projects in the 2020 investment round is $18 million per year going forward.[20]

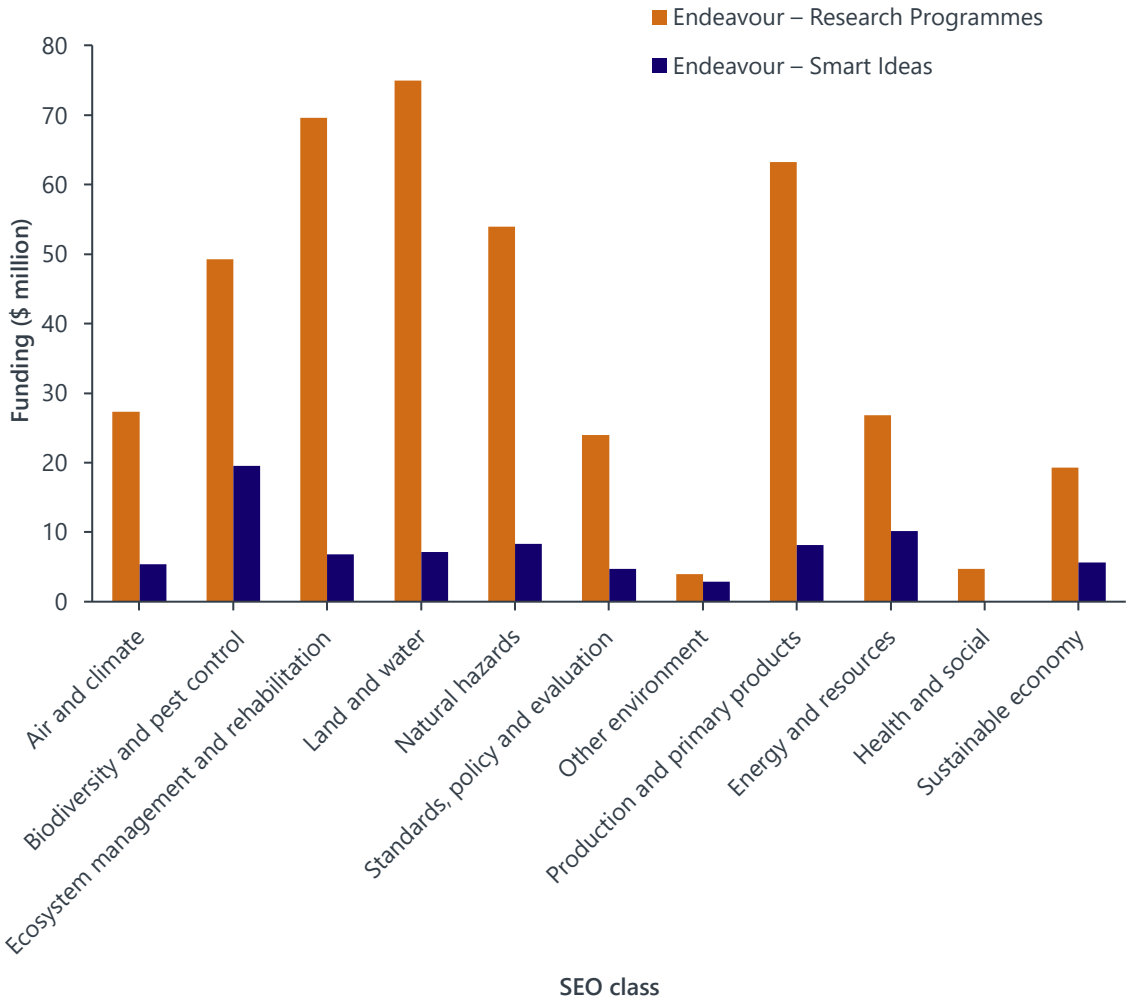
Figure 2.3 shows the total amount announced on environmental research sorted into the 11 classes of our broad definition of environmental research for the Endeavour Fund's Research Programmes and Smart Ideas between 2016 and 2019.

[17] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/application-and-assessment-information/.

[18] MBIE, pers. comm., July 2020.

[19] The 2020 Smart Ideas investment round was cancelled due to the Covid-19 lockdown. Only the Research Programmes were funded.

[20] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/.



Source: MBIE

Figure 2.3: Total Endeavour funding on environmental research announced between 2016 and 2019 by SEO class.

Strategic Science Investment Fund

The SSIF is a negotiated fund between MBIE and science providers that invests in research that has long-term beneficial impact on New Zealand's health, economy, environment and society.[21] The SSIF investments are stated to be:

- strategy driven
- primarily mission led
- a purchase mechanism
- clear about expectations of performance.

[21] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/.

Between 2015/16 and 2019/20, the SSIF has invested $1,488 million, with 97 per cent allocated to CRIs in the years 2016/17 to 2018/19. This proportion dropped to 91 per cent in 2019/20 when other platforms, including independent research organisation (IRO) capability funding, were transferred into the SSIF mechanism and $1.7 million was allocated to universities.

The SSIF has two components: programmes and infrastructure. According to MBIE, SSIF Programmes provide funding for research platforms to enable organisations to undertake long-term, mission-led research programmes. SSIF Infrastructure provides funding for national research infrastructure platforms that offer access to research technology, facilities, infrastructure, Nationally Significant Collections and Databases (NSCDs) and associated support services.[22] Confusingly, the research platforms developed under SSIF Programmes become, in turn, the umbrella for small 'p' programmes.

There are 25 science platforms under SSIF Programmes. A platform is defined by MBIE as "a combination of people, facilities, information and knowledge that provide a particular, ongoing science and innovation capability for New Zealand".[23] Despite the claim of being focused on science and provider neutral, the platforms map squarely onto organisations. Nineteen platforms are hosted by seven CRIs and two IROs, with relatively few platforms shared between two or more research providers.

Out of the 25 platforms, the 21 that are relevant to environmental research are listed in Table 2.2, divided into those that are clearly mainly focused around environmental research, those that are partially so and those that provide infrastructure support for environmental research.

Table 2.2: The 21 MBIE SSIF platforms that have an environmental research focus. Dollar values in million per annum.[24]

Platform	Research institution/ government agency	2018/19 ($ million)	2019/20 ($ million)	Total ($ million)
Major contribution to environmental research				
Antarctic Science platform	Antarctica New Zealand	3.4	4.7	49
Geological processes and hazards	GNS Science	11.3	11.3	99.5
Geological resources	GNS Science	11.0	11.0	71.8
Enhancing land use	MWLR	-	-	64.2
Land-based ecosystems	MWLR	9.2	9.2	57.9
Combatting kauri dieback and myrtle rust	Ngā Rākau Taketake	0.5	7.2	34.5
Climate and weather hazards	NIWA	14.3	14.3	100.2
Freshwater environment	NIWA	11.5	11.5	80.6
Marine environment	NIWA	16.9	16.9	118.7
Nuclear and isotope science	GNS Science	2.6	2.6	21.6

[22] MBIE, 2017, pp.14 and 19.

[23] MBIE, 2017, p.7.

[24] Data from MBIE, received 20 Oct 2020.

Partial contribution to environmental research				
Forest systems	Scion	7.2	7.2	76.1
Manufactured products from trees	Scion	10.2	10.2	75.7
Agri-food production	AgResearch	31.4	31.4	220.5
Premium agri-foods, products and services	AgResearch	12.1	12.1	82.4
Seafood safety and shellfish aquaculture	Cawthron	2.0	2.0	12.2
Shellfish aquaculture	Cawthron	3.0	3.0	18.0
Plant-based food and seafood production	Plant & Food Research	20.9	20.9	146.3
Premium plant-based and seafood products	Plant & Food Research	21.8	21.8	152.7
Agricultural greenhouse gas mitigation technologies[i]	PGgRc and NZAGRC	-	6.8	24.0
Indirect contribution to environmental research				
Data Science platform	University[ii]	-	2.3	49.0
Advanced Energy Technology platform	University[ii]	-	-	40.8

Notes:

i. While the activities of the Pastoral Greenhouse Gas Research Consortium (PGgRc) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) focus on environmental issues, they also relate to agricultural research. This programme starts in 2020/21.

ii. Universities lead some projects that have been funded through these platforms, but do not manage them.

While the SSIF is described as being focused on science or science platforms, not providers, and on being about negotiated partnerships with providers while at the same time being provider neutral, the reality is a little different.[25] Most CRI platforms represent research that had previously been part of the 'core' funding of CRIs. From the outside, it is difficult to determine which agency drove these changes. The CRIs contend that they are responding to national needs and maintain both critical skills and infrastructure with this funding source.[26] Platform funds are integrated into whichever framework of research portfolios, projects or programmes that a particular CRI may operate.

For example, the Land-based ecosystems platform hosted by Manaaki Whenua – Landcare Research (MWLR) contributes to portfolios such as Characterising land resources, which includes research into the "monitoring of versatile land loss, ecosystem services, changes in land cover and land use, as well as supporting tools to model nutrient losses from land, hydrology and climate dynamics".[27] The Geological resources platform hosted by GNS Science contributes to the funding of the Understanding Zealandia programme, which aims to provide underpinning knowledge on the composition, structure, tectonics and geohistory of New Zealand's continental mass.

[25] MBIE, 2017, pp.11–12.

[26] NIWA and, MWLR, pers. comm., 29 October 2020.

[27] See https://www.landcareresearch.co.nz/partner-with-us/our-science-portfolios/characterising-land-resources/.

The reality is that the research undertaken to advance these portfolios or programmes draws on funding the CRIs can gather from whatever source, including contestable funds won from the Endeavour Fund, and even consultancy work. Given that SSIF funding levels have risen only slightly over the last ten years or so, the need to supplement these resources from other sources appears to have become increasingly acute.

The future shape of SSIF platforms may be signalled by two new environment-related platforms that assemble a coalition of providers – the first concerning Antarctica, the second combatting kauri dieback and myrtle rust. The Antarctic Science platform has two programmes – the Antarctic ice–ocean–atmosphere system and Ross Sea region ecosystem dynamics in a warming world – with a total operating budget of $49 million over seven years.[28] These platforms have been negotiated from the outset and appear to be science-based and provider neutral. They seem to encourage participation by all providers that bring relevant skills and capability to their intended outcomes. The host however does not manage capability.

Two platforms, Data Science and Advanced Energy Technology, contribute to a lesser extent to environmental research. These platforms fund three programmes that are run by New Zealand's universities.

In 2018/19, the only year for which SEO data are available, SSIF Programmes environmental research expenditure ranged from $91 million (44 per cent) using our narrow definition, to $116 million (57 per cent) using our broad definition, out of a total of $205 million.[29] To this, SIFF infrastructure expenditure needs to be added. However, SEO data are only available for NSCDs and Genomics Aotearoa.[30] Adding these, the total SIFF expenditure coded to SEO in 2018/19 was $138 million using our broad definition of environmental research.

As a result, this fund contributes a substantial proportion of the total environmental funding, and funds critical infrastructure and capability needed to underpin many other aspects of the total New Zealand science output relating to the environment.

National Science Challenges

Eleven NSCs were established in 2014. The NSC topics were decided by Cabinet, following considerable public engagement and recommendations by an independent National Science Challenges Panel. The challenges are *mission led*. The aim of the challenges was to remove institutional barriers and break silos and disciplinary boundaries to focus on "large and complex issues" providing major and enduring benefits for New Zealand.[31] NSCs draw on and rely on the people and capability employed in their host organisations.

In 2013, MBIE published a call for proposals for the first tranche of funding. Proposals, which included research and business plans, were assessed in depth by an independent panel convened for that purpose. MBIE's science board allocated the funding on recommendations from the panel.

[28] See https://www.antarcticscienceplatform.org.nz/.

[29] Note expenditure data differs from funding data discussed above and in Table 2.2.

[30] Other SSIF Infrastructure expenditure is not coded to SEO as contracts do not directly fund research.

[31] MBIE, 2019a.

Proposals were required to respond to the following requirements:

(a) The proposal is collaborative and will respond to the most important, national-scale issues for New Zealand

(b) The research, science and technology will be excellent quality

(c) The governance, management, and financial arrangements are sound and enduring

(d) The proposal is focused on delivering impact.[32]

NSCs place a strong emphasis on collaboration, Māori and stakeholder engagement and public participation.[33]

MBIE uses its NSC funding to leverage CRI, university and industry resources and align them around the complex issues of national importance that were nominated. The NSCs are directed by their own governance boards.

The NSCs received a total of $258 million from MBIE over their first five years to 2018. They operate principally on the basis of the government grants and aligned funding within their host organisations.

In 2018/19, the only year for which we have SEO classified allocation, NSCs received just under $74 million in total.[34] Five challenges fall completely within our narrow definition of environmental research:

- New Zealand's Biological Heritage
- Our Land and Water
- Resilience to Nature's Challenges
- Sustainable Seas
- The Deep South.

Another three NSCs carry out activities that fall within our broad definition:

- Building Better Homes, Towns and Cities
- Science for Technological Innovation
- Healthier Lives.

We estimate that between $19 and $31 million was allocated to environmental science, using our narrow and broad definitions, respectively, that is between 25 and 41 per cent of the total fund allocated to the NSCs.[35]

Figure 2.4 shows the distribution of environmental research expenditure by SEO classes across all NSCs. This is dominated by ecosystem management and rehabilitation (17 per cent), air and climate (16 per cent), sustainable economy (15 per cent) and production and primary products (13 per cent).

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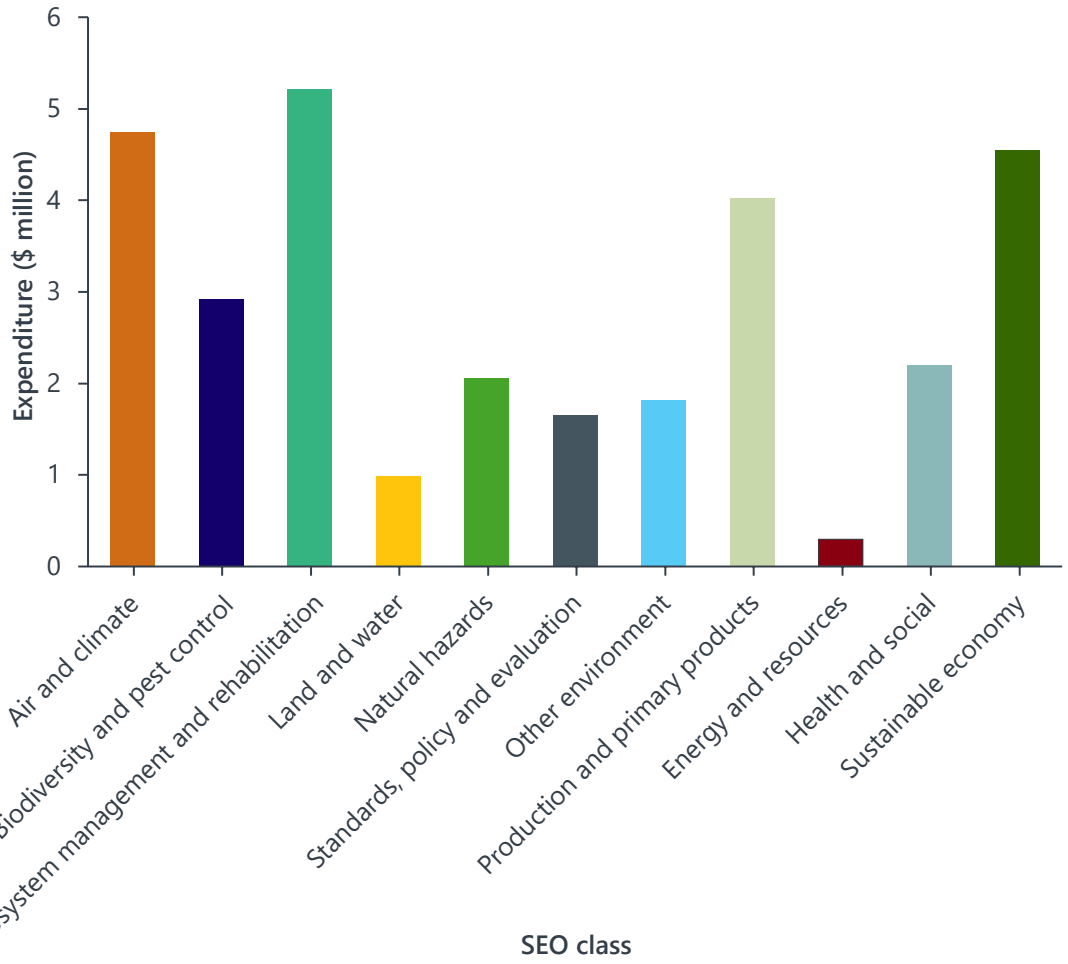
[32] See https://gazette.govt.nz/notice/id/2013-go6245.

[33] For more information see https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/.

[34] New Zealand Government, 2018, p.5.

[35] The conservative amount corresponds to activities specifically coded to the ANZSRC environment category, while the high value includes all our groups (see chapter one for our narrow and broad definitions).

In 2019, the challenges entered their second five-year funding period, for which $423 million was provided. The total funding for the challenges over ten years is $681 million. The current NSC contracts will mature in 2024 and there is no indication to date whether this funding mechanism will be continued.



Source: MBIE

Figure 2.4: Environmental research expenditures grouped by SEO classes for the National Science Challenges, for the year 2018/19.

Envirolink

The Envirolink fund "invests in the transfer of environmental science knowledge to support select regional councils each in their environmental management."[36] With a total allocated budget of $1.6 million – all of which targets environmental research using our narrow definition – this fund is extremely limited compared to the Endeavour Fund and SSIF.[37] It funds between 65 and 85 projects every year for the nine eligible councils.[38]

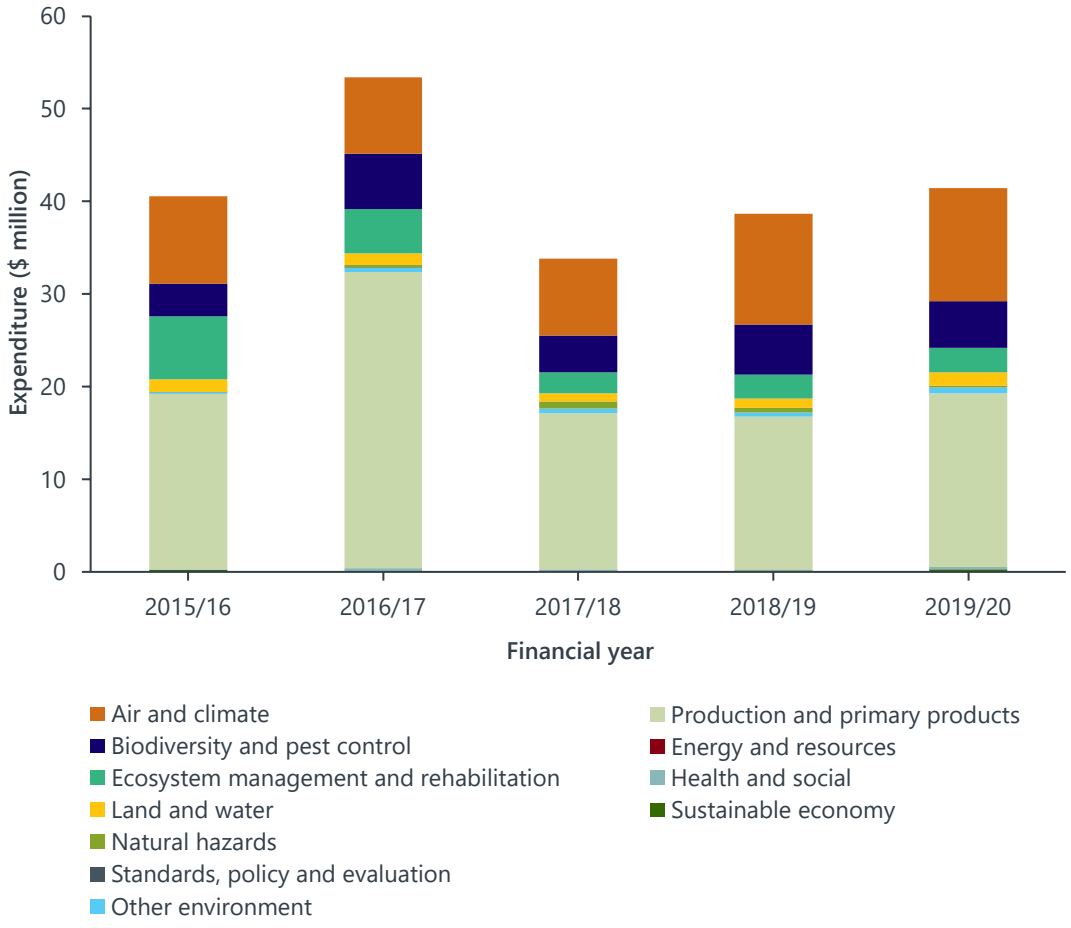
[36] Spee and Oakden, 2019. p.1. The nine eligible councils are Northland Regional Council, Gisborne District Council, Hawke's Bay Regional Council, Horizons Regional Council, Nelson City Council, Marlborough District Council, Tasman District Council, West Coast Regional Council and Environment Southland.

[37] In 2020, Envirolink grant thresholds have increased. Less projects will funded but for higher amounts; see https://www.mbie.govt.nz/about/news/increase-to-funding-thresholds-for-envirolink-advice-grants/.

[38] Source: MBIE data. Count of projects at year start.

Ministry for Primary Industries

From 2015 to 2020, MPI spent an average of $42 million per year on environmental research, ranging from $34 million to $53 million (Figure 2.5). Over the last five financial years, approximately 50 per cent of the expenditure on what MPI classifies as environmental research was spent in the production and primary products SEO, the remainder being largely allocated to air and climate (24 per cent), biodiversity and pest control (12 per cent) and ecosystem management and rehabilitation (nine per cent). Research on fishery sustainability and environmental impact represents between 48 and 70 per cent of the total spent on environmental research by MPI.[39]



Source: MPI

Figure 2.5: MPI spending per SEO classes for the financial years 2015/16 to 2019/20.

[39]The remaining 50% not directly focused on environmental research includes funding extension and commercialisation activities, many of which are focused on environmental sustainability (see https://www.mpi.govt.nz/funding-and-programmes/); John Roche, Chief Science Adviser, MPI, pers. comm., October 2020.

Ministry for the Environment

During the last five years (2015–2020) MfE has spent an average of $4.8 million per year on environmental science. Over the last ten years its environmental science spending increased from around $3 million to over $7 million. The ministry's science investment is with CRIs, DOC and private providers, essentially to develop and improve policy advice. In 2019/20 MfE spent $6 million using our narrow definition and $7 million using our broad definition on environmental research.[40]

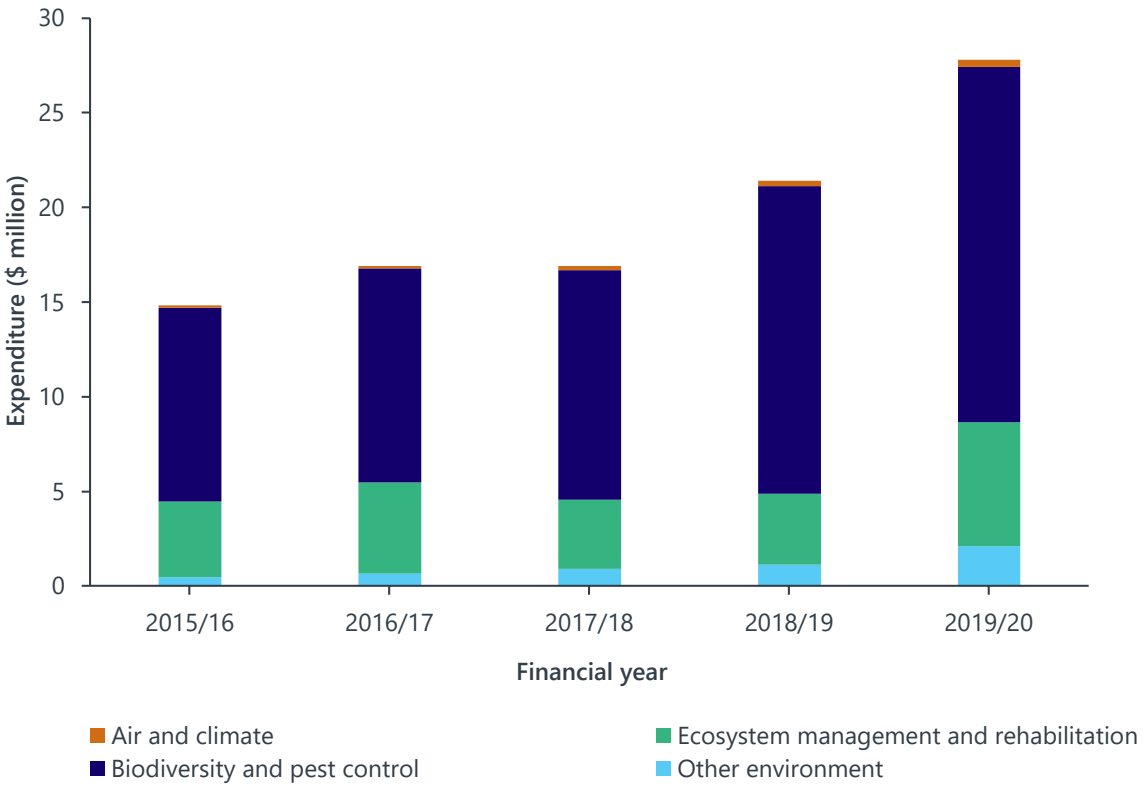
Department of Conservation

DOC conducts a significant amount of operational research to support its statutory role as manager of the conservation estate and the agency responsible for the protection of New Zealand's indigenous biota. In addition, its monitoring makes a contribution to the evidence base on which the wider environmental science community draws. Over the last few years DOC has, in addition, progressively increased its fundamental knowledge research portfolio.

In the 2019/20 financial year, DOC estimates that it spent $27 million on environmental research. Around one third of this was spent on pest and disease control (32 per cent), and just over one third on flora, fauna and biodiversity SEOs (36 per cent).[41] Of the remaining categories, ecosystem management and rehabilitation is the largest, and has increased in volume in recent years. Figure 2.6 shows a consistent increase in expenditure on environmental research in recent years.

[40] MfE notes the following caveats with their dataset: The information is based on a "by-hand" analysis of invoices/providers and some providers may have inadvertently been missed. The categorisation is based on limited information describing the work, and some of the categorisation is arbitrary as there are significant overlaps across work areas (MfE, pers. comm., September 2020).

[41] Combined, these relate to the biodiversity and pest control SEO class in Table 1.1. Expenditures include overheads pro rata to individual SEO classes.



Source: DOC

Figure 2.6: DOC expenditure in environmental research. DOC work programmes and Intermediate Outcome Objectives have been amalgamated into SEO classes (see Table 1.1) and carry an element of subjectivity. Species research and development is included under biodiversity and pest control.

Royal Society Te Apārangi

RSNZ administers several research funds and fellowships, some on behalf of MBIE, such as the Marsden and Catalyst funds. The most prestigious include the Marsden Fund and the James Cook Research, Rutherford Discovery and Rutherford Foundation fellowships. None are targeted towards a specific discipline.

The Marsden Fund is a fully contestable, investigator-led source of funding. It is primarily focused on fundamental science at the H3 horizon, aiming to generate new knowledge and grow future capability. Successful Marsden Fund are highly regarded and sought after, which may partly explain its low success rate of approximately 11 per cent for the 2015–2019 period.[42]

[42] 603 proposals funded out of 5670 expressions of interest (RSNZ, pers. comm., November 2020).

The Marsden Fund Council, which awards the funds, consists of ten discipline-based panels, four of which have an environmental focus. In 2019, the Marsden Fund Council awarded a total value of $84 million, of which a third ($31 million) had elements that could be attributable to environmental research.[43]

The average amount invested by RSNZ in environmental research since 2015 is $29 million using our broad definition, which has been relatively static over that time.[44] The Marsden Fund makes up the bulk of this ($24 million on average).

Regional councils and unitary authorities

Regional councils have substantial responsibilities and an important role in managing the environment, for which science-based decision making is a critical component. While councils have their own ratepayer-based sources of funding, they also rely heavily on environmental research funded by central government, which supports many of their goals. They also collaborate with central government agencies and departments, CRIs, IROs and NSCs.[45]

Councils have a statutory duty to gather information and undertake research to the extent necessary to effectively carry out their functions under the Resource Management Act 1991.[46] To discharge this responsibility, most councils have developed comprehensive monitoring programmes. The need to standardise and align regional monitoring to support national state of the environment reporting was detailed in my 2019 review of the environmental reporting system.[47] Currently the level of reporting is very uneven across different domains and regions.

Producing high-quality data from environmental monitoring requires up-to-date methods, infrastructure and a drive towards use of best practice. Fulfilling state of the environment monitoring and data management requirements is costly for councils. Some of the larger councils also develop specific science projects to deliver on these issues, often in partnership with universities or CRIs.

Fifteen councils provided details on their expenditure in environmental research from 2015 to 2020, with most classifying it based on the ANZSRC codes (see chapter one).[48] The total averaged $74 million per year. However, only fourteen councils provided a breakdown by SEO, shown in Figure 2.7.

[43] The Marsden Fund does not restrict proposals to a particular (Frascati) stage. It does fund a small amount of applied research and experimental development (see https://www.royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden/marsden-announcements/information-on-the-2019-marsden-funding-round/).

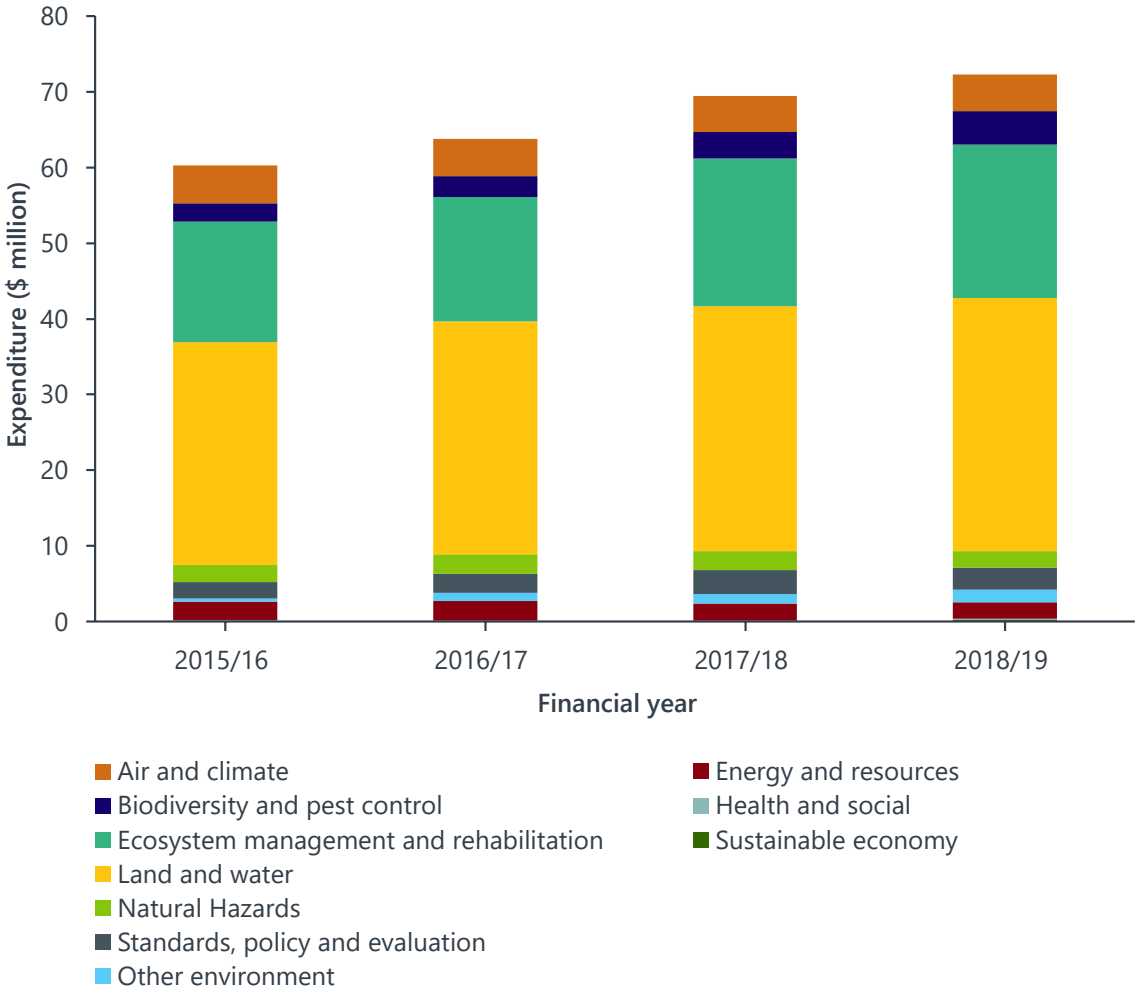
[44] Source: RSNZ. Estimated investment in environmental research using SEO classes carries a degree of subjectivity due to RSNZ having only classified projects by the 2008 ANZSRC Field of Research. Projects will be classified by SEO from 2020 onwards.

[45] Science Advisory Group, 2016.

[46] RMA 1991 s 35.

[47] PCE, 2019a.

[48] West Coast Regional Council and Chatham Islands Council did not provide information.



Source: Compiled from regional council responses

Figure 2.7: Expenditure in environmental research for regional councils by SEO classes for the financial years 2015/16–2018/19. Only includes data from 14 regional councils for which SEO data were received.

Tertiary education

Funding for universities and other institutions that make up the tertiary education sector, such as polytechnics and wānanga, come from a range of sources. Large sources include tertiary education-specific mechanisms, such as the PBRF, other TEC grants and money drawn from the institutions' own funds. In addition, they receive some funding from contestable funds such as the Endeavour and Marsden funds, other government research contracts and overseas and business funding.

The design of specific tertiary funding mechanisms makes it difficult to apportion how each contributes to environmental research. Unlike MBIE grants, funds are not assigned to individual research projects, rather they form bulk allocations to institutions. Any tracking undertaken by universities does not align with the categories of research activity used by MBIE or in this report.[49]

[49] University of Auckland, pers. comm., 27 July 2020.

The Government's most clearly identifiable contribution to research in the tertiary sector is the PBRF administered by TEC. The PBRF does not fund research directly, rather it rewards and encourages excellence in research by assessing the quality of researchers, research degree completion and external research income.[50] Because funds are allocated to institutions not projects, it has not been possible to align the funding with the categories of research examined in this report, and the pool of $315 million 2019 funding is not separated into SEO classes.

Beyond the PBRF, TEC is also responsible for the approval and funding of Centres of Research Excellence (CoREs). The CoREs Fund was established in 2001 to "encourage the development of excellent tertiary education-based research that is collaborative, strategically focused and creates significant knowledge transfer activities."[51] Funding for CoREs is allocated through a competitive process.

TEC has $49.8 million per year to invest in up to ten CoREs. Of the ten CoREs currently being funded, three have significant environmental components. They are Bio-Protection Aotearoa hosted by Lincoln University, Ngā Pae o te Māramatanga hosted by the University of Auckland and Coastal People: Southern Skies hosted by Otago University.[52]

The only relatively complete data source for environmental research in tertiary institutions comes from the 2018 Stats NZ research and development survey.[53] It indicates that $71 million was spent on environmental research by higher education institutions in 2018, an increase from $40 million a decade earlier. This represents seven per cent of total higher education expenditure of $906 million in 2018.

To this, a portion of the research undertaken in tertiary institutions in the primary industries, economic and other sectors could be added in line with our broad definition. However, research in this area is not easy to align to the areas defined in this report, and the total allocation is unclear. For this reason, no estimation of this funding has been made.

Putting it all together

The preceding sections have described the diverse range of public funding sources for environmental research in New Zealand.

Figure 2.8 and Table 2.3 draw this information together to provide a picture of where public environmental funding is coming from and what environmental domain it is going to for the 11 SEO classes that represent the narrow and broad definitions of the environment in the 2018/19 financial year.

The graphic represents only one year of data, as this was the only year for which such comprehensive mapping has been possible. In previous years either data were missing for some funds or there was an absence of information on which to base a categorisation using SEO classes.

Caution is called for in making any judgements based on Figure 2.8 due to a lack of consistency in reporting and classification of environmental research by different institutions. Notwithstanding that, it represents the most up-to-date assessment of how funding for environmental research by central government is currently being allocated in New Zealand.

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[50] See https://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/performance-based-research-fund/.

[51] See https://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/centres-of-research-excellence/.

[52] See https://bioprotection.org.nz/, http://www.maramatanga.co.nz/ and https://www.otago.ac.nz/sciences/research/coastal-people.html.

[53] Stats NZ, 2019.

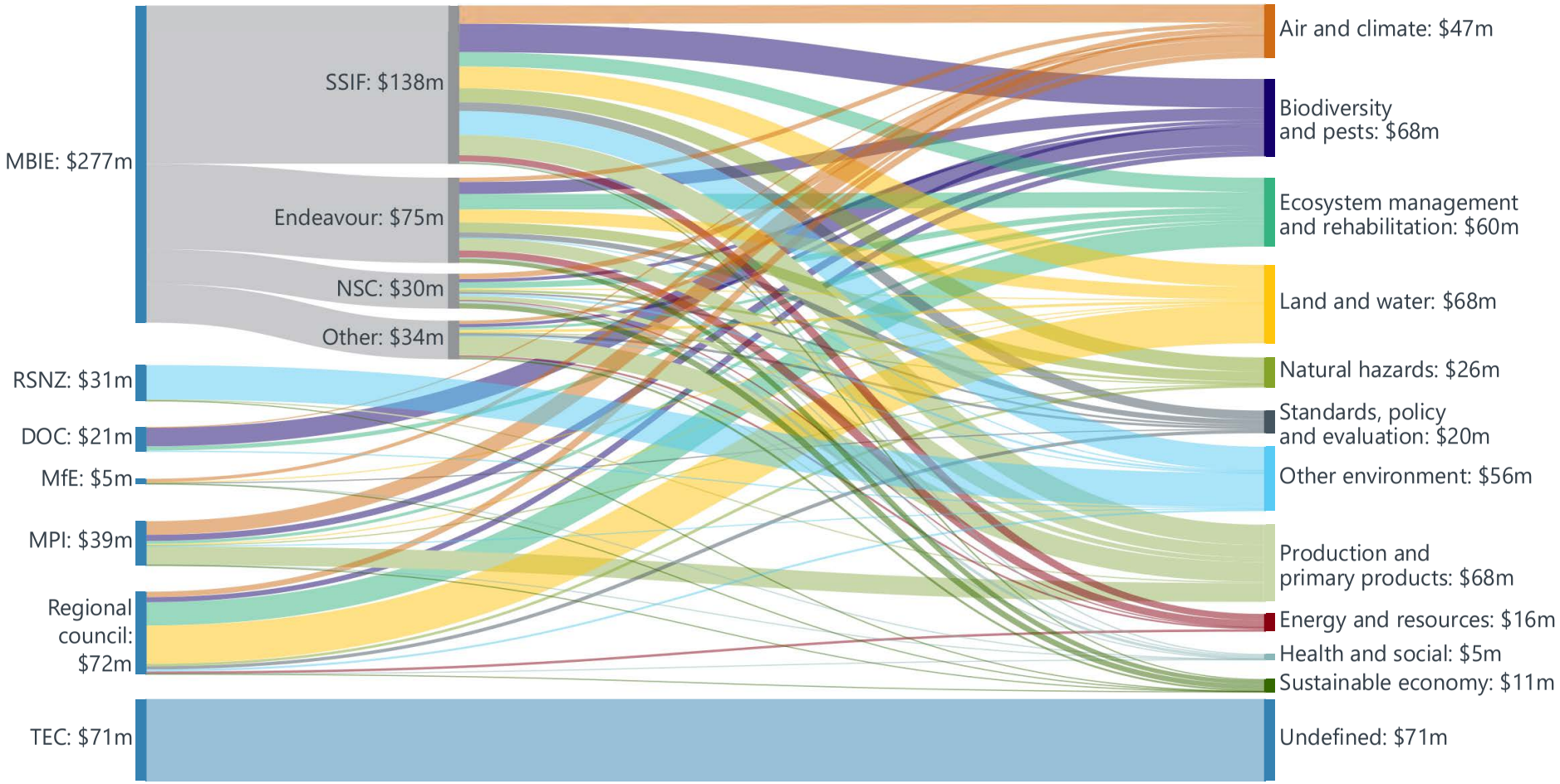

Figure 2.8: Funding flow from central government to SEO classes for the year 2018/19; the intermediate bands are MBIE funding mechanisms. See Table 2.3 for data sources.

Table 2.3: Expenditure in environmental research by central government agencies and regional councils.[i]

Agency	2015/16 ($ million)	2016/17 ($ million)	2017/18 ($ million)	2018/19 ($ million)
MBIE SSIF[ii]	n.d.	n.d.	n.d.	113.0–138.2
MBIE Endeavour[iii]	n.d.	13.6–19.4	31.2–45.8	52.9–74.6
MBIE NSC[iv]	n.d.	n.d.	n.d.	19.4–30.5
MBIE other[v]	34.3–72.4	23.3–52.3	17.7–42.0	13.3–33.7
RSNZ[vi]	25.7–26.7	35.0–36.2	27.2–27.8	30.0–31.2
DOC[vii]	14.8–14.8	16.9–16.9	16.9–16.9	21.4–21.4
MfE[viii]	4.5–4.6	3.2–3.5	4.0–4.1	4.1–4.6
MPI[ix]	21.4–40.6	21.1–53.4	16.7–33.8	31.9–38.7
Subtotal central government				**285.7–372.9**
TEC[x]	57.0	n.d.	71.0	n.d.
Regional councils[xi]	57.7–60.3	61.1–63.8	67.1–69.5	69.8–72.3
Total				**426.8–516.0[xii]**

Notes:

i. Expenditure includes MBIE's funds managed by Royal Society Te Apārangi. The range represents the narrow to broad estimates for each agency's contribution to the total funding per year. n.d. indicates no data available.

ii. Data provided by MBIE. Projects have only been categorised by SEO since 2018/19. Includes SSIF Programmes and NSCDs and Genomics Aotearoa, which are part of SSIF infrastructure.

iii. Data provided by MBIE. Endeavour created in 2016. Note values represent amount paid out by MBIE in the respective financial years, not the amount announced.

iv. Data provided by MBIE. Projects have only been categorised by SEO since 2018/19.

v. Data provided by MBIE. Includes all other MBIE administered funds. These include the Catalyst Fund, Partnerships Fund, PreSeed Accelerator Fund and discontinued funds such as Targeted Research and Sandpit rounds prior to 2016.

vi. Data provided by RSNZ. Data include all funds administered by RSNZ such as Marsden, Catalyst and Rutherford Discovery Fellowship. Note: (1) RSNZ projects are based on ANZSRC Field of Research (FoR) codes, as categorisation by SEO began in 2020; (2) no weighting of FoR codes is available, therefore the total amount is likely to be an overestimation as the presence of a single environmental FoR code resulted in a 'narrow' categorisation; (3) value represents the amount announced in the later year, not the amount paid out in the financial year.

vii. Data provided by DOC.

viii. Data provided by MfE.

ix. Data provided by MPI.

x. TEC does not provide environment-specific spending. Figures come from Stats NZ (2019) for higher education environmental expenditure so are likely to be an overestimation, as they will include funds in addition to those from TEC.

xi. Includes data provided by 14 regional councils who categorised their spending by SEO.

xii. Total includes funding from TEC for the year 2017/18 to generate the most complete picture of expenditure possible.


Hymenophyllum rarum

3 Collections and databases

What are collections and databases?

The collection of observations and specimens, and the interpretation of their occurrence are fundamental to environmental science.[1] Any review of environmental research has to encompass these key research tools.

In the New Zealand context, there are collections and databases that record the status and trends of biogeophysical features of the environment (e.g. rainfall, soils, weather, water depth, water quality, landcover), and specimen collections and databases used to define the distribution and identification of species in time and place.

Databases can be assemblages of information from many sources. For instance, records of invasive species caught through trapping can inform data about species occurrences. Or they can result from modelling exercises. For example, a map of the depth to the ocean floor – represented as a digital bathymetry model, or a relief map of the landscape – represented as a digital elevation model, are the result of modelling many thousands of depth or height data points.

Some databases rely on citizen scientists' records uploaded into a centralised system, (e.g. iNaturalist, New Zealand Plant Conservation Network). These become increasingly useful for science when the observations are repeated at regular intervals using comparable methods and observation effort.

There is a huge volume of data held about many aspects of New Zealand's natural systems. These data are held in a high diversity of formats and housed in dozens of institutions. In their totality, they form a vital – but incomplete – picture of the way New Zealand's environment has changed, and can help us assess its capacity to adapt to future challenges such as climate change and land use change.

There appears to be very little planning about how to adapt for our future data needs. These datasets are not linked, as interoperability requires technical interconnectedness, and this opportunity to explore across datasets is often missed. While many of them are available through online portals, an important proportion are not.

[1] Science Staff, 2011.

Collections and databases are held by almost all research institutions in New Zealand. The scale and security of their funding reflects the way in which their host institutions are funded. Databases funded by CRIs tend to be funded by MBIE either through the SSIF or through project funding reliant on competitive funds. A small subset of these is called the Nationally Significant Collections and Databases (see Appendix 2).[2] The NSCDs comprise 25 collections and databases designated in 1996 and mainly held in CRIs, with one held at Cawthron Institute.[3]

IROs and museums fund collections and databases through their research activities and operational funding, largely outside MBIE funding channels. Universities hold a range of important collections and databases and are funded mainly through TEC. The databases identified in this enquiry cover a broad spectrum of specimen collections, sightings records, monitoring schemes and records of biophysical features. Many of the 25 MBIE-funded NSCDs are related to biodiversity and ecosystem functioning.

In my 2019 investigation on environment reporting, I called for greater consistency in data gathering to enable time series to be developed, and trends in key variables for environmental monitoring to be described.[4] This would require designation of specific environmental indicators, and a refocusing of efforts to ensure these data were collected in a standardised way through time and across regions. Some gaps would need filling, and any unnecessary duplication could be eliminated.

In *Focusing Aotearoa New Zealand's environmental reporting system* I recommended that environmental reporting should be organised under five overarching themes:

- land
- freshwater and marine environment
- biodiversity and ecosystem functioning
- pollution and waste
- climate change and variability.[5]

To provide a sense of the pervasive importance of collections and databases, Appendix 3 lays out, for each of these five themes, an illustrative selection of New Zealand collections, databases and data compilations from a range of research and management organisations. The value of these datasets is illustrated by reference to one or more examples, and the significance of data gaps briefly commented on.

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[2] See also https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/funded-infrastructure/nationally-significant-collections-and-databases/.

[3] Nelson et al., 2015.

[4] PCE, 2019a, p.30.

[5] PCE, 2019a, p.15.

Initiatives to combine data for management purposes

There is connectivity between the many datasets that describe the New Zealand environment, but this is often hindered by the multiplicity of providers and a lack of interoperability. Improvements are possible where key players in related domains collaborate to develop data-sharing infrastructure, five of which are described below.

A recent example under development is the **National Environmental Data Service (NEDS)**.[6] Still at the proposal stage, this initiative aims to use federated data infrastructure to mobilise datasets from MWLR, the Institute of Environmental Science and Research (ESR), Plant & Food Research, AgResearch, Scion, GNS Science and NIWA. The proposal "aims to create a framework providing natural resource software with standardised environmental and other data from existing data sources and providing software localisation support".[7] It allows applications to dynamically link diverse databases hosted by different organisations. These include several pivotal datasets for monitoring the state of New Zealand's environment, such as river flows, soils, groundwater, land cover and bathymetric databases and geological maps.

The **New Zealand Organisms Register (NZOR)** came into existence in 2006 as a collaboration between agencies that work with the natural world, including MPI, DOC, EPA, Te Papa, NIWA and MWLR.[8] The NZOR aimed to provide a unique identifier for each of the over 150,000 organisms known to occur in New Zealand. This exercise had a twofold aim of (a) removing confusion about the identification of organisms that may have different names in different contexts for research or management purposes; and (b) enabling effective management of those organisms where required to respond to biosecurity, conservation or human health concerns.

NZOR is currently hosted by MWLR. In 2015, NZOR stopped receiving regular financial support.[9] Since then it has received annual contributions, at variable levels, which are renegotiated each year with the funding institutions from their operational funds. These are enough to cover the basic maintenance of the system, but not enough to cover any developments to better meet stakeholder needs.[10]

Land, Air, Water Aotearoa (LAWA) draws together data collected by regional councils and unitary authorities about the environment, such as flood control, air and water quality, pest control, transport and park management.[11] Cawthron Institute and MfE are partners in the project. Additional funding comes from Massey University and The Tindall Foundation. It enables the user to explore this range of datasets and their changes through time.

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[6] Spencer et al., no date.

[7] Spencer et al., no date, p.2.

[8] See www.nzor.org.nz.

[9] Nelson et al., 2015.

[10] MWLR, pers. comm., September 2020.

[11] See https://www.lawa.org.nz/.

Compilations of data are available to explore different expert opinions or data-based tools. For example, a spatial data visualisation tool, **SeaSketch**, has been used by DOC to explore the spatial extent of estuarine habitats and plan marine protected areas.[12]

MPI has contributed static data layers for boundaries of marine areas (e.g. management areas) and species distributions in a system called the **National Aquatic Biodiversity Information System (NABIS)**.[13] A successor to NABIS that draws on live datasets is planned but has not yet appeared.

These projects are a means of exploring datasets that overlap spatially and provide some insights into what a fully interoperable system could deliver. They demonstrate the willingness of data holders to collaborate and provide products that meet the needs of discrete groups of stakeholders. Each of these systems is voluntary and has been funded outside of the main SSIF funding that supports the scientific collections and databases that are described as NSCDs.

More systematic and better-resourced approaches are required to boost users' access to government-funded datasets.

Reviews of collections and databases

RSNZ conducted a review of taxonomic collections in 2015, which identified major structural issues and underfunding across the sector. It highlighted challenges that had resulted from many years of diminishing investment, such as a large backlog of uncatalogued specimens, an insufficient specialist workforce with skills to conduct taxonomic research on New Zealand taxa and manage the collections, and lack of infrastructure and workforce to make specimens available online.[14]

At the same time, it noted increased expectations of digital access and use of new technologies to interpret the collections. Protection for collections in different agencies was found to vary considerably, some were protected by statute, others not at all. Similarly, levels of protection from natural hazards (flooding, earthquakes, etc) vary between locations. The RSNZ review called for the development of a clearer strategy and improved funding for the taxonomic collections sector.

Seeking improvements in structure, more certain funding, and the ability to better develop a nationwide strategy for collections and databases, the holders of 29 taxonomic collections and databases (later called Species Aotearoa) met with MBIE in 2018.[15] They proposed developing a platform like that implemented for Antarctica New Zealand or other SSIF platforms. This idea was not supported by MBIE, which noted that it would not be funding additional platforms in the coming years.

[12] See https://www.seasketch.org/#projecthomepage/5357cfa467a68a303e1bb87a for more information on estuarine habitats.

[13] See https://maps.mpi.govt.nz/templates/MPIViewer/?appid=96f54e1918554ebbaf17f965f0d961e1.

[14] Nelson et al., 2015, p.8.

[15] Species Aotearoa, pers. comm., November 2020.

In 2019, MBIE published a report on a partially completed review of government-funded collections and databases in New Zealand. This covered biomedical, environmental and natural history fields. It noted a lack of national perspective or strategy around the future development of collections and databases.

A strong focus of the MBIE review findings was around implementing the existing government open data policies. It noted that commercial incentives in some CRIs were preventing data openness, arising from internal conflict over the need to generate funding and provide access to publicly funded resources, along with issues of co-funding from multiple sources in the generation of some databases.

MBIE felt that there was a need to focus more on maximising public-good outcomes from the collections and databases. It had struggled to quantify the value demonstrated by users of the databases and considered that there should be greater transparency around the kinds of researchers using them, which collections and databases they were accessing and the purposes for which they were being used.

MBIE proposed that there should be a "focus on enabling excellent, high-impact science: The scientific value of a C&D [collection and database] should be the primary driver of funding (as opposed to the cultural or heritage value)."[16] MBIE noted that reorganisation of institutions might be beneficial to improve organisational culture and improve efficiency. It concluded that "the current funding level may be sufficient, but redesign is required so that existing inefficiencies can be overcome."[17] It did not specify where these efficiencies should be sought.

Species Aotearoa took strong exception to MBIE's proposal that the value of scientific collections should be defined in relation to the definition of scientific excellence being applied by MBIE. It argued, instead, that the value of scientific collections should be gauged by their contribution to scientific, cultural and heritage values.[18]

All parties in these reviews noted that the integration of Māori scholarship and access by Māori researchers and communities to these collections was limited and needed improvement. MBIE noted that a commitment to Māori data sovereignty was required, with measurable shifts towards this outcome needing to be demonstrated. Species Aotearoa further noted there was a need to acknowledge and discuss the integration of WAI 262 in the policies and practice around collections and databases.[19]

[16]MBIE, 2019c, p.5.
[17]MBIE, 2019c, p.40.
[18]Species Aotearoa email response to MBIE 2019 Update report.
[19]See https://teara.govt.nz/en/video/45798/wai-262.

Security of funding

The set of 25 NSCDs, designated in 1996 has remained fixed since that time. Yet, as the preceding discussion and Appendix 3 make clear, they make up only a small subset of the many sources of scientific information used in environmental science in New Zealand.

The NSCDs were designated as 'nationally significant' using criteria developed by the Foundation for Research Science and Technology in 1996. Those criteria were:[20]

1. Is the science asset funded in whole or in part from the Public Good Science Fund?
2. Is the science asset nationally important?
    - 2.1. Does the asset make a substantial contribution to the goals set out in the Statement of Science Priorities?
    - 2.2. Is the asset important to a wide range of stakeholders?
    - 2.3. Does the asset deliver substantial benefits to users?
    - 2.4. Is the asset unique nationally and/or internationally?
    - 2.5. Is the asset irreplaceable?
3. Is funding of the science asset on a priority basis consistent with the Foundation for Research Science and Technology Act and with the Statement of Science Priorities?

These appear to mirror the need expressed in this report to (a) provide a policy setting in which to allocate funding, and (b) assess the national importance of the assets and ensure their long-term viability. However, from this distance the selection of qualifying collections and databases appears somewhat arbitrary.

At some level, the 25 NSCDs, could be seen as 'the lucky few', receiving stable (if inadequate) funding year on year. The distinction between the 25 NSCDs and many other databases identified in this survey is, if judged by the criteria above, slight (see Appendix 3). Many of the databases identified would qualify as nationally significant if assessed using these criteria. The price of their non-inclusion is funding that is fragile, intermittent, and reviewable annually by the agencies responsible for managing them. They have been described as "often contestable and uncertain in the long term."[21]

In addition, the compliance and infrastructure costs associated with running databases have risen so that the level of funding originally allocated is significantly out of step with what is needed today.

[20] MBIE, 2019c, p.11.
[21] MBIE, 2019c, p.12.

Currently, funding for environmental research tends to be 'projectized' leading to many short runs of information being collected.[22] Long-running datasets, such as many of those listed under the overarching theme headings in Appendix 3, are reportedly maintained on a shoestring by the host organisations.[23] The lack of direction and foresight that results from this approach means that they do not tend to evolve through time to keep up with modern data management trends. While some databases are available through online portals such as data.govt.nz, the LINZ website or research agency data websites, others remain distinctly 'artisanal' in their management style, requiring interaction with the keeper of the data to extract important information.

Source: Rosino, Flickr

Figure 3.1: The Pūtangirua Pinnacles in Wairarapa are seven to eight million years old, with the exposed fossils an important record of ancient climatic and environmental change.[24] The New Zealand Fossil Record File is a nationally significant database that records the location, context and details of fossils around the New Zealand region, including the wider Pacific and Antarctica.[25]

[22]NIWA, pers. comm., September 2020.

[23]NIWA pers. comm., September 2020.

[24]See https://www.geotrips.org.nz/trip.html?id=52.

[25]See https://www.gns.cri.nz/Home/Products/Databases/New-Zealand-Fossil-Record-File.

Conclusions

The knowledge delivered by collections and databases is of an extremely fundamental nature. They are the building blocks for developing far-reaching scientific endeavour, defining the current status of natural systems and providing the evidence basis for describing change. They are ill-suited to being projectized in the context of a competitive funding model.

Several stakeholders have identified the need for greater latitude in defining the core set of collections and databases for New Zealand, and to enable those to evolve through time, while leveraging the important heritage of information and collections that exist.

The lack of significant investment in data infrastructure over time has meant that various piecemeal attempts are being made to overcome the problem of data connectivity. These are laudable and honest attempts to bring together important datasets and demonstrate the value of collaborative approaches. But they are not a sustainable solution that will enable New Zealand scientists, environmental managers and other users to make the most of data collected over time to address today's environmental challenges. Something more fundamental, that provides long-term, sustained, and stable data infrastructure and collections support, is needed.

The funding model for collections and databases needs to be one that ensures much greater value can be derived from them. It should be informed by a considered view of the key environmental challenges facing New Zealand and the need to facilitate access by researchers, environmental managers and policymakers alike.

4


Blechnum novae-zelandiae

What long-run strategic priorities exist for environmental research and how are they reflected in the allocation of research funds?

National policies and roadmaps driving environmental science

In chapter two we estimated a total investment in environmental research by central and local government agencies (including tertiary institutions) of around $427–$516 million per annum ($286–$373 million for central government). The range given by using both narrow and broad SEO classes gives an indication of the uncertainty associated with this estimate. But it is of this order of magnitude and not a small sum. So it is reasonable to ask if the investment is allocated in a way that addresses the range and complexity of New Zealand's environmental challenges.

There has been no shortage of strategic level documents flowing from central government over the last decade or so. Table 4.1 lists some of the key national strategies relevant to environmental research that have been developed over the last ten years and referenced in research funding proposals.

Table 4.1: Some of the key national strategies, roadmaps and documents reviewed for this report.

Agency	Key national strategies, roadmaps and documents	Date released
MPI	Fit for a Better World: Accelerating our economic potential	2020
DOC	Te Mana o Te Taiao – The Aotearoa New Zealand Biodiversity Strategy 2020	2020
Rauika Māngai	A guide to Vision Mātauranga: Lessons from Māori Voices in the New Zealand Science Sector	2020
MBIE	Te Pae Kahurangi	2020
MBIE	New Zealand's Research, Science and Innovation Strategy: Draft for consultation	2019
MBIE	Strategic Science Investment Fund: Investment Plan 2017–2024 – 2017 Update	2017
MPI	Primary Sector Science Roadmap: Te Ao Tūroa	2017
MFE–DOC	Conservation and Environment Science Roadmap	2017
MPI	Biosecurity 2025: Direction Statement for New Zealand's biosecurity system	2016
Regional and unitary councils	Research for Resource Management: Regional Council Research, Science and Technology Strategy 2016	2016
MBIE	National Statement of Science Investment: 2015–2025	2015
Antarctica New Zealand	New Zealand Antarctic and Southern Ocean Science: Directions and Priorities 2010–2020	2010
MBIE	Vision Mātauranga: Unlocking the Innovation Potential of Māori Knowledge, Resources and People	2005

While some of these relate specifically to research, others are broad sectoral strategies pitched at the level of the economy, society and the environment. It is at this level that strategic guidance for research priorities should be evident in relation to the primary outcomes governments seek to deliver: care for the environment, the wellbeing of society and the economy.

Outside of academia and a specialised fund like the Marsden Fund, investment in environmental research should be directed to the major challenges that our biophysical environment holds for us. For example, we have high levels of species endemism and globally rare ecosystems. While these may be of international interest, no other country is going to make the long-term investments needed to understand them.

Or there are the challenges of a changing climate. While there is huge international investment in understanding this phenomenon, no other country has the incentive to understand what adapting to its consequences will entail for us. And then there are the problems we have created for ourselves by misusing or misunderstanding environmental assets (like waste generation, degraded water quality or wilding plant species).

The **National Statement of Science Investment: 2015–2025** sets out future investment directions and describes how policy actions will contribute to delivering the vision for 2025 to "achieve excellent economic, environmental, social, and cultural outcomes for New Zealand".[1] The two pillars of the strategy are excellence and impact – which have been carried into the Endeavour Fund as the two main criteria for allocating funds.[2]

The environment is listed as one of four dimensions of 'impact', along with the economy, health and wellbeing and society. But the direction provided in the statement implies that any environmentally focused research would need to underpin the strategy's economic goals. While it recognises the need to "improve our information and evidence base, and our understanding of environmental opportunities and limits", it asserts that the strategy will "seek to fund research that increases the productive potential of our environment, while preserving and enhancing its quality and sustainability."[3]

It refers to strategic plans and priorities for environmental management, and the unique relationship of Māori with their environment, but insists that it needs to balance productivity and sustainability, noting the strong links between environmental research and primary industries.[4]

The statement is now five years old and work is ongoing to update the strategy, drawing on submissions received on the draft Research, Science and Innovation Strategy released by MBIE in September 2019.[5]

The **Research for Resource Management: Regional Council Research, Science and Technology Strategy 2016** aims to "influence central government decision-making … and to also provide direct guidance to CRIs, universities, and other research providers involved in environmental/natural resources and related research relevant to councils."[6] While it naturally reflects many of the national-level strategic documents and policy initiatives under development at the time – including amendments to the National Policy Statement for Freshwater Management and *Biosecurity 2025: Direction Statement for New Zealand's biosecurity system* (see below), as well as the newly announced NSCs – it provides a commendably clear set of research priorities from the point of view of those charged with on-the-ground management of the biophysical environment.

Central government was given clear notice that the sector gave particular priority to:

- integrating land and water science to 'manage within limits'
- five specific goals under biosecurity and biodiversity headings
- hazard risk management
- coastal management
- better use of Māori customary knowledge.

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[1] MBIE, 2015, p.4.
[2] MBIE, 2015, p.7.
[3] MBIE, 2015, p.45.
[4] MBIE, 2015, p.45.
[5] MBIE, 2019b.
[6] Science Advisory Group, 2016, p.2.

MPI's **Primary Sector Science Roadmap: Te Ao Tūroa** in 2017 was intended to provide a 10- to 20-year outlook on the science needs of the primary sector.[7] However, this was superseded in July 2020 by the policy *Fit for a Better World: Accelerating our economic potential*.[8] The actions identified are around transformation opportunities in the areas of productivity, sustainability and inclusiveness.[9]

The MPI 2017 roadmap and 2020 policy strategies are aligned with those of MfE and DOC's CESR (see below). MPI's roadmap stated that MfE and DOC's roadmap "will also be an important guiding document for the strategic directions of the National Science Challenges".[10] It identifies its audience in terms of a wide range of 'partners', including funders and policymakers such as MBIE and MPI itself.[11] The 2020 strategy, too, has partnerships at its heart, particularly with the Māori agriculture community and Māori economy.

Te Mana o Te Taiao – The Aotearoa New Zealand Biodiversity Strategy 2020 is focused on how government agencies, civil society, landowners and iwi can collaborate better.[12] This lengthy document proposes a framework for action based on three pou or pillars with goals for 2025, 2030 and 2050.

Under the Tūāpapa/getting the system right pillar, research makes an appearance as one of six objectives: "Improved systems for knowledge, science, data and innovation". It includes five 2025 goals aimed at environmental indicators, monitoring and reporting; national data standards and access; a prioritisation framework; investment, innovation and collaboration; and the development of new tools and technologies from a range of sources.[13]

There is also mention of research under the Tiaki me te Whakahaumanu/protecting and restoring pillar, with the goals of comprehensive baseline information and knowledge of species management to support adaptive management by 2050. This is as specific as the strategy gets in respect of research. Worryingly, scientists and research organisations are not mentioned among the galaxy of "people, organisations and agencies involved in the biodiversity system".[14]

By contrast, scientists and research organisations are clearly identified in MPI's **Biosecurity 2025: Direction Statement for New Zealand's biosecurity system** among those who make up 'the biosecurity system'.[15] The document seeks, among other outcomes, "activities and investment in science [that] are prioritised to ensure they are aligned with and deliver whole-of-system needs."[16] The direction statement also notes the importance of datasets and biological collections. This 32-page document sets out five strategic directions, 16 goals and 51 outcomes, all focused around communities and industry engagement, and the systems and science underpinning biosecurity in New Zealand.

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[7] MPI, 2017.

[8] MPI, 2020.

[9] See https://www.mpi.govt.nz/about-mpi/our-work/fit-for-a-better-world-accelerating-our-economic-potential/.

[10] MPI, 2017, p.7.

[11] MPI, 2017, p.44.

[12] DOC, 2020, p.49.

[13] DOC, 2020, p.49.

[14] DOC, 2020, p.22.

[15] MPI, 2016. This was updated in July 2020 by the new strategy *Fit for a better world: Accelerating our economic potential* (MPI, 2020).

[16] MPI, 2016, p.15.

Vision Mātauranga: Unlocking the Innovation Potential of Māori Knowledge, Resources and People was implemented in July 2005 to "provide strategic direction for research of relevance to Māori, funded through Vote Research, Science and Technology", with one of four research themes specifically focused on "Taiao: Achieving Environmental Sustainability through Iwi and Hapū Relationships with Land and Sea."[17]

Mātauranga Māori is highlighted in all subsequent government policies. Science-focused strategies (see Table 4.1) recognise the need to weave mātauranga Māori throughout environmental research. Recently developed programmes of work such as the BioHeritage Challenge implement this approach, and there is support for mātauranga Māori research both as a specialist field and as an integrated kaupapa in science programmes.

Along with empowering Māori scientists, Māori knowledge and Māori resources, the importance of mātauranga Māori lies in the fact that it is environmental knowledge developed and embedded in Māori culture over hundreds of years, which helps us understand the unique environment of Aotearoa New Zealand.[18]

However, funding directly targeting mātauranga Māori environmental research remains limited.[19] While research organisations are implementing Vision Mātauranga with targeted actions, clearly there is more to be done. Several interviewees have noted that this strategy is a good start, but that "the real starting point is to engage with Mātauranga Māori as understood by Māori, not as others perceive it to be. When that happens the potential of Mātauranga Māori to help understand and manage the environment will really start to be appreciated."[20]

[17]MoRST, 2005, p.4.

[18]Rauika Māngai, 2020.

[19]The first of two main funding sources is Te Pūnaha Hihiko: Vision Mātauranga Capability Fund (MBIE, 2020), which allocates approximately $6 million per year to "the development of skilled people and organisations that plan to undertake, or are undertaking, research that supports the themes and outcomes of [MBIE's] Vision Mātauranga policy". The second is Ngā Pae o Te Māramatanga New Zealand Māori Centre of Research Excellence (http://www.maramatanga.co.nz/), which has 21 research partners generating indigenous research relevant to Māori communities, funded to the level of $6.3 million by TEC.

[20]Rob McGowan, pers. comm., October 2020.

Source: Helen Buttfield, School Journal, 1968; Archives New Zealand, Flickr

Figure 4.1: Maramataka is a complex guide for when to hunt and fish, and when to plant, harvest and prepare different foods throughout the year. The ancient Polynesian system, handed down over generations, follows the moon and the seasons, and varies across New Zealand according to local environments.[21]

[21] See https://teara.govt.nz/en/maramataka-the-lunar-calendar/page-3 and https://www.stuff.co.nz/national/health/118718384/ministry-of-health-stands-by-funding-of-traditional-maori-system.

The **New Zealand Antarctic and Southern Ocean Science: Directions and Priorities 2010–2020** clearly focuses on a key environmental issue for New Zealand, even though it is region specific. The strategy states that "to receive government support, research must align with this framework."[22] It intends to coordinate the use of funding from five government Votes, including negotiated and contestable funds, and focus them on three key research outcomes: climate, cryosphere, atmosphere and lithosphere; inland and coastal ecosystems; and marine systems.

The 2017 MfE–DOC **Conservation and Environment Science Roadmap** represents by far the most significant attempt to date to distil some of the key challenges that should be the focus of public-good environmental research.[23] It builds on the Ministry of Research, Science and Technology's 2007 *Environment Research: Roadmaps for Science – A guide for New Zealand science activity*.[24]

The CESR was formulated by a collective of government officials from the natural resources sector, research providers and specialists intended to represent key stakeholders for the natural environment. The composition of the stakeholders assembled for the exercise has however been criticised for lacking mātauranga Māori input.[25]

Major themes covering processes, pressures, domains and the human dimension were delineated, with research priorities for the following five years, and high-level, policy-related science questions that would "need to be answered to provide the evidence base to inform environmental and conservation policy" over a 20-year time frame. Each of the six themes and five subthemes (listed in Appendix 4) is addressed in terms of:

- key questions
- priorities
- capabilities and strategic needs
- links to other strategies and policies.

With respect to the last point, the CESR was developed in parallel with MPI's 2017 *Primary Sector Science Roadmap: Te Ao Tūroa*. There appears to have been a concerted effort to optimise complementarity between the two strategies and possibly for one to influence the other.

As such, the CESR represents clear, high-level guidance for the investment of research funds. The roadmap states that the themes were "to be used by research providers to identify priority areas for research bidding that meet the 'impact criteria' used by the Ministry of Business, Innovation and Employment in their funding decisions."[26] The onus was placed on research providers to respond to the priorities identified.

Beyond funding allocation, the CESR sets out to describe the kinds of science culture most likely to give effect to its objectives, including better collaboration, fewer overlaps or redundancies and a reduction in gaps between research, databases, collections and environmental monitoring.

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[22] Antarctica New Zealand, 2010, p.6. Except for funding and logistical support for high-risk, blue-skies research.
[23] MfE and DOC, 2017.
[24] MoRST, 2007.
[25] Dr Jessica Hutchings, pers. comm., July 2020.
[26] MfE and DOC, 2017, p.15.

How are such strategies taken up in funding decisions?

Given the investment of official and ministerial time in developing so many high-level documents, one could reasonably expect that, to the extent that they say anything tangible about environmental research priorities, those priorities should be visible in the research funding decisions being taken by key agencies, pre-eminently MBIE. However, an examination of the criteria governing the allocation of funds under the various 'pots' described in chapter two provides no line of sight with the stated priorities for environmental research on current, medium- or long-term issues that are preoccupying New Zealand's environmental management agencies.

The CESR is not mentioned in the 2019 Endeavour Call for Proposals. And the 2019–2021 investment plan that drives the Endeavour Fund mentions only in very general terms the need for proposals to relate to "appropriate Government policy, strategy and roadmap documents", and that "alignment with such documents is one way to help demonstrate future value".[27]

MBIE's *Strategic Science Investment Fund: Investment Plan 2017–2024 – 2017 Update* lists each of the main strategies, stating:

> "This Plan was developed with regard to relevant government strategies. … Some of these strategies are broadly applicable to research proposals, others are specific to sectors or areas of research. We expect SSIF research providers to have regard to all government strategies relevant to their research area."[28]

A "non-exhaustive" list of relevant strategies provided by MBIE for SSIF research providers to reference includes the *National Statement of Science Investment*, the Business Growth Agenda, *He kai kei aku ringa: The Crown-Māori Economic Growth Partnership,* Vision Mātauranga, *2016 Research, Science and Innovation Domain Plan*, New Zealand Antarctic and Southern Ocean Science, Biodiversity Strategy 2000, Biosecurity 2025, *Environment Domain Plan 2013: Initiatives to address our environmental information needs*, CESR, Primary Sector Science Roadmap and Predator Free New Zealand 2050.[29]

Understandably, as a fund aimed at generating new knowledge and fostering creativity and innovation, Marsden guidelines make no mention of government research strategies, citing only excellence and impact as criteria for funding.[30]

The NSCs also made extensive reference to existing strategies when developing their objectives and work plans. This was not required by MBIE, but strongly encouraged. The BioHeritage Challenge conducted a review of around 30 strategies from government, industry and iwi, and developed three impact statements that took the core values of earlier strategies as the basis for their approach.[31]

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[27] MBIE, 2018a, p.6.

[28] MBIE, 2017, p.9.

[29] MBIE, 2017, p.9.

[30] The Marsden Fund's Terms of Reference state that "the research is not subject to government's socio-economic priorities" (see https://www.royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden/about/tor/).

[31] BioHeritage Challenge, pers. comm., October 2020.

It may seem contradictory that despite having many strategies, roadmaps and direction statements there is a feeling that "there is vacuum of policy for environmental science".[32] But most stakeholders we consulted felt that while the national or sector strategies and roadmaps were useful guides to understanding the Government's priorities for environmental research, they were not always clearly reflected in funding decisions.

It is unclear why the links between the way environmental research is funded and the many high-level strategic documents affirming its importance are so weak. A possible explanation may involve two elements.

In the first place, allocation criteria (impact and excellence) and bidding systems (where funding is competitive) are not designed to give effect to previously identified long-run environmental priorities. None of the research bidding assessment processes for contestable funds are designed to give effect to these strategies. It is effectively up to the researchers to develop projects that respond to the strategies – and it is clear that in many cases they do. What is lacking is the ability of the agencies who developed these strategies to judge whether what research providers propose is indeed the embodiment of what the strategies are calling for.

Secondly, where funding is negotiated (as is the case with the SSIF platforms) it should be easier to insist on reference to these high-level documents. And indeed, there is the injunction to research providers to "have regard to all government strategies relevant to their research area."[33] But this is a message addressed more to providers than the funding agency. In the case of SSIF, the funding agency has no specialised expertise to judge the way in which environmental priorities are being reflected.

This leads to the most frequently cited criticism encountered in discussing the various strategies: that they are not backed up by funding. There is, for example, no direct link between the five-year priorities spelt out in the CESR and the bodies that allocate hundreds of millions of dollars of research funding. The objectives set out in the CESR (or other strategies) do not align closely enough with MBIE's funding criteria – whether it be for contestable or negotiated contracts – to have been influential. Contestable proposals are triaged first by excellence, then by impact, followed by the extent to which they are 'transformative'. Negotiated contracts (SSIF and NSCs) are driven by the provider rather than the funder.

While agencies such as DOC and MfE can invest directly in research that supports their immediate operational and policy roles, their ability to influence the much larger body of mission-led and more fundamental research is less clear. Environmental research would ideally be overseen by a body with the expertise both to understand national environmental priorities and discriminate between the possibilities being proposed by the research community. The following chapter discusses possible ways to achieve this alignment.

[32] AgResearch, pers. comm. August 2020.

[33] MBIE, 2017, p.9.

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Aligning the allocation of research funds with national environmental priorities

In my review of environmental reporting, I identified significant gaps in *what* gets reported about the changing state of our environment, and a lack of consistency in *how* we report the things we do manage to report.[1] I recommended that we set about systematically filling those data gaps and that the Government should seek advice on the best way to link New Zealand's environmental reporting system with the research system to ensure that key knowledge gaps are closed.

Filling gaps for the sake of it is not the point. This is not stamp collecting. Reliable and comprehensive data provide the evidence base needed to manage our relationship with the environment, to inform regulatory decisions and underpin investments. If that evidence base is to be truly valuable, we need to know how to interpret it, and also – crucially – to understand its limitations. So it is vital that we are clear about what we do not know, and where research should be focused to fill the most important knowledge gaps.

In a well-functioning system, environmental reporting would be telling us about the health of our environment and alerting us to emerging trends that we need to be concerned about. To recognise and understand those trends we need to be able to mobilise research – whether it be about fundamental ecological dynamics or practical ways of dealing with new challenges. Our responses will be as good as the knowledge we can bring to bear.

It is time for our research resources to be focused on the environmental challenges that have been described in so many strategic documents. And time to ensure that we are funding environmental research in a way that accommodates the long game that many of its researchers have to play.

[1] PCE, 2019a.

The problem with current arrangements

New Zealanders are entitled to know that the environmental research they fund is focused on addressing the most important challenges we face. To provide that reassurance, there is a need to connect the following three elements:

- defined research priorities, elaborated in a regularly reviewed strategy led by the relevant government agencies and engaging a wide group of research users, iwi and the community
- the right research approaches to deliver on this strategy, developed with input from the research community and embedding mātauranga Māori perspectives
- adequate national investment in environmental research programmes that secures critical research capability – both human and technical.

There is a widespread view that there is a disconnect between what many governmental documents *say* about the strategic importance of environmental research and its focus, and the actual research investments that are *made*. It is not that such investments are unable to be related to the various strategies at some level. They are broad and open-ended. Rather, the way resources are allocated engenders little confidence in our ability to maintain a comprehensive portfolio of environmental research that addresses national priorities over time. Furthermore, these mechanisms may or may not be managed by people who understand the nation's environmental research needs.

These concerns are in part a reflection of the fragmented funding machinery that is being used. Multiple models of investment have been developed over the years, which makes a joined-up view of the environmental research landscape almost impossible to achieve. That does not mean that the different allocation mechanisms pictured in Figure 2.2 are wholly lacking in valuable attributes.

The NSCs, for example, have been designed to ensure the inclusion of iwi and community interests in a way that has largely been absent from New Zealand's research funding system. The Endeavour Fund provides researchers with the opportunity to construct large, complex and ambitious proposals. The SSIF-funded platforms have provided stable support for core national research providers to lead their specific areas of research.

However, none of this potpourri of mechanisms enables a fulsome and deliberate investment of scarce resources in research to address the critical issues facing New Zealand's environment. Nor is it inclusive of mātauranga Māori and the centuries of knowledge attained from living on, and with respect for, the whenua.

Researchers will generally know far more about the research questions they are funded to unlock than the agencies that fund them. The last thing that is needed is a funding system that leads to bureaucratic interference in research at the programme or project level. But neither should we ask researchers to weigh overall priorities and invent high-level strategies. We need a funding system that ensures research directions are informed and prioritised by policy choices that governments are elected to make.

The attributes of a well-designed environmental research funding system

This review has focused on how to allocate funding to environmental research. Its approach has been unashamedly top-down and is driven by the needs of government and our wider society for knowledge – of a largely public-good nature – that will enable us to better understand and manage our biophysical environment. This review has *not* focused on research providers – the CRIs, IROs, tertiary institutions, regional councils and private businesses. The proposals here assume the status quo is preserved with respect to the number, function and governance of the CRIs.

Indeed, trying to manage the environmental research portfolio through a series of arrangements with each of these very differently configured providers would be very resource intensive. In any case, it is not my role to be advocating changes to the 'delivery' model for research providers. We know we want them to collaborate where the need for public-good knowledge is in play. The way we allocate funding is one of the forces that will no doubt drive an evolution of delivery models. But that is not central to this review.

In my view, a well-designed environmental research funding system for New Zealand would have the following attributes:

1. It would be guided by **a clear and unambiguous national-level environmental research strategy**. It should be rooted in a constantly updated evaluation of what environmental monitoring is telling us. It should be informed by research insights and should reflect the evolving concerns and interests of iwi, the community and all users of research.

   MfE should take leadership for the strategy. Rather than reinvent the wheel, the current CESR provides a solid basis and an excellent starting point for developing such a research strategy.[2]

   The challenge will be to find the right balance between a strategy that is too high level to be able to discriminate between claims to priority, and a strategy that is too specific, written to advance the interests of specific parties and descending into operational research. It needs, on the one hand, to be comprehensive (embracing all environmental domains). On the other, it has to be able to nominate those broad areas where the weight of research funding has to be directed. New Zealand cannot afford to do everything and some knowledge gaps are more important than others when viewed from a national perspective.

2. It would provide **dedicated, long-term funding** for environmental research that would be ringfenced. The starting point for such a fund is provided by current actual spending on environmental research. Table 2.3 indicates that for central government agencies this is around $255 million per annum using my narrow definition of environmental research.[3] The fund should be invested in a way that responds to the priorities identified in the environmental research strategy.

   The fund should *not* be available to those arms of government (central or regional) seeking funding for operational research, whether directed towards environmental monitoring or any other policy or delivery role. Such research should be a part of their core operating business.

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[2] MfE and DOC, 2017.

[3] This figure excludes TEC funding as it is designed to support higher education more broadly, and also excludes expenditure by regional councils as it comes from non-central government funding sources. The Marsden Fund and other funds administered by RSNZ (ca. $30 million for environmental research) have also been excluded from this figure as they fulfil a specific purpose in the science funding system.

3. Funding should be **allocated by people familiar with environmental research** and the environmental challenges that we are seeking to address. In other words, they need to understand not just 'how' research is conducted and managed but also 'what' is being funded. Without this familiarity, it will be very difficult to ensure a line of sight between what any environmental research strategy says and what gets funded.

4. There should continue to be **a mix of negotiated and contestable funding** in stable proportions over the long term. Given the long-term nature of so much environmental research (which results from the fact that we are dealing with natural ecological change and forced changes with long lags caused by human interventions), stable negotiated programmes with 7–15-year time horizons should comprise the bulk of the funds. The current 'platform' system could provide a basis on which to build this funding model, which could account for maybe two thirds or more of the available funding.

   A smaller fraction of the available funds should continue to be allocated on a contestable basis. This provides a way of enabling emerging issues to be addressed. Funding can be allocated on a shorter-term basis while the relative importance of the new field is being assessed. This approach could incorporate learnings from the Smart Ideas model.[4]

5. The **criteria used to allocate funding should be relevant to the particular characteristics of environmental research**. The emphasis on 'excellence' and 'impact' and the current drive for 'transformational' research that has prevailed in Endeavour funding criteria is widely perceived to have permeated other funding mechanisms where it is unsuited to many core, long-term research programmes, including the maintenance of collections and databases (see Box 5.1).

6. Funds should be allocated in a way that **supports collaboration** and has regard for the viability of research providers. The present pretence that research platforms are 'provider neutral' is a somewhat futile concept in a small country like New Zealand with a relatively small number of research providers with a high level of specialisation. It is in the Government's interest to maintain critical mass and institutional memory within the key providers of environmental research, while supporting, where possible, additional research capacity vested in other institutions (for example universities or IROs). Relative institutional stability is needed when long-run strategic national research capability is required. This is quite different from much of the innovative and transformational research funded to encourage new industrial and technology-based sectors.

7. It would explore with Māori leaders the best model(s) for delivery of a **fully developed mātauranga Māori programme of work**, and implement it. Such an approach is needed to change the current system that has been built largely from a western view of individual endeavour, and excellence essentially defined by international peer review, publications and citations (see Box 5.1). In te ao Māori, collective activity and community endorsement appear to be much stronger drivers of excellence. This might require rethinking how we invest in research in a way that allows both approaches to prosper.

[4] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/.

8. It should ensure that New Zealand has the **critical mass of researchers and the right infrastructure** to deal not just with day-to-day research, but respond to underpinning research that is required to address threats (such as biosecurity incursions) that may require urgent interventions. A critical mass of research infrastructure and capability includes:
   - the critical research workforce and its development, including career pathways and succession planning
   - a set of open-access databases and collections, which are well resourced, covering all government-funded research priorities. Māori interests in relation to data access and data sovereignty should be represented and incorporated in these activities. These should be maintained in a way that enables them to evolve through time as new research foci and technologies emerge
   - federated data infrastructure that enhances information accessibility for all users of research information, including government agencies, iwi and the community.
9. **Administrative costs should be minimised** to optimise expenditure on research and the research workforce.
10. The funding entity should be **accountable** for how its allocation of funds brings the environmental research strategy to life, and **fully transparent** about how it makes its funding decisions.

Box 5.1: What criteria should be used to allocate funding to environmental research?

New Zealanders are entitled to expect that those who allocate public funds to research do so in a way that is transparent and seeks to make the best use of scarce resources. Those allocating funding need to be able to demonstrate that the portfolio of research they support is both comprehensive and of high quality.

Under current arrangements, explicit assessment criteria are gazetted by the Government spelling out how research proposals submitted to the Endeavour Fund will be assessed. The fund uses non-topic-specific criteria of which 'excellence' is the pre-eminent qualifying requirement. Moreover, research providers appear to be presenting their work for the negotiated SSIF platforms in a way that internalises the Endeavour criteria.

Excellence is defined in the Gazette notice as research that is well designed, involves risk and/or novelty and is likely to leverage additional value from wider research.[5] Excellence must be demonstrated before a proposal can then proceed to be assessed in terms of one of two impact categories: 'Transform' or 'Protect and add value'. The case for many environmental research proposals can clearly be mounted under the 'protect and add value' category. But to get a hearing, they must first clear the excellence hurdle.

The need for excellence in research should not be in question. But excellence is not a panacea, and the ubiquitous use of the concept of excellence alone as a metric to fund and reward research has been questioned.[6] To satisfy the excellence criterion, proposals that add

[5] The full definition can be found at https://gazette.govt.nz/notice/id/2020-go3268.

[6] Moore et al., 2017.

to the body of knowledge about the biophysical environment or fill knowledge gaps will only succeed if they can demonstrate ambition in terms of scientific or technical risk, novelty or innovation. This insistence on novelty and the intense competition that often arises from the need to demonstrate 'excellence' does not sit well with the collection and interpretation of datasets that are so often essential to environmental understanding, decision making and ultimately the public good. An excessive preoccupation with novelty or risk as evidence of excellence can result in the underfunding of the 'normal' work that makes science function. It can also divert attention from national priorities to performance measures.[7]

Likewise, delivery of mātauranga Māori research activity in these contexts has proved difficult. These programmes may or may not be delivered using novel techniques but are nonetheless of high value for understanding the New Zealand environment, its changes and challenges.

In this report I recommend that environmental research funding be ringfenced and explicitly linked to an environmental research strategy. The allocation criteria, including 'excellence' (whether for negotiated or contestable funds), should be tested for their fit with the sort of research that is required to understand our highly dynamic natural environment over appropriate time frames.

The patient interpretation and understanding of environmental change unfolding over decades does not need to be a slave to novelty or innovation (although those qualities may well be in evidence). It is often through meticulous, continuous work that real, perennially applicable discoveries are made. These serve to overturn long-held assumptions about ecosystem function and very often spawn new ideas and directions.

[7] Moore et al., 2017.

Box 5.2: A note on platforms

Throughout this review, I have run up against a plethora of labels such as platforms, research hubs or research units. Having arcane debates over how research entities are labelled will add nothing. But in the interests of clarity, I have used the term 'platforms' in the proposed schemes to mean:

- A group of researchers or specific research providers that deliver work on a programme of activity around a common theme.
- They are accountable to the funders, but also to their home agencies.
- Their structure and function combine the best aspects of the various existing research entities, such as NSCs, SSIF platforms and research hubs. To this end they are collaborative, inclusive, display research excellence, are driven by a mission to meet the agreed objectives of the research, integrate mātauranga Māori and Vision Mātauranga objectives into their programme of activities and engage with their stakeholder communities.
- They provide long-term, stable structures that support the critical mass of infrastructure and workforce necessary to deliver high-quality research outcomes.
- They are focused on public-good outcomes with minimal commercial imperatives in their mandate.

Two models: roles and responsibilities

To provide a sense of how these attributes might be realised in practice, I outline below two models. They are effectively variations on the same theme, the difference being principally institutional.

The first proposes no new entities and seeks to promote change through altering the roles of key government agencies and the skills available to them. The second (and preferred option) embeds the necessary expert skills within a dedicated funding agency. Under both options it is proposed that all institutions with relevant expertise should be able to access the available funds, whether they are negotiated or contestable. In both cases the emphasis should be on collaboration, thereby providing a strong incentive for research institutions independent of central government, such as tertiary institutions and IROs, to align their work with the proposed environmental research strategy.

Model 1: No institutional changes

- Environmental research funds are identified and separated into a pool, including a share of the Endeavour Fund. This would be drawn from the $255 million identified under the narrow definition.[8]
- MfE takes responsibility for developing an environmental research strategy. It should create this by building on the existing CESR. In doing so it should seek input from ministries, including DOC, MPI, LINZ, TPK, the Ministry of Health, regional councils, research providers, iwi, relevant industries and the standing science advisory panel proposed in my review of environmental reporting.[9] The strategy should set out both short- to medium- and long-term priorities and key research goals in each field.
- Support the continuing development of mātauranga Māori by nurturing cultural competencies within funding and research organisations.[10]
- MBIE continues to manage the allocation of both negotiated and contestable funds, subject to amended criteria that are suited to the nature of environmental research, and support improved transparency.
- The allocation process is supported through MBIE recruiting specialist staff who understand not just the 'how' of research, but the 'what'. This is essential to ensure that programmes are aligned with the environmental research strategy, while allowing outcome monitoring.
- MBIE is responsible to MfE for ensuring that the levels of investment in different fields of environmental research are clearly stated, and that in aggregate, the full portfolio of research needs indicated in the environmental research strategy is met across all horizons.
- Research providers decide how best to invest in capacity and capability, including the development of the Māori workforce.[11]

Model 2: An Environmental Research Council

- Environmental research funds are identified and separated into a pool including a share of the Endeavour Fund. This would be drawn from the $255 million identified under the narrow definition.[12]
- MfE takes responsibility for developing an environmental research strategy. It should create this by building on the existing CESR. In doing so it should seek input from ministries including DOC, MPI, LINZ, TPK, the Ministry of Health, regional councils, research providers, iwi, relevant industries and the standing science advisory panel proposed in my review of environmental reporting.[13] The strategy should set out both short- to medium- and long-term priorities and key research goals in each field.

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[8] See above and Table 2.3.
[9] PCE, 2019a, pp.67–68.
[10] Rauika Māngai, 2020.
[11] Rauika Māngai, 2020.
[12] See above and Table 2.3.
[13] PCE, 2019a, pp.67–68.

- An independent **Environmental Research Council** is established with specialist, dedicated staff. The council:
  - works within the environmental research strategy framework to define priorities and key research goals
  - ensures the continuing development of mātauranga Māori by nurturing cultural competencies within the council and research organisations[14]
  - sets the criteria for funding allocation
  - develops and negotiates research platforms or programmes with long-term (7–15 year) time horizons
  - allocates a contestable funding pool to provide for emerging issues and opportunities
  - runs both the negotiated and contestable allocation processes in transparent consultation with the research community. This includes putting out bounded requests for proposal and, where appropriate, conducting meetings to facilitate collaboration
  - monitors the research it is funding and conducts outcome evaluations.
- The Environmental Research Council would be accountable to MfE for ensuring that the level of investment in different fields is clearly stated, and that in aggregate, the full portfolio of research needs indicated by the environmental research strategy is met across all horizons.
- The Environmental Research Council would also be required to report on the contribution that its funding decisions make to ensuring a critical mass of researchers and the infrastructure (including collections and databases) required to deliver on the environmental research strategy over the long term.

One common feature of the two models is the development of a national environmental research strategy with defined goals that provide the reference points for the investment of all funds dedicated to environmental research. Another is the importance of further strengthening consideration of mātauranga Māori and how it can be better incorporated into the system.

The major obvious difference between the two models revolves around whether or not to leave the funding allocation function within MBIE or hand the task to a dedicated arm's-length entity. There are pros and cons that should be debated.

The advantage of leaving the mechanics of funding allocation within MBIE are twofold. In the first place, institutional change can be costly and institutional knowledge lost along the way. MBIE has amassed significant expertise. Its exposure to the deliberations of the Science Board have given it a close-up understanding of the mechanics of high-quality bid evaluation.

Secondly, MBIE is a large agency. There is security for staff in being able to depend on the administrative heft of such a ministry and proximity to a wide array of policy expertise in many areas of the economy. MBIE provided frank and penetrating commentary to me in the course of my research and I have no difficulty recognising the competence and thoughtfulness of those overseeing the current system.

[14]Rauika Māngai, 2020.

On the other hand, MBIE would not for one moment claim to be an expert on environmental research. It is candid about the fact that it has set out to understand the 'how' of research, but – at least when it comes to environmental research – not the 'what'. For its largest and most prestigious contestable fund, Endeavour, it can of course draw on the expertise of the distinguished researchers who make up the Science Board. But when it comes to the very large sums dispensed under the SSIF, it is the research providers who are familiar with the 'what'.

The question that needs to be debated is whether it makes sense for a non-expert agency (MBIE) to act as an intermediary funding body between those responsible for national environmental research goals (ministries) and the research providers without whose expertise these goals cannot be realised.

There is something to be said for having the allocation of funding undertaken by an agency with people who have deep knowledge of the 'what' as well as the 'how' of research and who can be held directly accountable to agencies like MfE, DOC and MPI for seeing that their strategic research objectives are being advanced. Furthermore, a dedicated research council with deep environmental expertise is likely to enjoy greater confidence on the part of research providers, particularly if long-term funding is to encourage greater collaboration between research providers.

The Health Research Council of New Zealand provides a precedent of long duration for research funding in a specialised field.[15] RSNZ has similarly won the confidence of researchers by supporting "excellent research projects that advance and expand the knowledge base and contributes to the development of people with advanced skills in New Zealand" through the Marsden Fund.[16] In each case, central government has seen fit to use an expert body to make important funding decisions on its behalf. It is also a reflection of the fact that not all research is the same.

I have reached the conclusion that environmental research is sufficiently distinct to merit its own funding allocation body with criteria that are tuned to the particular characteristics of research directed to environmental problem solving. While there are challenges in establishing small specialist entities, they also have some advantages. Attracting first-rate staff with deep knowledge of the environmental research domain is likely to be easier for a dedicated research council than a large bureaucracy. Once assembled, a specialist dedicated team has the best chance of winning the confidence of both policy agencies and researchers alike because it will speak the same language as they do.

MfE and other central agencies are entitled to be demanding about the focused implementation of any research strategy they develop. Researchers are entitled to expect that those who allocate funds and weave together research alliances have a deep understanding of the significance of what they are doing. An Environmental Research Council has the best chance of delivering that confidence. And it responds most directly to the widespread judgment that there is a serious gap between the words governments have uttered in strategic documents and the allocation of research resources to meet them.

[15] See https://www.hrc.govt.nz/.
[16] RSNZ, 2017.

Most importantly, a dedicated Environmental Research Council would unite in a single entity responsibility for the oversight of strategy, investment and accountability. This could – at least for environmental research – reduce the fragmentation and duplication of effort currently involved in those managing the many different research delivery mechanisms trying to ensure alignment with one another. Research providers should set priorities and manage investment processes close to the research, but alignment with national strategies and their delivery by a range of agencies would be steered by the council.

This would make for stronger accountability. An Environmental Research Council would be tasked with demanding and delivering accountability for evidence of a return to the nation on its investment in environmental research. This is very difficult for an agency like MBIE lacking understanding of the science in question.

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Appendices

Appendix 1: 2008 ANZSRC group codes[1]

Narrow
Air and climate
9601 Air quality 9602 Atmosphere and weather 9603 Climate and climate change
Biodiversity and pest control
9604 Control of pests, diseases and exotic species 9608 Flora, fauna and biodiversity
Ecosystem management and rehabilitation
9605 Ecosystem assessment and management 9612 Rehabilitation of degraded environments 9613 Remnant vegetation and protected conservation areas
Land and water
9609 Land and water management 9611 Physical and chemical conditions of water 9614 Soils
Natural hazards
9610 Natural hazards
Standards, policy and evaluation
9606 Environmental and natural resource evaluation 9607 Environmental policy, legislation and standards
Other environment
9699 Other environment 9701 Expanding knowledge*

[1] See Pink and Bascand (2008) and https://www.abs.gov.au/Ausstats/abs@.nsf/Latestproducts/CF7ADB06FA2DFD69CA2574180004CB82?opendocument

Broad
Production and primary products
8201 Forestry
8298 Environmentally sustainable plant production
8299 Other plant production and plant primary products
8304 Pasture, browse and fodder crops
8398 Environmentally sustainable animal production
Energy and resources
8498 Environmentally sustainable mineral resource activities
8499 Other mineral resources (excl. energy resources)
8503 Preparation and production of energy sources*
8504 Energy transformation*
8505 Renewable energy
8506 Energy storage, distribution and supply
8507 Energy conservation and efficiency
8598 Environmentally sustainable energy activities
8599 Other energy
Health and social
9204 Public health (excl. specific population health)*
9401 Community Service (excl. work)*
9503 Heritage
9504 Religion and ethics*
Sustainable economy
8615 Instrumentation*
8698 Environmentally sustainable manufacturing
8701 Construction planning
8798 Environmentally sustainable construction
8898 Environmentally sustainable transport
8998 Environmentally sustainable information and communication services
9004 Water and waste services
9098 Environmentally sustainable commercial services and tourism
9105 Measurement, standards and calibration services*
9199 Other economic framework*

Note: *Only relevant objectives included.

Appendix 2: Nationally Significant Collections and Databases

Nationally Significant Collections and Databases[2]
• Allan Herbarium and associated databases (MWLR)
• Cawthron Institute Culture Collection of Microalgae (Cawthron Institute)
• Crop Germplasm Resources Unit (Plant & Food Research)
• International Collection of Microorganisms from Plants and associated databases (MWLR)
• Land Resource Information System (MWLR)
• Margot Forde Germplasm Centre (AgResearch)
• National Climate Database (NIWA)
• National Collections of Fruit and Crop Germplasm (Plant & Food Research)
• National Earthquake Information Database (GNS Science)
• National Forestry Herbarium and Database (Scion)
• National Groundwater Monitoring Programme (GNS Science)
• National Nematode Collection of New Zealand (MWLR)
• National Paleontological Collection and Database (GNS Science)
• National Petrology Reference Collection and PET Database (GNS Science)
• National Vegetation Survey (MWLR)
• New Zealand Arthropod Collection (MWLR)
• New Zealand Fossil Record File (GNS Science)
• New Zealand Freshwater Fish Database (NIWA)
• New Zealand Fungal Herbarium and associated databases (MWLR)
• New Zealand Geomagnetic Database (GNS Science)
• New Zealand Volcano Database (GNS Science)
• Ngā Tipu Whakaoranga Ethnobotany Database and New Zealand Flax and Living Plant Collections (MWLR)
• NIWA Marine Benthic Biology Collection (NIWA)
• Regional Geological Map Archive and Database (GNS Science)
• Water Resources Archive (NIWA)

[2] See https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/funded-infrastructure/nationally-significant-collections-and-databases/.

Appendix 3: An illustrative selection of New Zealand collections, databases and data compilations

Land

Value and importance

Land use in New Zealand is very dynamic and depends on policies and incentives operating at any one time. For example, in the primary sector, adjustments in the carbon price and an increasing focus on offsetting agricultural emissions are changing the incentives for afforestation, as well as the mix of native and exotic species being planted. MPI is currently exploring how to account for soil carbon, and with increasing market-based incentives for mānuka honey production, more land is being reserved or converted for apiculture use.

S-map Online

A database developed for use in this area is S-map Online – a digital soil spatial information system. This database has been developed by MWLR and sits outside the set of NSCDs. Its funding is sporadic and has been drawn from multiple sources. As of August 2019, S-map had four funding sources: the SSIF; the successful NextGen S-map research programme funded from MBIE's contestable Endeavour Fund for five years (2016–2021); commercial licensing fees (S-map is proprietary for commercial use); and contributions from regional councils and Envirolink grants.

The proposed National Policy Statement for Highly Productive Land (consulted on in 2019) has put more emphasis on land that is capable of multiple uses (horticulture, cropping, grazing and production forestry). A country reliant on primary industries for much of its income needs to know what is happening on the land, what soils there are and how best to manage them. S-map provides vital information to ensure that New Zealand manages its land wisely by planning how and where to expand or adapt New Zealand's primary sector, food production and urban development into the future.

S-map is designed for use at the 1:50,000 scale and the S-map data include fundamental soil property information (e.g. depth, stoniness, clay and sand content) created from field observations and expert knowledge, as well as derived soil data based on models (e.g. available water). This soil property information is used as an input into Overseer, a model that describes nutrient flows on farms.[3] Thus, soil information imported directly from S-map is used to optimise production and manage nutrient losses within water quality limits. As of August 2020, S-map covered 36.6 per cent of New Zealand, including 67.3 per cent of the 'multiple-use land' in the country.

Nationwide monitoring networks

MWLR, along with DOC, has developed a nationwide ecosystem monitoring programme (mostly on public conservation land but applicable anywhere), called Tier 1 monitoring.[4] This involves 1,300 monitoring plots in which plants, invertebrates, birds and introduced pest mammals are monitored. With repeated sampling, scientists have been able to determine trends in productivity across a range of ecosystems, identifying species population trends and management needs for threatened species such as kea, some invertebrates and vulnerable plant ecosystems.[5]

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[3] PCE (2018). For more information see my 2018 report *Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways* (https://www.pce.parliament.nz/publications/overseer-and-regulatory-oversight-models-uncertainty-and-cleaning-up-our-waterways).

[4] Tier 1 monitoring conducted by DOC is a ground-breaking, systematic sampling programme for all public conservation land, and potentially over the whole of New Zealand (see https://www.doc.govt.nz/our-work/monitoring-and-reporting-system/).

[5] MWLR, 2019.

Tier 1 monitoring and the National Vegetation Survey are also instrumental in combatting biosecurity incursions such as myrtle rust, as the datasets help identify where myrtle tree and shrub species occur.[6] Myrtaceae are the dominant species in many of Aotearoa's forest ecosystems and provide habitat for threatened birds and other animals. Without this network of sites and associated datasets, along with monitoring by councils, DOC staff and citizen science observations, management of the risk of forest dieback would be nearly impossible.

MWLR is using Sentinel-1 and -2 satellites to support the Land-use and Carbon Analysis system. It explores, among other things, questions of whether native old-growth forests are as effective carbon sinks as exotic plantation forests in reducing greenhouse gases emitted into the atmosphere. MWLR is also using LiDAR technology to understand the composition and change in productivity of individual trees in forest research plots, which can then be linked to possum browsing and 1080 treatments to remove introduced predators.

Work with iwi and hapū is underway to integrate mātauranga Māori into this research and find complementary environmental health indicators.[7]

Source: Hindaandjohn, Flickr

Figure 6.3.1: Knowledge about the composition of old-growth forest is important for estimating standing stocks of carbon, exploring how land cover is changing over time, and understanding how ancient forests influence rainfall and water retention between the mountains and water courses.

[6] MWLR, 2019.
[7] MWLR, 2019, p.34.

Yet New Zealand has no robust, comprehensive and nationally representative dataset that characterises New Zealand's land use and how this is changing spatially and temporally. Current estimates are cobbled together from data derived from a variety of sources and proxies.

Further, our understanding of how land cover is evolving (the types of vegetation and other features that cover the land) is also patchy and irregularly undertaken (every four to six years). Funding to carry out land cover surveys currently has to be cobbled together on a one-off basis, as information on land cover is not part of the securely funded set of NSCDs. Current Endeavour funding to provide an updated Land Cover Database will cease shortly, with no visibility about where the funding to continue this work will come from.[8]

Data gaps

Comprehensive and up-to-date information about what is happening on the land would seem to be indispensable to an economy like New Zealand's – an economy reliant on primary industries and tourism for much of its income. However, major gaps exist.

For example, the rapid conversion from sheep and beef to dairy farming since the 1990s has altered New Zealand's agricultural nutrient cycling, but the impacts of changes in land use at local levels are poorly monitored in terms of their ecosystem effects.[9]

In their *Environment Aotearoa 2019* report, MfE and Stats NZ noted that with the current information, changes in land use due to fragmentation from the development of lifestyle blocks were difficult to quantify.[10] They further noted that information about land management practices was largely lacking and not available at a national scale. Management practices such as stocking rates, fertiliser application and disposal of agricultural effluent, or management measures such as riparian plantings, could not be assessed against the flow of nutrients into freshwater systems.[11]

MfE and Stats NZ also identified an important data gap around the effects of native vegetation removal on vulnerable ecosystems susceptible to sedimentation.[12] Erosion is only patchily monitored in regions, with erosion modelling available but no national, systematic monitoring scheme in place.[13]

Some aspects of land use change may be observable from satellite imaging (e.g. via land cover mapping, repeated in 1996, 2002, 2008, 2012 and 2018).[14] Change can be tracked at both coarse- and fine-grained scales. The level of native vegetation removed can also be followed by satellite imagery, but the downstream consequences of this action are harder to track by remote sensing.

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[8] Richard Gordon, Chief Executive Officer, MWLR, pers. comm., 23 October 2020.

[9] MfE and Stats NZ, 2019, p.62.

[10] MfE and Stats NZ, 2019, p.43.

[11] MfE and Stats NZ, 2019, p.62.

[12] MfE and Stats NZ, 2019, p.39.

[13] MfE and Stats NZ, 2019, p.28.

[14] See https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/.

Table 6.3.1: Selected databases, collections and analyses that contribute to New Zealand's understanding of the land environment.

Datasets and collections	Modelled outputs and data collations
• Auckland War Memorial Museum natural sciences collection (AWMM) • Bird banding dataset (DOC) • Canterbury Museum natural history collection (CM) • Dame Ella Campbell Herbarium (Massey University) • ebird (Birds New Zealand) • Ecosystem monitoring data (councils) • iNaturalist (New Zealand Bio-Recording Network Trust) • Land Cover Database (MWLR) • Lincoln University Entomology Research Collection (Lincoln University) • National Environmental Monitoring Standards (MfE) • New Zealand Bird Atlas (Birds New Zealand) • New Zealand Organisms Register (MWLR) • New Zealand Plant Conservation Network (NZPCN) • NZ Aerial Imagery Set (LINZ) • NZ Property Titles (LINZ) • NZ River Centrelines (LINZ) • Otago Museum taxonomic science collection (OM) • Rodent monitoring (DOC) • Te Papa natural history collection (Te Papa) • Tier 1 monitoring plots (DOC) • Unitec Herbarium (Unitec) • University of Canterbury Herbarium (University of Canterbury)	• Checklist of the Living Mollusca Recorded from the New Zealand Exclusive Economic Zone (University of Otago) • Digital Elevation Model (LINZ) • Kā Huru Manu (Te Rūnanga o Ngāi Tahu) • New Zealand Birds Online (Te Papa) • New Zealand eFlora (MWLR) • New Zealand Mollusca (private) • New Zealand Virtual Herbarium (MWLR) • NIWA fire weather (NIWA) • S-map Online (MWLR) • Te Kāhui Māngai (Directory of iwi and Māori organisations) (Te Puni Kōkiri)

Those funded through SSIF as Nationally Significant Collections and Databases	
• Allan Herbarium (MWLR) • International Collection of Microorganisms from Plants (MWLR) • National Earthquake Information Database (GNS Science) • National Forestry Herbarium and Database (Scion) • National Vegetation Survey (MWLR) • New Zealand Arthropod Collection (MWLR) • New Zealand Freshwater Fish Database (NIWA) • New Zealand Fungal Herbarium and associated database (MWLR) • NIWA Marine Benthic Biology Collection (NIWA) • Water resources archive (NIWA)	• Land Resource Information System (MWLR) • New Zealand Volcano Database (GNS Science) • Regional Geological Map Archive and Database (GNS Science)

Freshwater and marine environment

Value and importance

The datasets and modelled outputs available to analyse freshwater and marine issues are highly diverse in their depth and administration. Some are huge, such as the MPI Fishery Catch Effort Database that contains 19 million detailed records about fishing events through 32 years of activity – every trawl net, longline, set net and hand-gathered fishing capture in commercial operations. Others, such as the Cawthron Institute Culture Collection of Microalgae, comprising just 454 algal cultures, are small but vital for safeguarding food safety and environmental health.[15] These data assets are not easily shared between institutions – many use unique database formats so links between the same geographical regions, species, ecosystems, rohe or other common threads are not easily explored.

Freshwater

The New Zealand Freshwater Fish Database held by NIWA contains over 34,000 observations.[16] These data are available online and can be downloaded for any catchment or species of fish. For example, searching kōwaro (Canterbury mudfish) generates 1,318 lines of data, about events in prosaically named sites such as Dog Kennel Stream and the Waianiwaniwa River oxbow. However, as documented in the database, the methods used for the surveys are varied and some observations have little associated methodology. Sampling effort, along with fish abundance, is either recorded in a variety of ways or not at all.

[15] See https://www.cawthron.org.nz/biotechnology/services/cawthron-culture-collection/.

[16] See https://niwa.co.nz/information-services/nz-freshwater-fish-database.

While the data are useful, their ragged pedigree makes interpretation challenging. This can lead to problems when the data are interpreted to infer population size, its trends, the density of fish in a stretch of river, or even the presence or absence of fish. Yet this database forms the backbone of efforts to manage freshwater fish and determine national population trends and degrees of extinction risk.

Marine

Reserves established under the Marine Reserves Act 1971 are created to preserve, for the scientific study of marine life, areas of New Zealand that contain underwater scenery, natural features, or marine life, of such distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest.[17] They are also havens for biodiversity and an important tool for protecting the nuclei of marine species populations, which can go on to enhance the productivity of ecosystems in the surrounding areas. To be sure that marine reserves are achieving these beneficial management outcomes, it would be desirable to systematically monitor the abundance and diversity of marine life inside and outside of them.

While there are datasets held by DOC relating to marine reserves (Table 6.3.2), these currently contain monitoring data for only four regions where there is regular monitoring: Tonga Island, Long Island–Kokomohua and Horoirangi in Te Tau Ihu region (the top of the South Island); Taputeranga in Wellington; Te Tapuwae o Rongokako in Gisborne; and Whanganui a Hei (Cathedral Cove) Marine Reserve in Coromandel. At these sites the monitoring focuses on key species only (large, easy to observe, mobile species in rocky reef areas, such as blue cod, lobster, kina and snapper).

For another seven marine reserves there have been annual historical monitoring programmes (Cape Rodney–Okakari Point, Tāwharanui, Te Angiangi, Ulva Island–Te Wharawhara, Tapuae, Tuhua (Mayor Island) and Poor Knights). Finally, at ten reserves in Fiordland, there has been more comprehensive monitoring, including indicator species for this region, such as black coral and rock lobster. For New Zealand's remaining marine reserves there has been no systematic monitoring. As a result, the data are of limited utility in assessing the status and trends of marine reserve ecosystems or the benefits of management activity.[18]

There has been limited investment in data management for marine monitoring by DOC. This means that data that have been collected have not been curated in a centralised data management system, which has led to some data loss. This may be because students finished their research projects, or data were lost by contractors or mislaid between different DOC offices. While DOC is making efforts to improve this situation, a centralised data management system is needed to ensure that data are gathered in a way that enables the outcomes of management actions to be evaluated over time, as well as to assess the impact of pressures in the marine environment, including climate change.

In 2018, DOC secured funding to increase the number of marine reserves that are fully managed with respect to monitoring and compliance. This included the development of a framework to monitor marine reserves systematically and gather data that would provide a national picture of changes in these ecosystems. To date, only some of the data that exist have been collected using standardised methodologies. The rest have been collected on a project-by-project basis and are therefore unsuitable for making useful comparisons across timescales and regions.

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[17] Marine Reserves Act 1971 s 3(1).

[18] See https://www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/marine-reserve-monitoring/.

Data gaps

Important gaps exist, such as country-wide coverage of freshwater environmental indicators for water quality.[19] Voluntary initiatives such as the National Environmental Monitoring Standards (NEMS) have been established to improve data comparability but are far from universally used, and a lack of standardisation in data collection across regional councils under this framework persists.

Developing a national picture of trends in many environmental variables, such as water quality, is difficult. In 2019, MfE and Stats NZ identified a series of data gaps for monitoring ecosystem health, including a lack of national datasets for deposited sediments, dissolved oxygen and algal biomass, and patchy monitoring of pollutants such as *E. coli*.[20] CRIs have repeatedly tried to address these gaps with funding proposals, without success.[21]

There has been a lack of systematic surveys of offshore and coastal areas, for example, to determine habitat types. As a result, for marine spatial planning work, analyses for representativeness of marine habitat types need to be based on proxies such as the geological substrate – which may be an unreliable indicator of the types of habitat being proposed for protection. Mahinga kai sites are now important parts of the National Policy Statement for Freshwater Management, and data gaps around their location and state have been signalled for some years.[22,23]

DOC and Land Information New Zealand (LINZ) are coordinating their sampling efforts to improve cost effectiveness and coverage. However, MfE and Stats NZ also noted in 2019 that data to monitor biodiversity in marine and coastal areas were lacking.[24] The report noted that the extent of marine habitats and their fundamental characteristics remained unclear. The lack of data in marine and coastal environments also included data gaps about concentrations and trends of heavy metal and bacterial contaminants.[25]

[19] PCE, 2019a, p.34.
[20] MfE and Stats NZ, 2019.
[21] NIWA, pers. comm., November 2020.
[22] New Zealand Government, 2020.
[23] Zaiko et al., 2018, p.6.
[24] MfE and Stats NZ, 2019, p.89.
[25] MfE and Stats NZ, 2019, p.66.

Table 6.3.2: Selected databases, collections and analyses that contribute to New Zealand's understanding of the freshwater and marine environment.

Datasets and collections	Modelled outputs and data collations
• Ecosystem monitoring data (councils) • Fishery Catch Effort Database (MPI) • Freshwater Biodata Information system (NIWA) • Hauraki Gulf Spatial Planning SeaSketch project (DOC) • Marine reserve information and monitoring (DOC) • MPA Science Advisory Group SeaSketch project (DOC) • National digital river network (NIWA) • National Environmental Monitoring Standards (MfE) • National freshwater benchmark station network (NIWA) • National freshwater diatom collection (NIWA) • National macroinvertebrate traits database (NIWA) • National water quality database (NIWA) • New Zealand Ocean Data Network (NIWA) • NIWA marine macroalgae database (NIWA) • NZ Aerial Imagery Set (LINZ) • NZ River Centrelines (LINZ) • Regional council coastal monitoring (councils via LINZ) • Sea levels (NIWA) • Seagrass and mangroves extent (DOC)	• Beach type classification (NIWA) • Checklist of the Living Mollusca Recorded from the New Zealand Exclusive Economic Zone (University of Otago) • Coastal classification (NIWA) • Estuarine classification (NIWA) • Fishery management area boundaries (MPI/ LINZ) • Fishery stock assessments (MPI) • Flow forecasts (NIWA) • LakeSPI (NIWA) • Land, Air, Water Aotearoa (LAWA) • Marine Environment Classification (NIWA) • Marine habitats (NIWA) • Marine protected area boundaries (DOC/ LINZ) • MARLIN scientific metadata database (MPI) • New Zealand bathymetry dataset (NIWA) • New Zealand Mollusca (private) • NIWA charts (NIWA) • River Environment Classification (NIWA) • Seabird Tracking Database (BirdLife International) • SeaSketch (DOC) • Tide forecaster (NIWA) • Wave forecasts (NIWA)
Those funded through SSIF as Nationally Significant Collections and Databases	
• Cawthron Institute Culture Collection of Microalgae (Cawthron Institute) • NIWA Marine Benthic Biology Collection (NIWA) • Water resources archive (NIWA)	• Regional Geological Map Archive and Database (GNS Science)

Biodiversity and ecosystem functioning

Value and importance

The broad set of databases covering New Zealand's biodiversity and ecosystems are not the result of a systematically designed set of parameters intended to identify those features that most need to be recorded. Rather, these databases are the legacy of historical decisions on both topic and funding that have led to the development of datasets and collections used to answer specific questions.

In some of the data sources in Table 6.3.3, all records are available online. But for others, such as the specimen collections in museums, only a small percentage of the databases are digitised despite their high value for species identification and occurrence.

In the case of the Te Papa entomology collection, one example of a highly valuable record is the Hudson specimen collection of several thousand dried insects.[26] Collected over the lengthy career of amateur entomologist George Vernon Hudson with his wife Florence Woodhead Gillon and daughter Stella Hudson between 1881 and 1945, it records species found around New Zealand through that period, with particular emphasis on the Wellington region. Some specimens represent the only regional record of the species.

Source: Michael Hall, Te Papa

Figure 6.3.2: The Hudson collection of thousands of dried insects held at Te Papa is of national importance.

The collection represents a time-capsule of ecological information about which species were present in the regions visited. Specimens such as these are being used internationally to determine the changes in insect populations and diversity through time. Pollen and other material carried on their bodies, such as dust and parasites, can be used to determine plant diversity, pollution and pathogen loads in the environment.

[26]See https://collections.tepapa.govt.nz/topic/2413.

These moths, butterflies, cicadas, beetles, grasshoppers, wētā, wasps, flies and aquatic insects are mounted on pins, with their coded data labels hidden underneath, precluding the possibility of scanning or photographing for bulk data upload. The data for the specimens are recorded in manuscript legers, which have been scanned and are being decoded because of the efforts of more than 100 volunteers.

The value of this collection, and many others like it, is not realised given its inaccessibility. But collections like these hold huge potential for interpreting ecological change over time. The problem of undigitised collection data is widespread throughout New Zealand taxonomic research collections.[27] MBIE competitive funding is hard to unlock to deal with the accumulated 'backlog' of uncatalogued data since it is perceived to be neither novel information nor innovative science.

In the absence of specific population survey data, taxonomic collections provide key data to assess threat status, and need to be utilised more for conservation. Data on the locality, date, habitat and morphological measurements were digitised for nearly 25,000 specimens from 460 species held in the New Zealand Arthropod Collection curated by MWLR. Results suggested that the current New Zealand Threat Classification system does not accurately reflect the conservation needs of most insect species.

Source: Darren Ward, MWLR

Figure 6.3.3: Insect specimens in the New Zealand Arthropod Collection housed at Manaaki Whenua – Landcare Research are maintained in dried, pinned arrays, with their data labels and the digitised information associated with each individual.

The Antarctica New Zealand programme recorded the numbers of breeding Adélie penguins in the Ross Sea region for 36 years (1981–2017).[28,29] By contrast, a more chaotic assemblage of data was reviewed in 2012 to determine trends for the hyperabundant shearwater species, which number in excess of 12 million individuals from nine taxa, nesting at over 350 sites.[30]

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[27]Nelson et al., 2015.

[28]Lyver et al., 2014.

[29]See https://catalogue.data.govt.nz/dataset/adelie-penguin-census-data/resource/f82c5e1d-f04d-446d-9338-e9d0603360f8.

[30]Waugh et al., 2013.

No process led to a decision that the systematic collection of Adélie penguin data was more important than that for shearwaters. It is just the random outcome of different processes at different times. But the case for tracking shearwaters on a consistent basis is just as compelling. Because of their large biomass and distribution across almost all offshore islands throughout New Zealand, they contribute in important ways to the marine ecosystem that they feed on. For the islands where they nest, they provide nutrient transfer from the sea to the land, thus providing inputs for the soil and forest ecosystems on those sites.

The existing data were collated by museum researchers and are not held by DOC or a biodiversity monitoring agency. Because of the lack of systematic research methodology, review of the data collected throughout the nineteenth and twentieth centuries showed that population trends could be determined for only four of the nine species and at very few of the 350 sites surveyed. More systematic research efforts have been recommended.[31] But advancing such a case through current funding mechanisms would be very difficult.

Data gaps

As my 2019 review of environmental reporting noted, systematic recording of New Zealand's biota is not undertaken. In many other OECD countries, national surveys are undertaken, with systematic recording using a series of standardised environmental measures. From this basis, trends, new occurrences and anomalies can be identified and investigated. This framework is currently lacking in New Zealand. Sporadic, researcher-led initiatives mean that time-series data that capture important facets of our environment are the exception, rather than the rule.

MfE notes in its *Environment Aotearoa 2019* report that "it is difficult to measure the overall condition of our ecosystems" and "information is particularly limited for rare and naturally uncommon ecosystems." It goes on to state that "information is also missing at a species level – the conservation status of 2,805 species cannot be assessed because of a lack of data." Furthermore, it notes that while introduced species present particular threats to indigenous biodiversity, "we do not have accurate data about the location or number of introduced species or how they are changing."[32]

Significant gaps are recognised in the capability within New Zealand science institutions to manage biosecurity. There is recognition that New Zealand's expertise base is very thin, with critical mass of specialists lacking nationally.[33] This means that with the retirement of one specialist, or the need for a concerted effort on a particular plant or animal pest group (such as during a biosecurity incursion), there are not enough specialists to cover the work programmes needed, nor is there an ability to scale up activity rapidly, if required.

There are important gaps in research expertise relating to pastoral plant pathogens, as well as for nematodes, a group of invertebrates often linked to disease spread and pastoral system pathogens.[34]

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[31] Waugh et al., 2013.

[32] MfE and Stats NZ, 2019, p.27.

[33] Nelson et al., 2015.

[34] Richard Gordon, Chief Executive Officer, MWLR, pers. comm., 23 October 2020.

Table 6.3.3: Selected databases, collections and analyses that contribute to New Zealand's understanding of biodiversity and ecosystem functioning.

Datasets and collections	Modelled outputs and data collations
• Adélie penguin census data (Antarctica New Zealand) • Auckland War Memorial Museum natural sciences collections (AWMM) • Bat recordings database (DOC) • Bird banding dataset (DOC) • Canterbury Museum natural history collection (CM) • Dame Ella Campbell Herbarium (Massey University) • ebird (Birds New Zealand) • Ecosystem monitoring data (councils) • Fishery Catch Effort Database (MPI) • iNaturalist (New Zealand Bio-Recording Network Trust) • Land Cover Database (MWLR) • Lincoln University Entomology Research Collection (Lincoln University) • Marine Invasives Taxonomic Service (NIWA) • Marine mammal database (strandings and sightings) (DOC) • National Environmental Monitoring Standards (MfE) • New Zealand Bird Atlas (Birds New Zealand) • New Zealand Cetacean Tissue Archive (University of Auckland) • New Zealand fur seal demographics (DOC) • New Zealand Organisms Register (MWLR) • New Zealand Plant Conservation Network (NZPCN) • NZ Aerial Imagery Set (LINZ) • NZ River Centrelines (LINZ) • Otago Museum natural history collection (OM) • Rodent monitoring (DOC) • Seabird colony database (Te Papa) • Seabird demography and threats (DOC) • Seabird distribution database (DOC) • Seabird Tracking Database (BirdLife International) • Seabird tracking databases (DOC) • Seed rain monitoring network (DOC) • Te Papa natural history collection (Te Papa) • Tier 1 monitoring plots (DOC) • Unitec Herbarium (Unitec) • University of Otago Geology Museum (University of Otago) • University of Otago Herbarium (University of Otago) • Video trap fish sampling footage (DOC, Te Papa)	• Bathymetric model (NIWA) • Checklist of the Living Mollusca Recorded from the New Zealand Exclusive Economic Zone (University of Otago) • Coastal classification (NIWA) • Digital Elevation Model (LINZ) • Estuarine classification (NIWA) • Flow forecasts (NIWA) • Kā Huru Manu (Te Rūnanga o Ngāi Tahu) • MARLIN scientific metadata database (MPI) • New Zealand Birds Online (Te Papa) • New Zealand eFlora (MWLR) • New Zealand Mollusca (private) • New Zealand Virtual Herbarium (MWLR) • River Environment Classification (NIWA) • S-map Online (MWLR) • Te Kāhui Māngai Directory of iwi and Māori organisations (Te Puni Kōkiri) • Wave forecasts (NIWA)

Those funded through SSIF as Nationally Significant Collections and Databases	
• Allan Herbarium (MWLR) • Cawthron Institute Culture Collection of Microalgae (Cawthron Institute) • International Collection of Microorganisms from Plants (MWLR) • National Forestry Herbarium and Database (Scion) • National Paleontological Collection and Database (GNS Science) • National Vegetation Survey (MWLR) • New Zealand Arthropod Collection (MWLR) • New Zealand Fossil Record File (GNS Science) • New Zealand Freshwater Fish Database (NIWA) • New Zealand Fungal Herbarium and associated database (MWLR) • Ngā Tipu Whakaoranga Ethnobotany database and New Zealand Flax and Living Plant Collections (MWLR) • NIWA Marine Benthic Biology Collection (NIWA) • Water Resources Archive (NIWA)	• Land Resource Information System (MWLR) • Regional Geological Map Archive and Database (GNS Science)

Pollution and waste

Value and importance

To maintain healthy ecosystems and human health, knowledge of the presence of contaminants in the environment is crucial. Reports by my predecessors on contaminated sites have highlighted past negligence in this space. Work at Fruitgrowers' Chemical Company at Mapua in Tasman District to remove contaminants started in 2001 and was the subject of two PCE reports (in 2008 and 2010) regarding the contamination of land from pesticide residues.[35] This was identified as one of the worst contaminated sites in New Zealand. Remediation was completed 20 years later, and the treatment process may have placed the health of the adjacent estuary, as well as workers and residents, at further risk.

Monitoring and managing chemical hazards requires accurate information that is accessible in the long term. The task of tracking present-day releases of potentially hazardous chemicals and their wastes is herculean. The Environmental Protection Authority (EPA) is responsible for managing over 150,000 hazardous substances and keeps a register of substances approved for import or manufacture. However, New Zealand lacks systematic national reporting of the production, import, use, release and disposal of most chemicals – regardless of the scale of their use within our economy.

There is a risk that present-day releases are creating problems that will become our 'Mapua moments' of the twenty-first century and beyond. As a step towards improving this situation, in 2019 I recommended that MfE consider developing a Pollutant Release and Transfer Register (PRTR) to facilitate public access to information.[36] This would both assist the management of risks and provide the public with information about what is being introduced into their environment.

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[35] PCE, 2008, 2010.
[36] PCE, 2019b.

Monitoring data on chemical presence can provide information about the identity, location and concentration of contaminants in the environment. Such data can provide useful insights into whether chemical concentrations are within regulated limits, as well as trends over time. Some monitoring data are gathered by regional councils when carrying out their consent monitoring and environmental monitoring functions. These data often do not get used in any other contexts. Other data are gathered by some CRIs. However, limitations exist around the accessibility and scope of these datasets in terms of the chemicals monitored and extent of environmental media covered.[37]

With respect to solid waste, knowledge of waste and material flows is vital if we are to pursue 'circular economy' policies that seek to internalise waste streams and eliminate particular contaminants. As the speed of technological change and consumption increases, data capture of pollution and waste needs to be adaptive to enable the public and regulators to keep pace.

Data gaps

There remain significant gaps in New Zealand's data on pollution and waste management. MfE reported in 2019 that there was not enough data to report on the extent or magnitude of contamination occurring across New Zealand.[38] Four areas to highlight in relation to releases, disposal and monitoring are:

- the lack of accessible national-level data on chemical releases
- the lack of comprehensive, high-quality data on solid waste disposal, recovery and recycling rates
- pesticide and other chemical residues are not routinely monitored in surface water, and the suite of chemicals monitored is limited
- there is currently no mandatory reporting of $PM_{2.5}$, which is specifically highlighted as being inadequately reported in the 2017 OECD report on New Zealand's environmental performance.[39]

Currently there is only a partial gathering of information about the waste that is treated in landfills in New Zealand. These data are recorded at levied landfills only, which take less than half of all solid waste.[40] Moreover, there is no nationally consistent collection of waste data.[41] In relation to plastic waste, a recent report by the Prime Minister's Chief Science Advisor, Dr Juliet Gerrard, has highlighted the need for much improved data about plastic consumption, disposal, recycling and recovery to inform regulation and enable active consumer choice.[42]

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[37] PCE has commissioned a review of the chemical monitoring programmes managed by regional councils as part of a wider investigation into chemical contaminants in the environment (see https://www.pce.parliament.nz/our-work/current-investigations).

[38] MfE and Stats NZ, 2019, p.66.

[39] OECD, 2017, p.27; MfE and Stats NZ, 2019.

[40] MfE, 2019.

[41] The OECD noted there was a need to "improve the collection of data on the generation, disposal and treatment of waste, with a view to producing timely, comprehensive and internationally comparable information" (OECD, 2017, p.25).

[42] Office of the Prime Minister's Chief Science Advisor, 2019.

Table 6.3.4: Selected databases, collections and analyses that contribute to New Zealand's understanding of pollution and waste.

Datasets and collections	Modelled outputs and data collations
• Air quality monitoring data of PM_{10} (LAWA) • Annual reporting on 1080 aerial operations (EPA) • Chemical Classification and Information Database (EPA) • Environmental reporting series (Stats NZ) • Export and import documents database (New Zealand Customs Service) • Fire and Emergency New Zealand, Civil Defence, St John and New Zealand Police database on hazardous substances • Hazardous Activities and Industries List (MfE) • Hazardous substance and new organism application register (EPA) • Infoshare product value, imports of chemicals (Stats NZ) • Mercury inventory (MfE) • National Air Emissions Inventory (MfE) • National survey of pesticides in groundwater (ESR) • New Zealand blood and persistent organic pollutants (Ministry of Health) • New Zealand breast milk survey (Ministry of Health) • New Zealand Inventory of Chemicals (EPA) • New Zealand Non-Municipal Landfill Database (MfE) • Register of agricultural chemicals, veterinary medicine and vertebrate toxic agents (MPI) • Urban Runoff Quality Information System (NIWA) • Waste levy data on solid waste to levied landfills (MfE) • WasteTRACK (New Zealand Trade and Industrial Waters Forum)	• Air quality screening model (Waka Kotahi NZ Transport Agency) • Air quality social cost estimates and economics modelling (Emission Impossible) • Health and Air Pollution in New Zealand (Waka Kotahi NZ Transport Agency) • Stormwater modelling (NIWA)
Those funded through SSIF as Nationally Significant Collections and Databases	
• National Groundwater Monitoring Programme (GNS Science)	

Climate change and variability

Value and importance

New Zealand's climate data needs have their roots in three main research activities:

- understanding the nature of our weather and climate patterns and trends
- modelling likely climate changes and developing adaptation pathways to climate change
- investigating ways to mitigate greenhouse gas emissions.

Three examples illustrate the nature of our reliance on data gathering and modelling to understand climate change.

Monitoring our climate and atmosphere

New Zealand and global climate models rely on a consistent set of high-quality observational climate data recorded over long periods. These records feed into research programmes that enable earth systems to be modelled and predictive outputs to be generated.

Changes in climate are affecting our everyday lives.[43] Research products are needed that can help communities to mitigate hazards such as floods, drought, fire and storms. MfE noted in *Our atmosphere and climate 2020* that "robust observation systems and long-term datasets are therefore crucial to provide reliable, quality data. This allows us to detect and understand the trend of important changes."[44]

There is also a requirement to continuously observe concentrations of atmospheric gases such as ozone, methane, carbon dioxide and nitrous oxide to feed into global databases used to track changes in such gases. In the southern hemisphere there are relatively few high-quality atmospheric gas monitoring stations. New Zealand's contribution to the global network is therefore disproportionately important.[45]

New Zealand is a leader in this area, having set up the CarbonWatch NZ project in 2019. By combining direct measurements of greenhouse gases in the air with high-resolution weather models, CarbonWatch NZ will develop a complete top-down picture of the national carbon balance and enhance understanding of the carbon cycle in indigenous and exotic forests, farmland and urban environments.[46]

NIWA is funded through MBIE's SSIF to collect and curate climate and atmospheric gas observations and maintain the network of stations. MetService is also funded by the Government to collect weather observations, with the data collectively stored in NIWA's national database.

[43] MfE and Stats NZ, 2017, p34.
[44] MfE and Stats NZ, 2020, p.68.
[45] NIWA, pers. comm., October 2020.
[46] See https://niwa.co.nz/climate/research-projects/carbon-watch-nz.

Source: Simeon W, Flickr

Figure 6.3.4: The Baring Head Clean Air Monitoring Station has been operating since 1972 and has provided invaluable long-term data to help understand atmospheric gases in the southern hemisphere.

Local climate modelling for national uses

As a small but mountainous nation, positioned far from other land masses, our weather is difficult to predict and there are many localised microclimates. To understand localised variation in climate, monitoring stations measuring temperature, solar radiation, humidity, rainfall and wind are required. New Zealand's climate monitoring network is largely reliant on approximately 150 automated stations, with a wider network of 600 stations from which data are uplifted manually.[47]

There is little redundancy in the system. One station going offline has a substantial impact on the overall dataset because of this thin coverage. The scientists and technicians responsible for maintaining the network and ensuring data of the standard required indicate that we are slipping behind global best practice in this area.[48]

Currently, New Zealand's temperature measurement network is effective, but rainfall data are far from optimal. Only around one half of New Zealand's precipitation is currently measured via rain gauges in weather stations, the remainder falling in ungauged remote or mountainous areas.[49] This means we have a poor understanding of the characteristics of an important proportion of our water yield and the weather conditions that produce it. This, in turn, affects our ability to predict water availability for maintaining ecosystems or productive systems, and for uses such as irrigation or industry.[50]

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[47] See https://cliflo.niwa.co.nz/.

[48] NIWA, pers. comm., October 2020.

[49] NIWA, pers. comm., October 2020.

[50] MfE and Stats NZ, 2019, p.82.

Predictive modelling

There is a need for local-scale predictive modelling of the near- and long-term effects of climate change and more need than ever to accurately forecast weather and climate into the future. These models build on information from global climate models, which generate results at the scale of around 100 square kilometres. However, to predict climate patterns at a scale useful for the primary sector, for example, more detailed outputs are needed. Decisions about the kinds of crops, trees, pasture, stock and farming operations that are likely to be viable many years into the future hinge on accurate climate data and robust predictive modelling.

Climate change adaptation is not just reliant on understanding gradual increases in temperature, but importantly it is also about planning for an increasing prevalence of extreme weather events. These can include intense rainfall events, temperature extremes, storm surges and droughts.[51] Such weather impacts are very costly to mitigate in terms of infrastructure damage or damage to natural systems, but they are statistically rare events.[52] To understand the occurrence and characteristics of extreme weather events, a large sample size and a large modelling effort is required.

Currently, there are constraints on New Zealand's climate modelling capacity delivered by NIWA through its SSIF funding, which uses the NeSI computing system.[53,54] Access to supercomputer time to run climate simulations and weather models needs to be paid for, with limitations on this funding. This, in turn, places limits on the number of scenarios that can be modelled, such as under different future greenhouse gas emissions outcomes, and how these affect different regions.

Data gaps

MfE has stated that the biggest gap in knowledge is "knowing how global emissions will increase or decrease in the future, and what actions would be implemented to curtail emissions".[55] The sinks and sources of greenhouse gases are uncertain, and the extent to which native forests contribute as sinks for carbon emissions is currently poorly understood.[56]

MfE has also reported that there are few data to assess trends in many atmospheric contaminants, with insufficient coverage of all cities and towns.[57] There is a lack of data to assess trends in sulphur dioxide, ozone and carbon monoxide.[58] Detailed data on rainfall are lacking, especially in remote regions, which also contributes to our poor understanding of erosion rates nationally.[59,60] Information is lacking about abstraction of water for irrigation, which makes managing the available water difficult.[61]

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[51] Rosier et al., 2015; MfE and Stats NZ, 2020, p.27.
[52] Rosier et al., 2015; Seneviratne et al., 2012.
[53] See https://www.nesi.org.nz/.
[54] NIWA, pers. comm., October 2020.
[55] MfE and Stats NZ, 2019, p.97.
[56] MfE and Stats NZ, 2019, p.97.
[57] MfE and Stats NZ, 2019.
[58] MfE and Stats NZ, 2019, p.71.
[59] NIWA, pers. comm., October 2020.
[60] MfE and Stats NZ, 2019, p.39.
[61] MfE and Stats NZ, 2019, p.82.

Table 6.3.5: Selected databases, collections and analyses that contribute to New Zealand's understanding of climate change and variability.

Datasets and collections	Modelled outputs and data collations
• Agricultural Production Survey (Stats NZ) • Atmospheric aerosol observations (NIWA) • Atmospheric CO_2 observations (NIWA) • Atmospheric ozone observations (NIWA) • Atmospheric water vapour observations (NIWA) • Coastal sea-level rise and sea-surface temperature (Stats NZ) • Environmental reporting series (Stats NZ) • Fire and Emergency New Zealand wildfire database (NZFS) • Land Cover Database (MWLR) • National climate station network (NIWA) • National Soils Database (MWLR) • New Zealand rainfall intensity statistics (NIWA) • NZ Aerial Imagery Set (LINZ) • NZ River Centrelines (LINZ) • Site Information Management System (NIWA) • SolarView (NIWA) • Surface radiation observations (NIWA)	• Air quality screening model (Waka Kotahi NZ Transport Agency) • CarbonWatch NZ (NIWA, GNS Science, MWLR, University of Waikato, Auckland Council) • CliFlo (NIWA) • Climate change scenarios (NIWA) • Flow forecasts (NIWA) • Health and Air Pollution in New Zealand (Waka Kotahi NZ Transport Agency) • National greenhouse gas inventory (MfE) • New Zealand Historic Weather Events Catalogue (NIWA) • NIWA fire weather (NIWA) • Ozone and UV Index (NIWA) • River Environment Classification (NIWA) • S-map Online (MWLR) • Virtual Climate Station Network (NIWA) • Wave forecasts (NIWA) • Weather forecasts (NIWA)
Those funded through SSIF as Nationally Significant Collections and Databases	
• National Climate Database (NIWA) • National Groundwater Monitoring Programme (GNS Science) • Water resources archive (NIWA)	• Land Resource Information System (MWLR)

Appendix 4: The themes and high-level research questions set out in the Conservation and Environment Science Roadmap

Theme 1: Environmental monitoring and data management	
Key question	• How can we develop, improve and integrate the systematic observations, tools, databases, modelling and monitoring technologies for reporting on environmental management and its outcomes, leading to improved management practices and policy?
Theme 2: Mātauranga Māori	
Key question	• How can mātauranga Māori be recognised, developed and utilised in new ways, both alongside and integrated with other science approaches, to improve environmental outcomes and to support Māori to exercise traditional roles such as kaitiakitanga and rangatiratanga?
Theme 3: Climate change	
Key question	• What are the potential risks from climate change for New Zealand's environment, economy and society, and what options exist or can be developed to manage and reduce the risks, and/or adapt to the expected impacts? • What options and technologies exist or can be developed to reduce New Zealand's net greenhouse gas emissions, and what are their economic, environmental and social costs and benefits?
Theme 4: Biosecurity	
Key question	• What evidence, processes and procedures are needed to guide future policy and management options to achieve efficient and effective national-level prevention or management (including eradication) of invasive species to protect our environment, prosperity and well-being?
Theme 5: Integrated ecosystems and processes	
Key question	• What information is needed to guide policy development and management, and integrate cross-domain interfaces involving complex interactions between land, fresh water, coasts and oceans, urban areas and socio-ecological systems, including cross-cutting species and populations considerations? • How can decision-makers at all levels recognise, value, and manage 'mountains to the sea' as a single systems-based domain to improve the science-policy connection?
Theme 5: Integrated ecosystems and processes – land	
Key question	• What evidence do we need to guide policy development and management on how to effectively manage land to sustain and improve conservation and environmental outcomes, including restoration and regeneration of native ecosystems, while continuing to foster social and cultural prosperity and well-being?

Theme 5: Integrated ecosystems and processes – fresh water	
Key question	• What tools, systems and processes can be put in place to inform policy development and aid protective and restoration activities to ensure the following conditions while enabling the efficient, equitable and productive use of water: freshwater ecosystems and habitats are healthy and resilient; adverse human health impacts are avoided; cultural needs are met; recreational needs are met?
Theme 5: Integrated ecosystems and processes – coasts and oceans	
Key question	• What evidence do we need to inform the management and policy choices to enable the coastal and marine species/ecosystems and essential processes (eg, sea grass breeding grounds for snapper) to recover or be sustained at a level sufficient to provide for the conservation and environmental values of coasts and oceans and their contribution to the economic, social and cultural well-being of New Zealanders?
Theme 5: Integrated ecosystems and processes – urban	
Key question	• How can we develop our urban environments to make them more resilient and liveable, maximising their value for people and biodiversity while minimising negative impacts on public health, and on adjacent land, fresh water and coastal and marine environments?
Theme 5: Integrated ecosystems and processes – species and populations	
Key question	• What smarter, more innovative and cost-effective ways of cataloguing, understanding, managing and ultimately protecting our indigenous biodiversity in the face of multiple and increasing cumulative pressures can be developed to inform policy options to stop, and where possible reverse, the decline in populations of native species?
Theme 6: Social and economic factors	
Key question	• What do New Zealanders – individually and as a society – desire as a 'liveable' environment, and how can they be encouraged to make and implement long-term sustainable decisions that draw on robust science and which are beneficial for society, the economy and the environment? • How can the economic, social and cultural benefits we derive from ecosystems ('ecosystem services') and intergenerational benefits and costs to the environment be identified and built into decision-making?

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