Kia whakatere ai te raraunga taiao

Navigating the data landscape:
Role of data in support of environmental decision-making and stewardship

Bridging Paper 3

Secretary for the Environment's Science Advisory Panel, December 2023

About this report:

The Science Advisory Panel (the Panel) is commissioned to provide independent strategic advice grounded in science and mātauranga Māori, raising awareness of any science trends, risks, and opportunities to the Ministry for the Environment (the Ministry).

The Panel has produced this report independently on how to best position the environmental data system (beyond environmental reporting) to meet the future needs of the Ministry and New Zealanders.

It is intended to further the conversation started by the Parliamentary Commissioner for the Environment on New Zealand's environmental data, informing the Secretary for the Environment and other key contributors to the environmental data system such as Stats NZ.

Table of Contents

Stewardship for enduring environmental outcomes

In late 2022 the Parliamentary Commissioner for the Environment (PCE) delivered the report Environmental reporting, research, and investment – Do we know if we're making a difference? [i] The report noted that 'there is an increasingly urgent need to know what track we are on ...' and highlighted the need for 'a clear statement of the environmental outcomes that will endure across successive parliaments.' Importantly, the PCE commented: 'I for one don't want to be issuing a further report five years from now recording ongoing inaction. Rather, I hope to start issuing reports recording real progress based on real data.'

What does 'real progress based on real data' mean in practice? We interpret it as measuring the right things to track progress towards positive outcomes for nature and people. Data and evidence have a vital role in environmental stewardship: Aotearoa's ability to make good decisions based on evidence is recognised as crucial to effective implementation and operation of a reformed resource management system. Data and evidence are fundamental to inform policy design, implementation, and evaluation, and to deliver enduring outcomes.

To date however, our ability to make good decisions – to effectively 'navigate the data landscape' – has been limited. As part of proposed amendments to the Environmental Reporting Act, MfE is strengthening the Environmental Monitoring and Reporting System (EMRS), to support better environmental decision-making.

This piece of strategic advice explores the vital role of environmental data in Aotearoa's ability to make evidence-informed environmental decisions and asks whether we are measuring the right things to track progress. It builds on our previous advice (Bridging papers 1 and 2), providing insights into how to effectively navigate the wider data landscape not just to inform EMRS establishment but also broader system initiatives (including governance and direction).

For clarity, we use the term 'data landscape' in this paper to differentiate our advice for the wider system from the specific establishment of EMRS. As such we take a strategic and principles-based approach, rather than deep-dive on technical aspects.
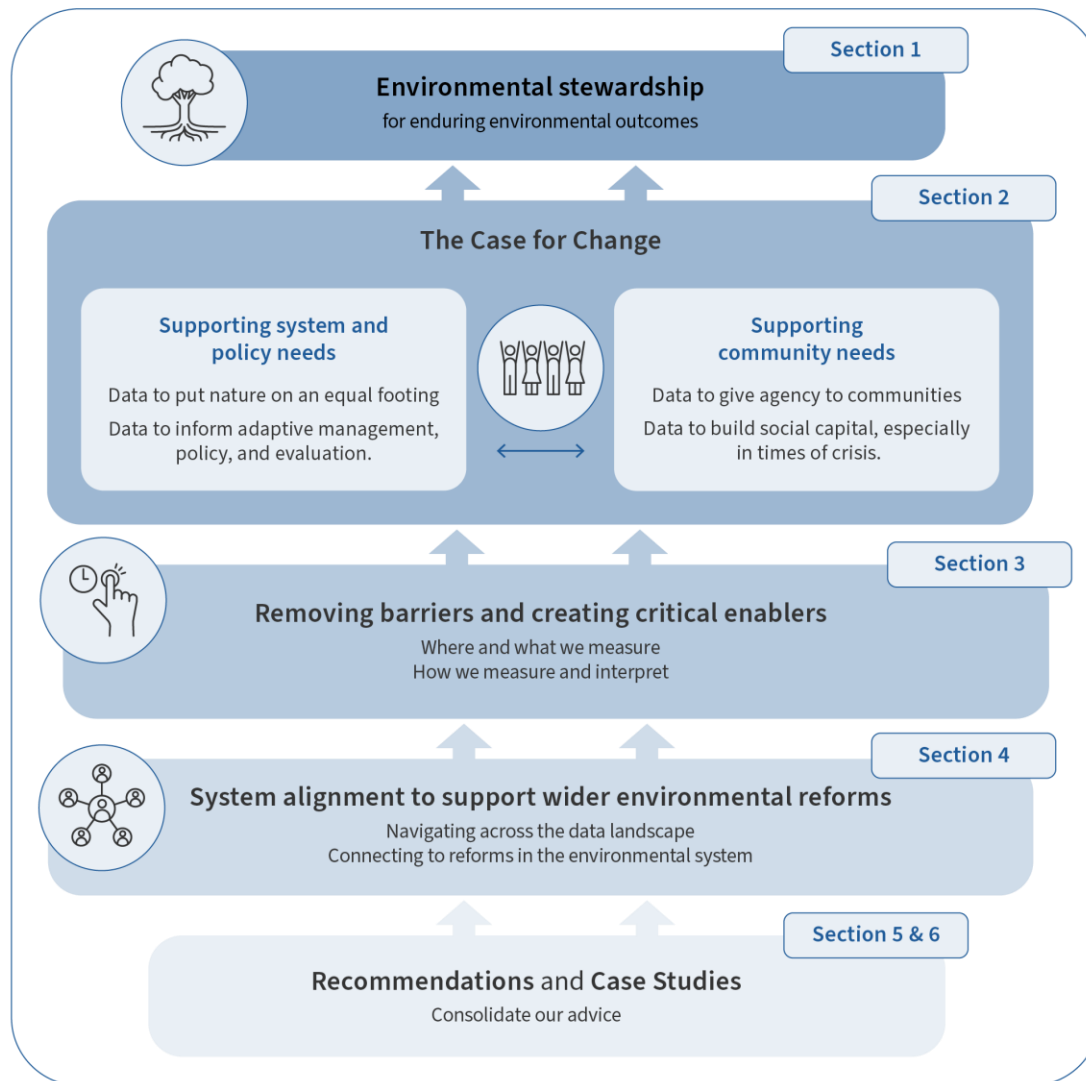
Responding to the complex and systemic emergencies of climate change, biodiversity loss, pollution, and waste 'will require skilfully combining a broad range of knowledge and understandings—both scientific and non-scientific—of earth systems and human societies.'[ii] It will require us to collect environmental data as a fundamental building block and incorporate it into collective decision-making, the same way we gather data on society and the economy. Addressing these global environmental emergencies will necessitate data collection at multiple scales and to serve multiple purposes: to inform and give agency to communities and kaitiaki as well to policy- and decision-makers.

The advice that follows first explores the case for change ('why' we collect data and 'who' should benefit; Section 2), and the enabling shifts needed 'what' we measure and 'how' we align the system; Section 3). In Section 4 we draw attention to key points of alignment across wider environmental reforms, and we conclude with recommendations in Section 5. Case studies in Section 6 expand on key points (**Figure 1**).

Case Study 1: Adaptive governance and the potential bridging role of government

A heavy strategic focus on technological protections around the Rhine in The Netherlands shifted following severe floods in the 1990s, which pushed them towards an integrated flood management paradigm. Climate change has driven a new rethinking, whereby spatial planning, flood management and landscape management of nature's contributions to people have been integrated. Policy and coastal/river management are nationally centralized processes with a strong influence on the regional level. Rijkswaterstaat, a technical governmental organization and centre of water expertise, leads policy and operational goal development, but its regional departments connect it well to implementation, ensuring effective vertical coordination. In both the 1970s (National Change Scheldt Estuary Plan) and 2000s (Regional Block Polder Construction) there was an important informal learning process, triggered by coalitions of diverse groups in opposition to policies. This opposition led to cross-group learning involving government, NGOs, science, and business during the development of alternative approaches and policy change. The outcome was a change in their flood management paradigm and realization of the importance of public and stakeholder participation early in the development and implementation stages.

http://dx.doi.org/10.5751/ES-05779-180458

Figure 1: Structure of this paper and definition of terms

The case for change

In this section, we explain why a fundamental shift is needed in the way Aotearoa New Zealand collects and uses environmental data, as well as who should be involved. We explore the critical role of data in decision-making, including the relationship between data, knowledge, information, and wisdom. We assert that giving agency to communities and citizens – empowering them to make decisions about Te Taiao – will help drive the systemic changes needed for environmental stewardship.

Supporting the system and policy to adapt in a changing world

Human interconnection with the environment should be fundamental to development of policy and legislation.[iii] Yet there is a difference between how law is constructed and how nature works: law requires certainty, which does not sit easily with the nature's complexity and variability.[iv]

Monitoring and reporting on the environment should be a cornerstone of stewardship, enabling 'evidence-informed policy' and evaluation of progress toward the delivery of outcomes. To do this well, data should be about more than simply recording state and trend. In addition, both collection of the right data to support decision-making, and tracking progress towards outcomes, must be maintained over decades to be successful.[v]

Globally, environmental knowledge systems that support decision-making are constrained by funding and hampered by eroding trust in public (and private) organisations.[vi] For governments to adaptively respond to urgent environment issues under constant fiscal constraint, they must be able to rely on a rigorous base of environmental information collected in advance of their needs.

Adaptive management and policy (e.g., the dynamic adaptative pathway planning approach used in coastal adaptation)[vii] is the logical implementation of evidence-based decision making, whereby prior information (data and modelling) informs a range of possible actions and trigger points for reconsideration or a change of approach, allowing subsequent information to modify and improve the path being followed.

This process is analogous to the need to tune a car after it has been manufactured; it is necessary to measure the impact of policy interventions and tweak the approach along the path towards desired outcomes. Such observable improvements should create a strong incentive for people in communities of interest to take further action in support of environmental stewardship.

Only with rigorous prior information (in the form of data and modelling) can adaptive frameworks manage the environment in a way that is sustainable and protects the health and security of citizens. It is particularly important to be aware of the need for rigorous prior information as the climate changes and extreme events become more common.

The role of data as prior information entails more than a baseline against which to identify deviations. It must also support modelling to identify thresholds and tipping points, which in turn allow pre-emptive decision making that accepts change as both inevitable and, at times, necessary. The coastal adaptation approach is an example of how uncertainty can be embraced in planning.[viii]

After an extreme event there are often calls to enact policy change to prevent or mitigate the effects of similar future events (e.g., the focus on the forestry sector after Cyclone Gabrielle).[ix] Policy changes that successfully improved environmental outcomes in response to such events typically had compiled prior baseline data to shape potential solutions, while maintaining flexibility to adapt to the sociopolitical context. In contrast, situations where such groundwork was absent resulted in reactive actions that missed the opportunity.[x] Social memory, and collaborative structures facilitated by 'bridging' entities, can also be leveraged to achieve success at these times.[xi] We expand on how such policies can support communities in the next sub-section.

Supporting community needs

Data to build social capital, especially in times of crisis

In the wake of recent events (e.g., Cyclone Gabrielle) the need for adaptive management and governance has become more pressing. Notwithstanding this need, implementing adaptive governance has been challenging in practice. The empirical literature on adaptive governance in practice can be synthesised into a set of design recommendations. Those relevant to the environmental data landscape in Aotearoa are:[xii]

a. *Linking knowledge and decision-making through data collection and monitoring*. Consistent monitoring of both base problem indicators and social-ecological outcomes is key for long-term governance success. The ad-hoc, reactive governance processes that emerge when data are not collected consistently (or at all) reveal the importance of starting ongoing data collection early, and from a variety of formal (published, peer-reviewed literature) and informal (citizen) sources. Learning through monitoring of interventions allows scaling up of successful pilot projects or trial initiatives.

b. *Building social capital.* This requires long-term communication with stakeholders and prioritisation of each partner's institutional memory where possible, even when there is a shared vision. Goodwill gestures (such as resource provision, trust in resource decisions of local actors and addressing power inequities) can be beneficial, particularly when prior mistrust in governance has previously eroded social capital.

c. *Community agency and engagement.* Governance policies will always be enacted by communities, and the above recommendations rely on community involvement and agency. The knowledge, aspirations, experiences, and methods of communities need to be legitimised, along with indicators they may identify locally. Successful adaptive management often occurs through networks that largely self-organise and connect knowledge systems, with branches of government often playing the role of 'bridging' organisations. Rather than attempting to steer networks, 'bridging' organisations instead aim to connect and support these networks to self-organise by creating policy that enables power sharing and reduces the costs of collaborative processes.[xiii]

d. *Capacity development.* After an initial stocktake of existing capacity and needs, further capacity can be developed through knowledge transfer (training courses, partnerships, collaboration or mentoring), gifts or loans of resources, feedback, and experiential learning.[xiv] Collective learning also generates and distributes social memory in a way that promotes reorganization after crises.[xv]

These design recommendations point to the data landscape as a pathway to connecting communities – partnering respectfully with tangata whenua and building social capital with, and within, communities.[xvi] The social capital and community involvement generated through these processes are necessary for linking environmental measurement to actions that lead to environmental improvement; dissemination of information alone is insufficient to change behaviour.[xvii] Community involvement in building an evidence-base for policy and governance thus helps to achieve greater public buy-in to environmental management decisions.[xviii] We highlight an international example of adaptive governance, and the bridging role of government, in practice in **Case Study 1**.

Data to give agency to communities

For communities, data also serve a purpose. Common access to reliable data and information establishes common ground. Data collection, especially place-based environmental monitoring, can and should be a process to (1) rebuild relationships with nature, and (2) empower local communities to be engaged in good environmental decision making.

Te Tiriti o Waitangi provides a unique context for the generation, use, sovereignty, and interpretation of environmental data in Aotearoa NZ. Te Tiriti enables a focused approach to data collection: environmental decisions that centre Te Tiriti must uphold the rights and interests of Māori and their aspirations. This means that the Crown must recognise the rights of Māori to make decisions for Māori (rangatiratanga), and value mātauranga Māori as a knowledge system.

Embedding Te Tiriti also allows for the broadening of epistemology to include kaupapa and mātauranga Māori as valid components of the data landscape. An Ao Māori view upends the data-knowledge-information-wisdom hierarchy (**Figure 2**),[xix] emphasising that 'wisdom' is of greater importance in creating meaning in an oral culture and highlighting the importance of identifying connections among disparate data to create knowledge or information. Such insights would give local communities agency to better manage risk and uncertainty.[xx]

At a local level, setting environmental limits and targets under the new National Planning Framework (NPF) will place expectations on local government to consider a Māori world view in tracking progress to achieving environmental outcomes. If such outcomes are based on Māori aspirations, it follows that local government must provide the space and the opportunity for mana whenua and tangata whenua to utilise their own monitoring approaches to support that world view.

Ultimately, the Tiriti context in Aotearoa places expectations on the Crown to share power, including – if not especially – when it comes to environmental data. Shared governance frameworks do not need to be invented: they can be adopted from other initiatives such as considerations for managed retreat.[xxi] **Case Study 2** outlines how Tiriti-based institutional arrangements can support a reformed environmental monitoring and reporting system.

Finally, it is worth contrasting such public-good, community-led approaches with the significant investment in planetary-scale data collection and collation by the private sector. Private control over such data suppresses other institutions (public and private), robust systems, and just processes, and is the antithesis of the required shift towards the types of data collection and governance structures that give agency to communities.

Case study 2: A shared governance arrangement for environmental monitoring

In 2020, Ngāti Tūwharetoa became the first iwi to utilise Section 33 of the Resource Management Action 1991, with the handover of water quality monitoring functions around Lake Taupō from the Waikato Regional Council. This meant that the iwi authority assumed local government functions and, effectively, resource management responsibility, confirming Ngāti Tūwharetoa's authority as kaitiaki of Taupō Waters. Other benefits included increasing the technical capability and knowledge of the community, employment opportunities, and strengthened relationships with stakeholders.

https://www.tuwharetoa.co.nz/ngati-tuwharetoa-set-to-become-first-iwi-to-utilise-a-section-33-transfer-with-waikato-regional-council/
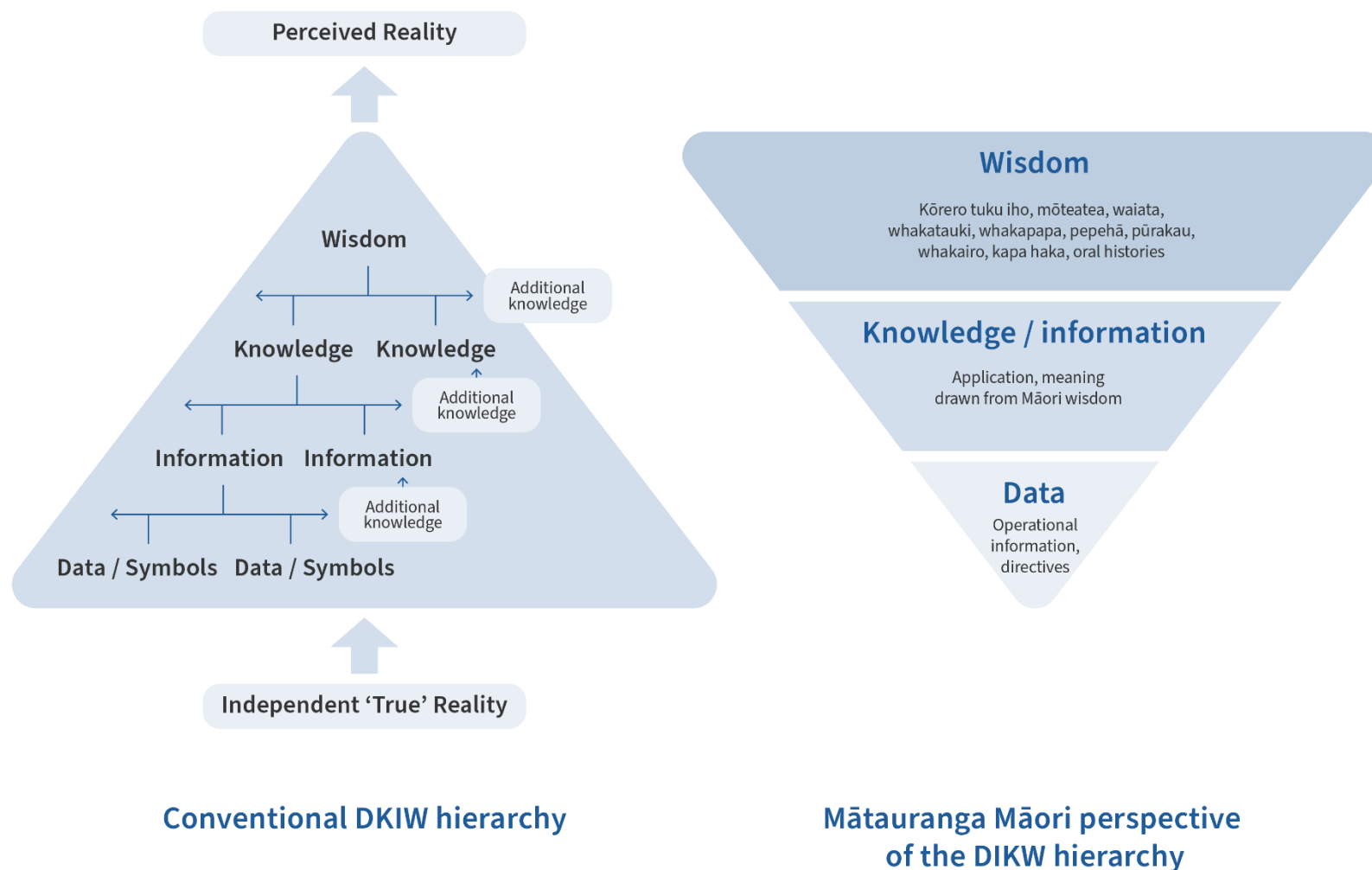
Conventional DKIW hierarchy

**Mātauranga Māori perspective
of the DIKW hierarchy**

Figure 2: Mercier et al. (2012) highlighted 'a mātauranga Māori perspective on the relative prevalence of wisdom, knowledge/information, and data. Wise words, forms and media were used as vehicles for delivering knowledge, information and data, rather than the other way around' (Mercier et al; Figs 2 and 5). Whilst we acknowledge the importance of using data to inform wisdom (e.g., through machine learning or data mining) our emphasis in this paper is on using wisdom to shape data collection ('tracking real progress using real data'), a reversal of the conventional data-knowledge-information-wisdom hierarchy.

Removing barriers and creating critical enablers

Section 2 discussed changes to future-proof our data landscape and why they are necessary. In this section we identify enablers and barriers which will need to be removed to drive those changes.

Mapping the data landscape; measuring for future needs

What and where we measure

While measurement is critical for management, a narrow measurement focus, e.g., on material ecosystem services (i.e., applying an economic model for political accountability) drives selective measurement that reinforces our existing extractive relationship with nature: *"measure mentality is part and parcel of the neoliberal paradigm in which science produces the raw materials for subsequent control and exchange."*[xxii]

We must understand our environment beyond merely the services it provides, to manage our own existence within it and our impacts on it. The current data landscape at times makes opaque the connections between society and the ecosystems and functions that are not economically exploitable, at a time when such connections need to be visible to all.

What we choose to measure is partly determined by dominant social values, and such choices privilege certain ways of viewing the world.[xxiii] A data landscape that is fairer, Tiriti-framed, and makes connections between society and ecosystems clear will require careful and transparent consideration of what we choose to measure, why, and where and how it is measured. Currently, local government and communities are unfairly burdened with the costs of managing local resources, and data quality is inconsistent among regions (in part because of the costs).[xxiv]

Purposeful choices about what to measure and where should enable us to quantify connections between nature and human wellbeing, allowing us to understand drivers of positive environmental behaviour (i.e., linking environmental measurement to actions that lead to environmental improvement). That requires both biophysical metrics (e.g., air quality) and social metrics (e.g., accessibility, connectedness) and their integration in holistic whole-system frameworks.[xxv]

While repeatable, quantifiable measures may enhance some elements of the data landscape, they are not exhaustive. Frameworks that include narrative and non-parametric data as complementary evidence to social and biophysical data are also required. An Ao Māori based approach could provide the holistic framing required to integrate such metrics and narratives.

A major goal of any data landscape should be sustainability; another is to collect a broad range of information that is relatable to a range of decision-making applications. We need to take courageous steps to ensure monitoring programmes efficiently and effectively facilitate our goals for the environmental data landscape. This means augmenting existing investments by committing significant resource into centralised support for core indicators that provide data at multiple spatial and temporal scales (i.e., data that are reliable locally, regionally, and nationally, and over a range of time scales). Achieving data at multiple scales makes choices about *where* we measure particularly important and obliges us to reconcile local needs with national needs where possible. If reconciliation is not possible, central government funding for metrics that meet national needs is an imperative, but this should be rare.

Critically, we must monitor actions to mitigate pressures alongside outcomes. It may take many years, or generations, for environmental outcomes to be measurable because of natural variability and measurement constraints. Rather than over-invest in outcome measures that may not provide useful data (or at worst give a false indication of failure) in the short term, it is advisable to use metrics that demonstrate early progress. These may look like the extent of actions taken, or changes to pressures creating harm. For example, in management of fresh water, metrics may include changes in area of wetland restoration, or changes to canopy cover of streams.

How we measure and interpret

A future data landscape will require us to collect data in a diverse range of ways. We will need to maintain and aggregate existing data streams. We will need to do this affordably, which will include prioritisation of what information is critical, and in what context (local, regional, or national). Given the parlous state of current environmental monitoring, it will require targeted increased support.

Globally, there has been a decline in high-level all-systems monitoring and a shift to specific domain monitoring (e.g., climate) or by technology (e.g., remote sensing). These are vital networks for interpolating historic trends and predicting future climatic changes[xxvi], and they also contribute toward whole-system understanding. It is for both these applications we need to ensure monitoring networks are maintained, as well as openly and freely accessible. An example of a curated dataset that is openly and freely accessible to the marine and climate science community, other stakeholders and users, and international collaborators is provided in **Case Study 3**.

Whilst we may have strong conceptual understandings of systems, some metrics provide limited or no information on ecological cause-and-effect (either because the wrong indicators are being measured, or because it is difficult to interpret such processes from existing metrics), making it challenging to find management options that lead to environmental improvements. In such situations, greater use of probability-based models (e.g., Bayesian inference) can assist decision-making.

Using such models also means making real-time decisions using imperfect data: uncomfortable, but necessary. Yet modelling can greatly assist in identifying how, when and where changes to policy or management plans may be needed once assumptions are validated, or data improves. Modelling thus has the potential to enhance adaptive approaches (see Section 2).

Future data collection also needs to be open to hybrid solutions that augment empirical data with modelled information, as long as there is a compelling case for augmentation. This could extend to AI and machine learning solutions where an evidence base and associated evaluation exists. Machine learning and AI are examples of emerging technologies that have enormous potential to revolutionise the data landscape.

Other examples include satellite imagery and LIDAR systems; environmental DNA (eDNA); sound measurement; and other environmental sensors. This is an area of rapid growth with little evaluation of long-term implications, so technology use needs to advance cautiously, and to integrate with existing data streams. However, emerging technologies are vital to measurement and interpretation across local, regional, and national scales, often in real time, and to offer greater resilience to rapid environmental change.

Finally, data are always useful to support decision making, but more data in isolation will not help connect people and nature, nor link measurement to actions that result in improved outcomes. That would require supporting communities to participate in environmental monitoring, and this should include resourcing for governance and management in addition to monitoring[xxvii] (see Section 2). Interpretation tools and storytelling in non-specialist language – so that citizens can understand and interpret their own data – then become critical to build insights that incentivise on-ground actions and create change.

Case Study 3: A multi-user Integrated Marine Observing System.

Australia's Integrated Marine Observing System (IMOS) has been operating a wide range of observing equipment throughout Australia's coastal and open oceans since 2006. IMOS makes all its data openly and freely accessible to the marine and climate science community, other stakeholders and users, and international collaborators. Australia's Integrated Marine Observing System (IMOS) is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent. IMOS has five missions: (i) data and knowledge to improve decision-making and support marine operational safety and efficiency, including weather forecasting and prediction services, (ii) an increased understanding of the environmental, economic, social and cultural impacts of and resilience to climate change and extreme events, (iii) enable improved understanding of conditions, species and habitats to support management and protection of our precious marine estate, (iv) support research, training and education, and facilitate innovative approaches to provide future ocean-monitoring capabilities for industry, science and management and (v) engage at local, national, regional and international scales to ensure the investment is leveraged for greatest impact.

https://imos.org.au/

System alignment to support wider environmental reforms

At time of writing, the government is undertaking a significant legislative reform programme – including the reform of both the Resource Management Act and the Environmental Monitoring and Reporting Act. These will reset environmental stewardship in Aotearoa for generations. Given the scope and scale of the reforms it is imperative that they are supported by good governance, system oversight, and operating principles.

Navigating across the data landscape

The 2019 PCE report highlighted that the system providing data on the state of the environment is fragmented, with many organisations contributing to the effort and no clear responsibility for oversight or coordination. This fragmentation means that we are not starting from a place of wisdom: environmental decision-making and stewardship is currently undertaken with significant gaps in data and knowledge, and with some users and needs better served than others.

Further, minimal coordination and oversight means datasets and monitoring efforts are not always valued for their utility to the overall knowledge system. Datasets of high value for the wider community are at risk when any one of the many organisations that maintain them from an independent budget face resourcing issues. Institutional-level decisions to disinvest in a particular dataset, or cease data collection altogether, can have significant impacts on:

- o Our aspirations for collective ownership and decision-making,

- o Implications for national monitoring and reporting, and ultimately

- o Environmental stewardship and delivery of outcomes.

Disinvestment is of particular concern in the environmental data space, given that environmental data are often collected for one purpose but used for many. The current devolution of investment decisions to the level of individual institutions – with little coordination or alignment amongst them – risks affecting such secondary or multiple uses.

Given the risks around lack of system oversight of and coordination; shifting data priorities; the enormous potential around emerging technologies; the scope of system reforms, and the need to embed Te Tiriti in the data landscape; we suggest that the Ministry considers how it can exercise greater oversight and coordination of environmental data collection and synthesis. We see this as critical in enabling making good environmental decisions for the future of Aotearoa. We highlight the power of a connecting and oversight role in **Case Study 4**.

Options for system governance span a continuum from a monolithic entity through to a collective of independent measurement systems and pooled data resources. Regardless of the option chosen, the following steps would be needed to ensure system-wide coordination:

- Adopt the report of Te Kāhui Raraunga, which puts forward a Māori Data Governance Model designed by Māori data experts for use across Aotearoa.[xxviii] Values articulated in that report provide a safe framework that supports Māori data sovereignty. Usage of the framework would provide a pathway to embed Te Tiriti in the data landscape and enhance partnership with hapū and iwi.

- Establish a fair and equitable governance framework for the collection, synthesis, and use of environmental data, including by citizens and non-specialists (**Case Study 2**). These frameworks should have the aim of making as much data available as possible while meeting Te Tiriti obligations, consistent with the AoNZ Government Open Access and Licensing (NZGOAL) framework. This could occur via Creative Commons Attribution 3.0 New Zealand licence (CC-BY) or similar.

- Implement common data-sharing standards and protocols to ensure that data collections have high levels of interoperability, standardisation, and metadata capture and control.

- Undertake broad consultation and co-development with organisations across the system to ensure partnership approaches are at the heart of monitoring networks' design, the collection of environmental data, and data use in decision making.

- Establish and implement a plan to allocate adequate resourcing across the system, facilitating distributed governance, leadership, and bridging support (Section 2) for communities to agency around monitoring and be actively involved in local decisions.

Connecting to reforms in the environmental system

System reform was called for strongly in the PCE's four substantive and comprehensive reports (2019 to 2022), which make a case for the changes required – particularly the need to focus on outcomes and to be purposeful about collection of environmental data.[xxix] Unusually, the Auditor General endorsed the PCE's 2022 report.[xxx]

The establishment of environmental limits and targets in the Natural and Built Environment Act 2023 will provide a significant fixed point in Aotearoa's data landscape. As limits and targets are specified and locked in under the National Planning Framework, care must be taken to ensure these align with indicators being developed for the ERA and EMRS.

We are also aware of the Ministry's work with the Ministry for Business, Innovation, and Employment on an Environment & Climate Research Strategy (ECRS) as a pilot of the Te Ara Paerangi Future Pathways reform.[xxxi] These strategies will shape the data landscape, so we recommend that the systemic shifts we identify in this advice paper should be embedded into the ECRS. Again, establishing a set of data priorities and an oversight function would give guidance to data providers and should be used to influence investment priorities through Te Ara Paerangi.

We are mindful that our advice in this paper, outlining the fundamental reasons why change is needed (Section 2) and the enabling shifts required (Section 3) in navigating the data landscape are taking place in this wider system context. We urge the Ministry to ensure alignment across these environmental reforms, including directing and shaping research investment in Te Ara Paerangi or similar future strategic initiatives in the research sector.

Case Study 4: Example of how system oversight and coordination improve access to environmental data

Australian environmental research infrastructures and their data partners collect large amounts of data each year on all aspects of the environment. In the past these data have not been integrated across infrastructures or provided at a scale and in a format suitable for environmental reporting at national, or state and territory levels. EcoAssets brings together environmental data collected from three national research infrastructures – the ALA, IMOS and TERN. By standardising the formats of these data resources and then sharing them, the information can be streamlined into integrated data assets to support Australia's environmental reporting needs. It has improved access to integrated environmental data in forms that can support national, and state and territory environmental assessment and reporting activities.

https://ecoassets.org.au

Recommendations

Addressing the complex and significant challenge to support better environmental stewardship will necessitate data collection at multiple scales and to serve multiple purposes. Using our collective wisdom to shape data collection will give agency to communities and kaitiaki and help inform policy- and decision-makers. We encourage a shift in mindset within the Ministry to focus on oversight, coordination, and system-wide governance in navigating Aotearoa's data landscape, using the following recommendations as signposts to create pathways to change.

Data considerations: improving what, how, why, and where we measure

1. **Connect people and nature:** Seek to adjust policy settings to ensure collection and curation of environmental data is done in a way that is fairer, Tiriti-framed, and draws clear connections between society and ecosystems. This includes exercising influence across government to adjust legislation such as the Wildlife Act and Conservation Act, which create barriers to community involvement in data collection. New ways of working need to start from a place of wisdom in choosing what, where and how to measure, involving communities in collecting data, generating knowledge, and providing access to centrally collated data in return.

2. **Maintain continuity yet build agility:** Work on protecting critical existing parts of the data landscape. Quality long-term baseline and trend data are essential for supporting future policy needs – particularly rapid responses to natural disasters. Under a changing climate greater focus will be needed on the maintenance and aggregation of existing data streams as well as prioritising what information is critical, and in what context (local, regional, or national).

3. **Be Tiriti-centric:** Commit to a Tiriti-centric approach to enable a focused approach to data collection, because environmental decisions that centre Te Tiriti uphold the rights and interests of Māori and their aspirations at place. The Crown must recognise the rights of Māori to make decisions for Māori (rangatiratanga) and must value mātauranga Māori. It will require taking proactive steps to lead protection of Māori data through mature sovereignty arrangements, particularly as mātauranga becomes an integral facet of the data landscape.

4. **Embrace holistic framing:** Draw on frameworks that include narrative and non-parametric data as complementary evidence to social and biophysical data. It is likely that an approach based in te Ao Māori that supports and reinforces the importance of place-based data will provide the holistic framing required to integrate such metrics and narratives.

5. **Modernise data interpretation**: Demonstrate leadership across government by ensuring an approach to data interpretation that is both relevant to need and receptive to emerging trends. This includes leading with Tiriti-centric and holistic frames (Recs #3 and 4); drawing on inference and prediction (through modelling and simulation), dynamic adaptive pathways approaches; and creating space for emerging tools, modelling, and simulation. This will help manage risk and uncertainty and enable greater resilience in a changing environment.

System considerations: supporting real progress based on real data

6. **Track progress:** Focus on tracking progress towards delivery of environmental outcomes. This includes being intentional around the outcomes to be achieved, what is monitored, the and the metrics of evaluation. In a reimagined data landscape monitoring must be with purpose and support the aims of putting nature on an equal footing, reconciling local and national needs, and giving agency to communities. Tough choices will need to be made both in augmenting existing investments, and in deciding which metrics are no longer fit for purpose.

7. **Design with the outcome in mind:** Reinforce the critical role of the data landscape in adaptive management and adaptive policy, especially with regards to evaluation and tracking progress towards environmental outcomes. This requires ensuring the system architecture and design is supportive of this purpose.

8. **Connect across system reforms:** Connect across system initiatives, including those of other government agencies, to ensure alignment support of the wider environmental reforms programme. This includes the amendments to the Environmental Reporting Act, refinement of the Environmental Monitoring and Reporting System, and development of Limits and Targets in the National Planning Framework, under the Natural and Built Environment Act.

What these considerations mean for the Ministry's role

9. **Maintain system oversight:** Consider forming a governing body that would be accountable for oversight and coordination of environmental data collection and synthesis. A human-centred design approach in developing new governance architecture should focus on ensuing diversity of thought and realising the intended shifts towards both adaptive policy and community agency noted in recommendations 6 and 7.

10. **Bridge and connect diverse communities and stakeholders:** Actively model a 'bridging' role to connect communities and stakeholders. The Ministry should focus on fostering self-organising networks at community level that build social capital by bringing people, the system, and data together. Emphasis should be on strengthening the ability of hapū and iwi Māori to actively participate in these networks.

i   Parliamentary Commissioner for the Environment (PCE). (2022). *Environmental reporting, research and investment, Do we know if we're making a difference?*. ISBN 978-0-947517-33-5 (electronic)

ii   Lawrence, M. G., Williams, S., Nanz, P., & Renn, O. (2022). Characteristics, potentials, and challenges of transdisciplinary research. *One Earth*, *5*(1), 44–61. https://doi.org/10.1016/j.oneear.2021.12.010; and Head, B.W. (2022). *Wicked Problems in Public Policy: Understanding and Responding to Complex Challenges*. Cham: Springer Nature. https://library.oapen.org/handle/20.500.12657/53360

iii   Benjamin Bratton (2021), *The Revenge of the Real: Politics for a Post-Pandemic World*. London: Verso Books.

iv   Green, O.O., Garmestani, A.S., Allen, C.R., Gunderson, L.H., Ruhl, J., Arnold, C.A., Graham, N.A., Cosens, B., Angeler, D.G., Chaffin, B.C. and Holling, C. (2015). Barriers and bridges to the integration of social–ecological resilience and law. *Frontiers in Ecology and the Environment*, *13*, 332-337. https://doi.org/10.1890/140294

v   Intergovernmental Panel on Climate Change. (2023). *Sixth Assessment Report*. IPCC. https://www.ipcc.ch/assessment-report/ar6/

vi   Chabbi, A., Loescher, H. W., & Dillon, M. S. (2017). Integrating Environmental Science and the Economy: Innovative Partnerships between the Private Sector and Research Infrastructures. *Frontiers in Environmental Science*, *5*. https://www.frontiersin.org/articles/10.3389/fenvs.2017.00049

vii   Bell, R., Lawrence, J., Allan, S., Blackett, P., & Stephens, S. (2017). *Coastal Hazards and Climate Change, Guidance for Local Government.* Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/coastal-hazards-guide-final.pdf ISBN: 978-1-98-852535-8

viii   Ibid.

ix   Olsson, P., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C., & Holling, C. S. (2006). Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. *Ecology and Society*, *11*(1). https://www.jstor.org/stable/26267806

x   Sharma-Wallace, L., Velarde, S. J., and Wreford, A. (2018). Adaptive governance good practice: Show me the evidence!, *Journal of Environmental Management*, *222*, 174-184, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2018.05.067

xi   Ibid. and Folke, C., Hahn, T., Olsson, P., Norberg, J. (2005). Adaptive Governance Of Social-Ecological Systems. *Annual Review of Environment and Resources*, *30*(1), 441-473. doi: 10.1146/annurev.energy.30.050504.144511

xii   Sharma-Wallace, et al. (2018).

xiii   Folke, et al. (2005).

xiv   Sharma-Wallace, et al. (2018)

xv   Folke, et al. (2005): and Allen, W., Bosch, O., Kilvington, M., Harley, D. and Brown, I. (2001). Monitoring and adaptive management: resolving social and organisational issues to improve information sharing in natural resource management. *Natural Resources Forum*, *25*, 225-233. https://doi.org/10.1111/j.1477-8947.2001.tb00764.x

xvi   Sharma-Wallace, et al. (2018).

xvii   Wyborn, C. (2015). Co-productive governance: A relational framework for adaptive governance. *Global Environmental Change, 30*, 56–67. https://doi.org/10.1016/j.gloenvcha.2014.10.009

xviii   Aceves-Bueno, E., Adeleye, A.S., Bradley, D. et al. (2015). Citizen Science as an Approach for Overcoming Insufficient Monitoring and Inadequate Stakeholder Buy-in in Adaptive Management: Criteria and Evidence. *Ecosystems*, *18*, 493–506. https://doi.org/10.1007/s10021-015-9842-4

xix   Mercier, O. R., Stevens, N., Toia, A., & Kawa Māui, T. (n.d.). Mātauranga Māori and the Data-Information-Knowledge-Wisdom Hierarchy: A conversation on interfacing knowledge systems. *MAI Journal*, *1*(2), 103–116. http://devr.net/system/files/Pages%20103%20-%20116.pdf

xx   Hyslop, J., Harcourt, N., Awatere, S., Hikuroa, D., Blackett, P., & Heron, R. L. (2023). Kia aiō ngā ngaru, kia hora te marino: smoothing the waters in natural resource management to mitigate risk and uncertainty. *AlterNative: An International Journal of Indigenous Peoples*, *19*(2), 229-239. https://doi.org/10.1177/11771801231174317

xxi   Maxwell, K. H., Ratana, K., Davies, K. K., Taiapa, C., & Awatere, S. (2020). Navigating towards marine co-management with Indigenous communities on-board the Waka-Taurua. Marine Policy, 111. https://doi.org/10.1016/j.marpol.2019.103722

xxii   Turnhout, E., Neves, K., & de Lijster, E. (2014). 'Measurementality' in Biodiversity Governance: Knowledge, Transparency, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Ipbes). *Environment and Planning A: Economy and Space*, *46*(3), 581. https://doi.org/10.1068/a4629

xxiii   Turnhout, E. (2018). The Politics of Environmental Knowledge. *Conservation and Society*, *16*(3), 363–371. http://www.jstor.org/stable/26500647

xxiv   Interim Ministerial Advisory Group for Limits and Targets. (2023). *Proposed Attributes for the National Planning Framework*. https://environment.govt.nz/publications/final-report-of-the-interim-ministerial-advisory-group-for-limits-and-targets-proposed-attributes-for-the-national-planning-framework/

xxv   Parliamentary Commissioner for the Environment (PCE). (2022). *Environmental reporting, research and investment: Do we know if we're making a difference?*. https://pce.parliament.nz/publications/environmental-reporting-research-and-investment

xxvi   Etherington, T. R., Perry, G. L. W., and Wilmshurst, J. M. (2022): HOTRUNZ: an open-access 1 km resolution monthly 1910–2019 time series of interpolated temperature and rainfall grids with associated uncertainty for New Zealand. *Earth System Science Data, 14*, 2817–2832. https://doi.org/10.5194/essd-14-2817-2022

xxvii   Thompson, K. L., Lantz, T. C., & Ban, N. C. (2020). A review of indigenous knowledge and participation in environmental monitoring. *Ecology and Society*, *25*(2), 10. https://doi.org/10.5751/ES-11503-250210

xxviii Kukutai, T., Campbell-Kamariera, K., Mead, A., Mikaere, K., Moses, C., Whitehead, J. & Cormack, D. (2023). *Māori data governance model*. Te Kāhui Raraunga. https://tengira.waikato.ac.nz/__data/assets/pdf_file/0008/973763/Maori_Data_Governance_Model.pdf

xxix   Parliamentary Commissioner for the Environment (PCE). (2022). *Environmental reporting, research and investment: Do we know if we're making a difference?*. https://pce.parliament.nz/publications/environmental-reporting-research-and-investment

xxx   Ryan, J. (2022). *Report from Parliamentary Commissioner for the Environment reinforces need for effective public accountability*. https://www.oag.parliament.nz/blog/2022/pce-public-accountability

xxxi   MBIE. (2022). *Te Ara Paerangi: Future Pathways White Paper 2022*. https://www.mbie.govt.nz/assets/te-ara-paerangi-future-pathways-white-paper-2022.pdf