frontiers | Frontiers in Marine Science

TYPE Community Case Study
PUBLISHED 04 August 2022
DOI 10.3389/fmars.2022.898109

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Marine Ecosystem Ecology, a section of the journal Frontiers in Marine Science

RECEIVED 17 March 2022
ACCEPTED 08 July 2022
PUBLISHED 04 August 2022

CITATION
Hewitt JE, Lundquist CJ, Pilditch CA, Thrush SF and Urlich SC (2022) Barriers to coastal planning and policy use of environmental research in Aotearoa-New Zealand. *Front. Mar. Sci.* 9:898109. doi: 10.3389/fmars.2022.898109

Barriers to coastal planning and policy use of environmental research in Aotearoa-New Zealand

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Identifying barriers to the effective use of science in coastal management of Aotearoa-New Zealand is easy, due to the present lack of complicated governance and management structures, coupled with an emphasis on funding science that includes pathways to implementation. This opinion piece discusses four areas that still hinder effective use of science, all of which are likely to be problematic for other countries. We initially focus on why the science may not be used related to: misunderstandings (linguistic and conceptual differences including indigenous world views); timing of information delivery; uncertainty surrounding the information (knowledge limitations and funding); and top-down constraints (legal systems, politics and institutional objectives). We use Aotearoa-New Zealand examples to demonstrate the barriers operating within each area and discuss three potential solutions. Importantly our analysis indicates that researchers alone cannot transcend these barriers; rather, we need to work as part of an ecosystem, requiring commitment from all society, extending beyond the usual suspects (management agencies). We believe that ecological and systems education from junior school levels through to universities have an important role to play in setting the context to overcome current barriers.

KEYWORDS

management, planning, science provision, education, science-policy liaison, co-development

1 Introduction

Around the world there is recognition that, for coastal planning and management to achieve good environmental outcomes, there is a need for effective use of relevant science (Nursey-Bray et al., 2014; Dale et al., 2019). Unfortunately mechanisms to achieve this are largely lacking (Karcher et al., 2022). Two important factors should enhance the ability of Aotearoa-New Zealand to manage its coastal waters: no internationally shared responsibilities; and a fairly flat management hierarchy (national or sub-national within a national framework). However, policy and planning within both national and sub-national government agencies frequently appears to work in a vacuum, relatively uninformed by current, and sometimes even past, research (Gluckman, 2013; Urlich, 2020a). For example in Aotearoa-New Zealand, bottom-trawling and excessive terrigenous sediment inputs to coastal waters continue despite decades of national research demonstrating adverse effects (e.g., Shears and Babcock, 2002; Thrush et al., 2004; Pratt et al., 2014; Urlich, 2020a). Moreover, although government reports have lately summarized and described cumulative effects of multiple stressors on marine ecosystems (e.g., Ministry for the Environment and Statistics NZ, 2019), activities continue to cause ongoing adverse effects to marine biodiversity and ecosystem processes, apparently, to outsiders, with the permission of central (national) and regional (sub-national) agencies.

International literature has focused on researchers needing to improve their science communication styles, create effective knowledge exchange and increase the accessibility of information (Cvitanovic et al., 2016; Fernández, 2016; Greenhalgh et al., 2022). Frameworks have been developed to assist with this e.g., CRELE (credibility, relevance, legitimacy) and ACTA (applicability, comprehensiveness, timing, accessibility) to guide information presented at the interface of science and policy (Greenhalgh et al., 2022). Our experience as marine ecologists working in the field of disturbance and recovery highlights that this may be a simplistic view. For example, those who could ensure that the problems and solutions identified by researchers are used in plans, policies and decision-making frequently say that scientists focus on unnecessary detail and sensitivities, rather than producing lay summaries with clear understandings of risks and benefits of different options. However, this 'unnecessary' detail frequently provides the information needed to accurately contextualize and detail the risks and benefits. Similarly, planning legislation often uses the existing, and often degraded, ecological baselines from which to assess effects of activities and to measure change, failing to recognize how these baselines have shifted (e.g., Urlich and Handley, 2020). This constrains the scope in decision-making, planning and policy to facilitate restoration of degraded habitats. Scientists have sometimes not helped this situation, with overly cautious advice in the absence of complete information (Hendy, 2016).

Beyond the obvious differences in language and underlying concepts between marine researchers and those who could use the information, we feel that there are also many other issues. In this opinion piece, we begin by discussing misunderstandings caused by different use of languages and concepts. We also discuss: the difficulties of getting information to the right people at the right time; the effect of uncertainty surrounding the information (knowledge limitations and funding); and top-down constraints (laws, politics and agency objectives). We use Aotearoa-New Zealand examples to highlight these issues and discuss potential solutions. Our focus is not just on policy but also on planning and decision-making.

2 Issues

2.1 Misunderstandings

2.1.1 Scientific concepts

Translating the complexity of social-ecological systems, and their associated uncertainties, into accessible language for both science and non-science (i.e. policy, planners) audiences is critical (Le Heron et al., 2016; Gluckman, 2017). Over-simplification of complex ecological systems may result in failing to consider key environmental drivers or anthropogenic stressors, and incomplete understanding of systems dynamics and resilience (Scheffer et al., 2001, Lundquist et al., 2016a). In the Introduction we highlighted a problem associated with shifting baselines, but there are other essential science concepts that are often not considered by policy makers. For example, marine spatial planning has been influential in conveying the need to explicitly consider the mismatches between planning, decision-making and management with the ecology and environment. However, the realities of temporal variability in ecologies and their dynamics are important issues that are not well conveyed to the non-expert in such plans. Increasingly we are observing tipping points and thresholds in degradation of marine species and systems (Conversi et al., 2015). These abrupt, and often unexpected, changes mean that the operational practice of monitoring, predicting the need for action based on dose-response type relationships and having at least some time for institutions to make decisions around management frequently no longer work. Instead, we not only need to explain that a threshold may be approaching (despite no signs of any effect), but also that timely action is required (Hewitt and Thrush, 2019). Furthermore, when a threshold is passed and ecological states are degraded, then we need to predict whether recovery is possible once management actions to aid recovery are implemented and explain the likely time scales of any lags in recovery. In general, threshold responses

and slow recovery appear much easier for Aotearoa-New Zealand indigenous communities (iwi (tribal), hapū (subtribal)) and the wider public to understand, and for them to support timely management actions, than for most businesses and government management agencies (McCarthy et al., 2014). This has been demonstrated in various ways and places around Aotearoa-New Zealand. For example, recent iwi and public pressure to close scallop fisheries, and over 50,000 signed a petition to ban bottom-trawling on seamounts in 2020, https://www.rnz.co.nz/news/political/430888/bottom-trawling-petition-delivered-to-parliament.

Variability in coastal ecosystems is also viewed differently among planners, managers and ecologists. In Aotearoa-New Zealand, temporal variability in coastal ecological and environmental responses can be particularly high because the southern decadal oscillation and El Niño/-La Niña weather patterns have a strong effect on physical, chemical and biological parameters (Hewitt et al., 2021). The problem here is not convincing people that climate variability occurs, as in Aotearoa-New Zealand the El Niño or La Niña statistics are frequently reported on during the year, rather it is convincing them that this does not preclude understanding what is going on, and that small effects within this climate variability can still drive large changes.

2.1.2 Indigenous world views

Many countries need to work with Indigenous people when managing the environment (e.g., Soumi in Finland and Norway, First Nations in Canada, Aborigines in Australia, Mapuche in Chile etc.). Aotearoa-New Zealand is increasingly seeking to address Indigenous world views in its environmental management, with Māori concepts, such as *kaitiakitanga* (guardianship or stewardship for future generations) and *whakapapa* (ancestral connections with the environment) being incorporated in environmental management (Dick et al., 2012). Rivers and mountains have been given status as legal persons in an attempt to recognize in law the ancestral relationships of Indigenous peoples with these ecosystems, and to change the power relationship between Indigenous people and government agencies (Macpherson and Clavijo Ospina, 2018). Community activism for legal rights for rivers and ecosystems has occurred in countries as diverse as Mexico, the United States (US), Columbia and Bangladesh. *Ki uta ki tai* is a holistic concept that represents the connectivity within and between ecosystems for example from the mountaintops to the sea, and the concept showcases that, from a holistic Māori viewpoint, management should recognize the connections between land and sea, and that humans are embedded in the ecosystems (Tipa et al., 2016; Hepburn et al., 2019).

While we can attempt to translate these concepts into other cultural contexts, we often lose the depth of the relationships between Indigenous peoples and nature. Indigenous worldviews often more readily recognize environmental degradation, but existing systems often lack structures to incorporate indigenous knowledge into decision-making, and entrenched power dynamics mean that the role of indigenous peoples, their knowledge and their worldviews are often not recognized as equal to scientific evidence (Ens et al., 2015).

2.1.3 Sectoral and discipline linguistic differences

Languages also differ between different groups interested in environmental management, with different bottom lines (economic, societal, cultural, environmental) based on their key values. Terminology can appear similar, but when used in the context of a particular industry, meanings can differ. For example, the terms "baselines", "business as usual", and "sustainability" all have different interpretations across industry, government and environmental sectors. Similarly, many terms can become politically charged within a particular group due to perceived biases against the values of that group, and quickly fall out of favour. For example, marine protected area (MPA) and marine spatial planning (MSP) are terms that include a wide spectrum of approaches, but contentious debate is often based on a single approach. MPAs may be spoken of as if they only consist of fisheries no-take, although in Aotearoa-New Zealand, and many other countries, there are a range of protection levels (Douvere, 2008; Day et al., 2012; Grorud-Colvert et al., 2021). In some countries (including European Union countries), marine reserves (a subset of MPAs) prohibit any resource extraction (e.g., OSPAR, 2016, and sections of the Great Barrier Reef Fernandes et al., 2005). MSP may be relegated to simply being spatial allocations of various extractive uses (businesses) or always resulting in the production of an MPA (fishers), whereas it can be an extensive exercise with multiple stakeholders and create a variety of management options (Lundquist et al., 2005; Sayce et al., 2013; Davies et al., 2018a). A recent marine spatial planning initiative in Aotearoa-New Zealand (Sea Change Tai Timu Tai Pari Hauraki Gulf Marine Spatial Plan) at one stage drafted over 180 recommendations spanning multiple management categories (e.g., Marine protection, Protected Species, Aquaculture, Habitat restoration, Biosecurity, Ahu Moana, Fisheries management, Governance).

Ecosystem-based management (EBM) is another term that has evolved over recent decades from a simple approach considering the environment to a complex concept that also covers people, intergenerational use and knowledge uptake etc (McLeod and Leslie, 2005; Long et al., 2015; Hewitt et al., 2018). Again, the term is interpreted differently by different people. For example, in many areas around the world, the fishing sector has introduced the concept of EBFM, which is typically defined as fisheries management that takes into account environmental and

ecological impacts on an ecosystem, and the interconnectedness and interdependence of various components of the ecosystem, but does not take into account the needs of other users.

Knowledge gathering approaches and analyses also vary across disciplines such as biophysical sciences, indigenous and local knowledge, legal, social, and economic data (Allison et al., 2019). This also affects use of the term "best" available information, which can be found in a number of New Zealand policies and statutes (Davies et al., 2018b), with what is "best" for one situation not being the most relevant in another (Rudd et al., 2018).

Finally, probably the greatest variability in expectations between groups is generated by use of the terms "degraded", "healthy" and "desired states". In Aotearoa-New Zealand, policy is leaning towards defining environmental health states, measured by nationally consistent methods, and encouraging locally derived targets or bottom lines based on local values. Even this is not easy as, amongst ecologists, health can be variously associated with ecological functioning, multi-functionality, network connectivity, or animal or plant community-based health indices.

2.2 Mismatches between timing of information need and its availability

At present in Aotearoa-New Zealand, scientists need to time delivery of information to match policy and planning needs. Some of these needs are cyclic, with the timing dependent on the relevant government agency. For example, the New Zealand Coastal Policy Statement (NZCPS, see section 4.1) is mandated to safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land and is reviewed at the discretion of the Minister of Conservation. Since this policy statement first came into force in 1994, it has been reviewed twice (with no amendments made) and replaced once (in 2010). Other central government agencies have less clear work structures, driven by funding and political imperatives. For example, Fisheries New Zealand conducts single species fish stock assessments for the most important species every 3 to 7 years, but some stocks may be assessed much less frequently (Cryer et al., 2016; Gerrard, 2021), if at all (Ministry for the Environment and Statistics NZ, 2022). Stock assessment funding is allocated by fisheries working groups, with stocks receiving assessments driven by working group priorities, and tied to economic value. The Ministry for the Environment conducts reviews of, and produces new, national policies with no set time periods for review. Regional Councils (the local government agencies) are charged not only with implementing the NZCPS, but also creating a coastal plan for their region and reviewing this at least every 10 years. Less than half have implemented the 2010 NZCPS and all 16 regional management agencies work to their own timetables (Urlich et al., 2022).

Timing of policy windows was also recognized by Karcher et al. (2022) as a key factor in uptake of science into environmental management internationally. They also rightly recognized a "time for action" where knowledge is presented at the time when people are willing to change and create improved environmental outcomes. All of this means that researchers have to be nimble in adjusting their research schedules to have knowledge ready for use and contacts that will forewarn them about when it will be needed.

2.3 Knowledge uncertainty

2.3.1 Data limitations

A major challenge for all those seeking to manage the marine environment is knowledge sufficiency. Around the world there is strong variability in what is known about coastal marine species and habitats ranging from well-studied areas of the Western European countries and North America, through to less well-studied areas around South-east Asia, South America and the Pacific (Costello et al., 2010; Lundquist et al., 2016b). In Aotearoa-New Zealand there has been a sustained under-investment in nationally coordinated marine environmental monitoring (Parliamentary Commissioner for the Environment, 2020). Regional Councils and central government have responsibilities for providing state of the environment data to the Ministry for the Environment and Statistics New Zealand. This is used for national reporting but the list of variables monitored in common is not comprehensive, varies spatially, and often is insufficient to inform long-term change, or in some cases to confirm that changes have occurred. For coastal regions, even basic oceanographic information such as seawater temperature is not available to inform how systems are changing over time. The lack of consistent data collection challenges our ability to determine when to alter plans, policies or decision-making criteria (Parliamentary Commissioner for the Environment, 2019).

While measures of ecosystem health and environmental baselines provide important context for management decisions, understanding shifts in ecosystem function is critical. Worldwide there is a lack of knowledge around the functional responses of coastal ecosystems to cumulative stressors. Policy- and decision-makers, as well as researchers, resource managers, businesses or interested communities, struggle with this lack of knowledge and the uncertainty it creates. Lack of information is often used to stall creation of policy and decision making, or even used by two opposing sides to demonstrate what sort of decision should be made. Local communities often want information about effects on their local species or places, and may mistrust generalities derived from

elsewhere. While functional shifts require an understanding of context, ecological principles are evolving that provide perspective on the detail and facilitate action in the face of uncertainty.

"Adaptive management" is an approach frequently suggested to deal with lack of data. In Aotearoa-New Zealand, for activities that come under the Resource Management Act, this term is taken to mean that a limited form of the activity is allowed if there is good baseline information about the receiving environment, monitoring of effects can be undertaken and thresholds can be set for stopping the activity before effects become irreversible (Supreme Court, 2014). Where responses to activities are approximately linear (that is remedial action can take place before effects become overly damaging, and effects can be remedied before becoming irreversible), this is an appropriate way to gain more data without delaying decisions. Unfortunately, if strongly non-linear responses, thresholds or tipping points occur, and there is general lack of knowledge of appropriate thresholds, this method is inappropriate and the precautionary principle should operate.

In our experience, the precautionary principle suffers from a lack of translatability resulting in uncertainties for both science and non-science. For example, precautionary for who or what, and precautionary in the face of what is usually not well specified. This linguistic uncertainty allows cautious environmental management to be challenged on the basis that information is incomplete, such as the overharvesting of desirable fish species (High Court, 2021).

2.3.2 Research funding

Economically, Aotearoa-New Zealand is a small country, with a population of 5.1 m (per capita GDP is 21st in the OECD), but has the world's fifth largest exclusive economic zone and the 9th largest coastline (~15,000 km) in the world. Aotearoa-New Zealand's national investment in research and development is considered low at 1.4% of GDP in 2018 when compared with an OECD average of 2.4%. In 2018 total expenditure on environmental research was NZ$362 million (Parliamentary Commissioner for the Environment, 2020). How much of this investment is being spent on marine ecosystems is not transparent, due to how funding categories for environmental research are reported, but it is likely to be considerably smaller than funding toward terrestrial and freshwater ecosystems, a reflection of their 'economic value' to society. Most of the government's research funding works on an exceeding low trust model. Allocation of funds to fundamentally understand our natural environment (e.g., Marsden Fund) versus strategic grants to support environmental management (e.g., Endeavour Fund) all suffer from a lack of relevant scientific assessment processes and represent a very small part of the governments research investment. However, the National Science Challenges (formed in 2014, https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/) were an experiment in more collaborative and mission-led research, on pressing issues identified by the public. One of these Challenges was given the objective, by the Government, of "enhancing the use of New Zealand marine resources within environmental and biological constraints". Workshops with marine researchers determined that an appropriate approach to this objective would be to undertake the underpinning research to support the use of ecosystem-based management. This was accepted by the government funding agency and in 2014 Sustainable Seas (a partnership of research institutes and universities) gained funding for 10 years (in two 5-yr phases) with a vision of "Aotearoa New Zealand has healthy marine ecosystems that provide value for every New Zealander". Sustainable Seas funds research projects using a mainly negotiated process supporting bringing together the best teams, following a research agenda initiated by a leadership team and accepted by a governance group, stakeholder panel and Māori advisory group (Kāhui).

In the context of connecting scientific knowledge to management action the real question is whether the funding structure is optimized to grow the knowledge base and inform environmental management in a manner timely for achieving good environmental outcomes (see section 3.2).

2.4 Top-down constraints

2.4.1 Legal and political constraints

Researchers frequently may not fully appreciate the extent to which policy, plans and decisions are constrained by the law and political considerations. In Aotearoa-New Zealand there are many pieces of legislation affecting the coastal environment (see Figure 1), for example: the Māori Fisheries Act 2004; the Conservation Act 1987; the Marine Mammals Protection Act 1978; the Marine Reserves Act 1971; and the Marine and Coastal Area Act 2011. The Fisheries Act (1996) applies to all fishing activity within freshwaters, the Territorial Sea and the EEZ, with its purpose 'to provide for the utilization of fisheries resources while ensuring sustainability', whereas regional councils are legislatively tasked to manage activities including aquaculture and the environmental effects of fishing on biodiversity out to 12 nautical miles, but not fisheries allocation or access issues.

The Resource Management Act (RMA) is the major legal instrument for much of Aotearoa-New Zealand's coastal management (to 12 nautical miles offshore). Decision-making under the RMA is guided by national policy statements; in the coastal environment the New Zealand Coastal Policy Statement (NZCPS) provides decision makers with specifics on how the RMA is to be applied. A large body of case law has further defined how the RMA is interpreted. Since the passage of the

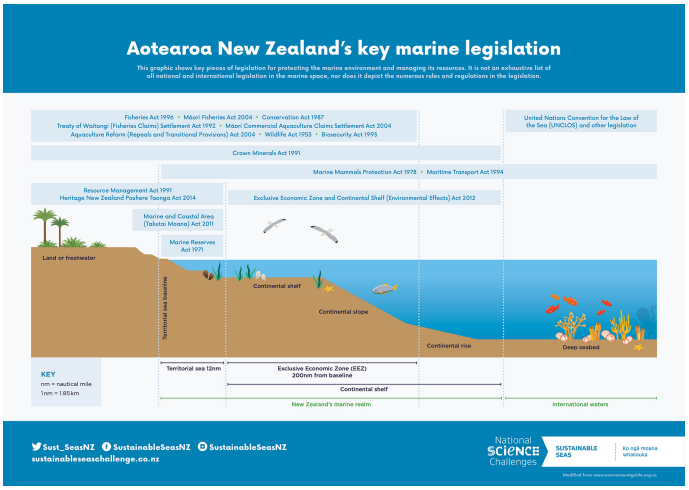

FIGURE 1
Summary of Aotearoa-New Zealand major legislation related to the marine area (from 19679-Sustainable-Seas-Marine-Legislation-Graphic-Nov20-FINAL.PNG (1920×1358) (sustainableseaschallenge.co.nz)). Grey shaded horizontal bars show the areas (terrestrial, coastal, territorial sea, exclusive economic zone and international waters) that the pieces of legislation refer to. Horizontal lines at the bottom define the national and international realms.

RMA in 1991 it has remained controversial, with complaints ranging from lack of protection of the environment, lack of clarity for decision makers leading to legal challenges, and for making development of resource use slow and expensive (Brown et al., 2016; Randerson et al., 2020). Both major political parties have seen the need for reform and the government of the day is presently considering replacement legislation.

These laws, regulations, policies and plans constrain the policies, plans and decisions made by central and regional government agencies. Inevitably, they contain phrases that allow for differing interpretations. For example, use of the word "should" rather than "must" creates options of whether to take an action or not, as does following the word "must" by "take into account" or "consider". Further many words are left undefined, for example, "cumulative effects", "precautionary", "adverse effects" and even "maintenance of biodiversity". For example, the RMA states that cumulative effects should be taken into account.

Local government agencies are overseen by locally elected representatives whose politics determine the balance between economic, social or environmental imperatives. The balance achieved in the decision or policy is not always transparently communicated and biases can be created (or in the case of existing uses) maintained. This balance is not always supported by public surveys or submissions and communities can surprise agencies in their desire to see environmental improvements (Spash, 2006). For example, in Aotearoa-New Zealand, the upgrade of the principal wastewater treatment plant in Auckland was undertaken between 1998 and 2005, at a cost of $450 million. A survey and public workshops around costs (reflected in rate increases) and options for treatment and disposal resulted in support for high quality tertiary treatment. Similarly, petitions to Parliament calling for controls on single-use plastic bags had attracted over 103,000 signatures prior to 2018. This resulted in the Ministry for the Environment seeking feedback on a proposal to implement a mandatory phase out through a submission process. Total submissions received were 9,354 submissions with the majority supporting the proposal (Ministry for the Environment, 2018).

Further constraints for decision-making result from Aotearoa-New Zealand's reliance on case law. Local decisions are frequently challenged in the Environment Court, where judges will often set precedents for future. Interestingly, this is one area where researchers can have an influence and information is actively sought (Urlich et al., 2022).

However, this court-based process does mean that new policies and plans based on environmental research (even when supported by local politicians and agencies) can be slowed. Industries with investment based on previous compliance may become litigious if their operations are then to be constrained (e.g., by replanting controls on erodible slopes to reduce excess fine sediment discharge into freshwaters and (finally) estuaries). Litigation that scrutinizes the science and cross-examines the scientist and their models is important but the burden of proof often falls on the regulator (or iwi, hapū, local community) to convincingly demonstrate the need for change. Given the political implications, scientists within, or contracted by, regulatory agencies can be understandably cautious in their advice, unless the research clearly demonstrates causal attributions. This is difficult to do where

there are multiple stressors from different, often diffuse, sources, such as a range of waste nutrients from intensive agriculture discharged into freshwaters. Policy makers are understandably nervous about scientific uncertainty if changes are to be made to regulations. Consequently the regulatory system is reluctant to shift from the status quo, and the expense of investment in science to determine causality becomes prohibitive.

Recently some regional councils have attempted to move the status quo and manage the effects of bottom trawling and shellfish dredging on biodiversity of the seafloor. This issue came to the Environment Court and eventually was determined by the Court of Appeal finding that a regional council may control fisheries, provided it does not do so to manage those resources for Fisheries Act purposes. This means it may control relevant activities for biodiversity purposes. However, implementation of the court decision is proving problematic as most regional councils have yet not introduced measures to regulate the environmental effects of fishing, and some are awaiting the result of legal challenges (Urlich, 2020b; Urlich et al., 2022). Making ongoing budgetary provision for funding the survey and monitoring of marine biodiversity is also problematic.

Increasingly in Aotearoa-New Zealand resource plans and policies need to reflect the interests of Māori as Treaty of Waitangi (1840) partners alongside the Crown and its representatives. Māori practice and knowledge of kaitiakitanga (Kahui and Richards, 2014) are essentially holistic and strongly based on Māori tribal (iwi and hapū) knowledge (Mātauranga). Mātauranga is founded on place-based dependencies and the interactions and relationships with the environment. Policies, plans and decisions increasingly need to demonstrate the use of Mātauranga in their development and, preferably, embed principles of co-governance. This opens up new opportunities to link traditional knowledge and different world views into the development of environmental policy and actions.

2.4.2 Institutional objectives and silos

Environmental domain (land, freshwater and sea) and geographic scale-specific management structures are common around the world, and Aotearoa-New Zealand is no different (Alexander and Haward, 2019; Flannery et al., 2019, Macpherson et al., 2021).

There are three major central government agencies with responsibility for the environment. All biosecurity issues are dealt with by the Ministry for Primary Industries, who also have oversight of Fisheries New Zealand. The Ministry for the Environment (MfE) has a direct role in reflecting the relationship between the Crown and Māori under the Treaty of Waitangi and in monitoring the outcomes of environmental decision-making. Under the RMA, MfE works with other government agencies to develop national policy statements and national environmental standards. The Department of Conservation (DOC) is charged with promoting conservation of natural and historic heritage with specific roles in conserving protected indigenous marine species (identifying and assessing the adverse effects of fishing on marine mammals and seabirds) and threatened non-protected species. It also has specific responsibilities for coastal management (under the RMA), including preparation of the New Zealand Coastal Policy Statement; facilitating approval of all regional coastal plans by the Minister; deciding on consents for Restricted Coastal Activities; planning and consent responsibilities for the offshore islands; and calling-in consent applications of national significance in the coastal marine area.

Regional Councils (and in a few cases local unitary authorities) manage other activities in terrestrial areas, freshwater and the Territorial Sea. Their interests include water provision, water treatment, parks, land development zoning, ports, airports, etc. Council boundaries are generally aligned with catchments, but can divide up marine systems.

There are two other agencies that also contribute to coastal management. The Environmental Protection Authority (EPA), established in 2011, has oversight of international obligations under the UN Framework Convention on Climate Change, the Kyoto Protocol, the Vienna Convention, and the Montreal Protocol. In the marine environment, it has specific management functions in the EEZ, but for the territorial sea it only evaluates nationally significant proposals. The Parliamentary Commission for the Environment is an independent agency, headed by a commissioner appointed by the Governor General (as advised by the House of Representatives). The Commissioner's role is to select, review and provide advice on environmental issues and the system of agencies and processes that manage the environment. Recent reports include "Managing our estuaries" August 2020 and "A review of the funding and prioritization of environmental research in New Zealand" December 2020.

The different objectives and statutory requirements of different government agencies can result in policy settings and research priorities in one agency conflicting with another's objectives or result in significant areas falling through the gaps (e.g., estuaries management as highlighted by the PCE "Managing our estuaries" August 2020). Information sharing between central government agencies is only mandated in very few instances, e.g., the Fisheries Act specifically brings DOC into the assessment of fishing impacts on seabirds and mammals. Information sharing is beginning to be more common between agency scientists, for example, the recently created Marine Science Advisory Group formed between MfE, DOC and MPI to classify seafloor habitats. Co-governance initiatives with Māori, due to their emphasis on holistic understanding, are likely to aid in decreasing institutional silos at multiple levels.

Even within organizations, barriers can form. Central and regional government agencies generally have teams (policy and

scientists) and management plans grouped around terrestrial, freshwater and marine areas. These artificial boundaries disrupt management of cumulative stressors in coastal ecosystems that often result from sediments and nutrients that are transported from land through freshwater streams. For example, recent regulatory plan changes to regional council catchment management plans in Canterbury omitted to control the effects of catchment pollution on an estuary, which was required by the existing coastal plan as well as the NZCPS (Urlich and Hodder-Swain, 2022).

The different objectives and statutory requirements of different government agencies also affect researchers, in the types of knowledge needed and through the level of certainty and type of risk assessments required. For example, additive feed fish farms require permission from regional councils to discharge feed, and for most councils must produce a comprehensive assessment of environment effects, including on the water column, seabed, seabirds, marine mammals, and sharks. An unpermitted activity on land also generally requires a robust risk assessment with strong processes that include assessing risks to the marine environment. In contrast, permitted land-based activities, such as farming, and forestry on low slopes, require no risk assessment, even when the activity affects the marine environment. Similarly, in the marine environment, information requirements are relatively minor for assessment of the environmental effects of bottom-trawling in neighbouring and wider areas, and even habitats of particular significance to fisheries remain generally unidentified after 25 years of the Fisheries Act (Gerrard, 2021).

3 Solutions

3.1 Science-policy liaisons

In Aotearoa-New Zealand, many marine management agencies employ in-house scientists to commission research they feel is needed to meet their objectives, to fill knowledge gaps at appropriate times (section 2.2) and overcome resourcing limitations. Importantly these in-house scientists ensure research findings have accurate and robust lay-summaries (section 2.1), that data limitations are understood (section 2.3.1), and that the findings are moved through the agency once the research has been completed (see Figure 2). This liaison or brokerage role has the potential to increase science use, allowing researchers the freedom to focus on ensuring that the underlying research has been done rigorously and is therefore available to guide actions and support a range of solutions.

However, successful use of research in policy formation and planning relies highly on evidence-based policy and planning development models. To date, in Aotearoa-New Zealand, there are no written requirements for agencies to use scientific data when creating policies, and no process for science-policy liaisons to affect legislation, politics or agency goals (Figure 2). There is an expectation that policy is evidence-based and recently (2021) the Department of the Prime Minister and Cabinet (DPMC) has bought out a policy quality framework - "The Policy Quality Framework - Quality Standards for written policy and other advice (dpmc.govt.nz)" that gives some guidance on the 4 major points that **should** be covered: context, analysis, advice and action.

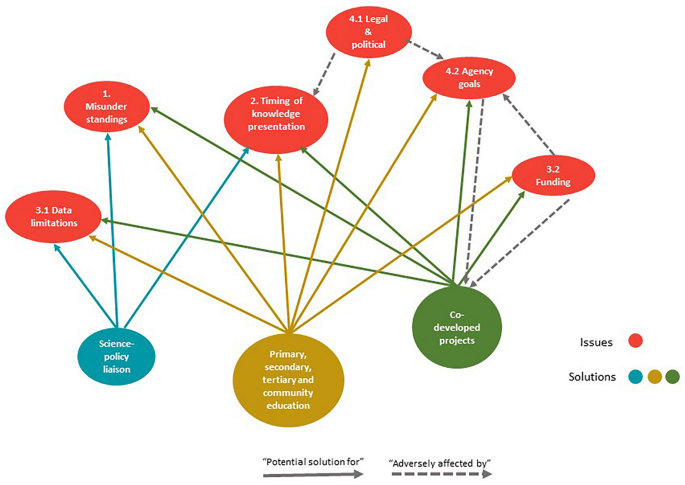

FIGURE 2
Summary of issues and presently used and suggested solutions for Aotearoa-New Zealand. Issues are labelled as they occur in the text. Solutions for the issues are tracked to each issue and colour coded by the solution. Issues are numbered as they are presented in the text, although without the preceding section 2 number. Solutions and issues that are adversely affected by issues are connected by a dashed line.

For analysis it states (final point out of 4) "is well informed (i.e. by up-to-date data, evidence, knowledge, experience, and research from New Zealand and overseas)". However, statements at the start are relatively weak, e.g., "These standards will help you assess and improve the quality of your agency's written policy and other advice, and whether it is fit for purpose——sometimes not all standards will be applicable".

Success also relies highly on effective individuals (Greenhalgh et al., 2022; Karcher et al., 2022). When liaison is working, trust is built, with existing relationships allowing for sharing and transparency, and clarification when concepts or outputs are not understood. Iterative conversations at the science-policy interface can improve understanding of the key opportunities for all parties, with those opportunities more likely to be realized when information flow permeates the agency and other interested parties. While some recommend hierarchical flow of information summaries (Dicks et al., 2014), the information flow process will be unsuccessful if its underlying information is incorrectly interpreted. In addition, uptake into policy can be poor if agency scientists are low in the management hierarchy or are not effective communicators (Greenhalgh et al., 2022). Without a strong science-policy liaison, outdated concepts can be perpetuated, science content reduced, and policy-sized chunks reinterpreted and snipped at each stage up the food chain resulting in incorrect policy advice, plans or decision making.

There are high rates of people turnover in central and regional government agencies in Aotearoa-New Zealand, e.g., 20%-26% for the 2015-2019 period at the Ministry for the Environment. People turnover disrupts relationships with researchers and with others, as time is required to re-establish these relationships and the trust that underpins acceptance of science outputs (Greenhalgh et al., 2022). People turnover and the accompanying loss of agency knowledge can result in problems navigating procurement policies to ensure appropriate research providers are engaged. Agency memory also affects maintenance of datasets and knowledge, wasting scarce resources on reinventing the wheel and not including relevant data in decision making.

High people turnover does offer an opportunity to researchers, as people who have worked in many agencies can build knowledge and connections across them. The National Science Challenge Sustainable Seas has taken advantage of such people, embedding them into projects to guide policy interactions. Conversely, training of new staff by those remaining can re-enforce the status quo, as agencies' cultures can be resistant and slow to reform (institutional inertia).

3.2 Co-development and transdisciplinary projects

Aotearoa-New Zealand is transitioning its government-funded environmental research from inter- and multi-disciplinary (e.g., between biological physical researchers and human geography researchers) to trans-disciplinary research (integrates knowledge across academic disciplines with non-academic stakeholders to address societal challenges). Transdisciplinary research engages stakeholders in significant ways throughout the research process, preferably by co-developing projects. In the view of the government funding agency (Ministry of Business, Innovation and Employment (MBIE)), co-development should deliver a partnership between different knowledge systems, thus helping to achieve management action or policy change. MBIE states a preference for projects that encompass a wide range of stakeholders from central and local government agencies, to businesses and local communities. Projects are expected to also partner with Māori entities, responding to their needs at a variety of levels, utilizing their knowledge and providing any capacity building needed. Thus, co-developed projects should more successfully address the issues solved by successful science-policy liaisons, including gaining funding (2.3.2) and providing a process for affecting agency goals (2.4.2). However, it stops short of providing any process whereby legislation and politics can be influenced (Figure 2).

Co-development offers considerable benefits for researchers, ranging from stakeholders understanding other perspectives, through policy development, to education about science and other knowledge systems. Sometimes the projects can offer a "safe" space for policy makers, planners and environmental decision makers to explore new thoughts. Unfortunately, in our experience working as researchers in such projects, there are several emerging barriers.

- High transaction costs, in terms of researcher time and organizational resources to write grant applications with no guarantee of funding, is inefficient, ineffective and a significant barrier to early career researchers. Currently, much of the funding for this type of research is competitive. Conversely, the Sustainable Seas National Science Challenge has worked with a negotiated process where topics, outcomes and funding are set at a high level and negotiated with a research team (see section 2.3.2). However, high transactions costs still occur, such as those from ongoing co-development processes which can be intensive due to frequent turnover in partners from agencies.
- Environmentally focused proposals not only need to demonstrate that the research is needed, but also need to guarantee delivery of results within 3 to 10-years, with at least some use of the results by businesses, decision-makers, planners or policy within that time period.
- Co-development partners are often time-poor people in operational roles with a limited ability to create change in their own organization. Many central and regional government agencies are not mandated to act on research findings. As we move to partnerships and co-production of solutions involving many different

partners, we need to move into spaces of shared responsibility and actions.

- New initiatives to co-develop projects with Māori partners e.g., MBIE's Vision Mātauranga funding program) are building engagement and involvement in proposal development and in research itself, but these often tax the time capacity of individual Māori as many roles in iwi, hāpu and Māori trusts are often only one person deep.
- Transdisciplinary research is a very human and organic process, yet in Aotearoa-New Zealand funding requires predictions in the proposal as to the timing of steps and milestones (more than one per year are expected) and then reporting on these from 3 monthly to annually. If transdisciplinary research is the way forward, central funding agencies need to create new structures that can accept that progress, like the environment we are trying to manage, is not linear and predictive, but requires flexibility to accommodate engagement and knowledge sharing with stakeholders. Reporting requirements could also be simplified, following the proliferation of reporting, accountability, and technical advisory groups and boards, that while required to some degree, often take up significant portions of research funding, and research time to manage.

3.3 Using education to build understanding across society

We urgently need to develop the ability of legislators, planners and policy- and decision-makers to understand complexity and stop trying to find a "silver bullet" or a "one metric" solution. We also need to shift emphasis from short-term economic imperatives to long-term environmental outcomes that support healthy ecosystems and also increase transparency in decision-making (Tadaki et al., 2021). The chances of good environmental outcomes for the next generation will increase with training to navigate different knowledge systems and undertake the joined-up thinking needed to transform relationships between people and nature. We need to foster development from school children through to universities, and on to whole-of-career learning. Ecology should be a foundation paper for degrees in business, planning etc. In a world of mis-information, alternative facts and complex problems, a critical skill for all is to know when to trust and how to judge the value of knowledge. Part of this may also need a shift in media focus from short catastrophic, or adversarial, stories to deeper narratives. We feel that education to build understanding across society is essential for solving issues related to using knowledge to support our environment (Figure 2).

Enthusiasm for science and an awareness of our interactions with the environment is beginning to be built into the Aotearoa-New Zealand school curriculum, generally on an area-by-area basis. For example, a curriculum around Ecosystem-based management is being developed for secondary school students through interactions between researchers and Marlborough Girls College. A group of schools (from primary to secondary) around the Manukau Harbour are interacting with researchers and scientists from Auckland Council, to understand the health of the harbour, what could be done to manage it better and how science can help. Ecologists working in marine science in many of Aotearoa-New Zealand's universities are co-supervising students working across the biophysical science, social science and economic disciplines in an effort to embed complexity and transdisciplinary understandings into students. Some of these students are already graduating and moving into various roles in government agencies.

An obvious next step is to add law into the educational mix to ensure that non-lawyers, lawyers and courts understand the implications of the language and concepts that science and policy use and vice versa. In the Sustainable Seas National Science Challenge, marine ecologists, policy makers and decision makers from multiple organizations are also working with environmental lawyers.

Many Māori concepts are beginning to resonate in the general public, with the increasing teaching of Te Reo (Māori language) in schools and institutions and the embedding of Mātauranga in all government agencies and partnership with science. These concepts serve Aotearoa-New Zealand well in articulating the importance of our connections with nature and bringing long-term benefits to the forefront of decision making.

Whether or not such educational initiatives will be a successful solution is yet unknown. We feel optimistic that this new knowledge and perspective is slowly diffusing out from successful science-policy liaisons and co-developed projects (particularly those including Māori partners). Directly targeting education initiatives is, however, required to speed up this process. Certainly, without the ability to create better cross-discipline, science-informed and nature-focused people across all of Aotearoa-New Zealand, science researchers will be continually doomed to having only marginal impact with our research, often after avoidable degradation, or restoration failures, have occurred.

4 Conclusions

Finding the place and role for environmental science in Aotearoa-New Zealand and the world is a non-trivial task. We must prize rigorous and relevant science and scholarship but embed this in society to effect the necessary fundamental change. Science's declaration of the existence and nature of the

Anthropocene demonstrated that everything is connected, and that critical problems are multi-dimensional and multi-scalar.

Our experience shows many barriers on the path to increasing the use of science in policy, plans and decision-making. Science researchers can help with barriers relate to different language and concepts, and how to deal with complexity, uncertainty and lack of knowledge, assuming that planners, policy-makers and decision-makers are allowed to listen and foster innovative solutions. However, other barriers, for example, legal and political constraints and conflicting agency objectives are not within the ability of science researchers to directly overcome. We agree that researchers certainly need to do what they can in "taking the horse to water". However, we believe successful use of science to achieve good environmental outcomes requires commitment across society. This requires new approaches and capacity building that can transform the ineffective or incremental ways of approaching crises in biodiversity, sustainability and climate. It also requires a conversation about values and norms towards nature and transparency about how decisions are reached and for what benefit(s). We, therefore, suggest that education from junior levels through to universities has a crucial role to play.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

All authors contributed to the discussion around the barriers and solutions and each wrote at least one section. JH assembled the individual sections. All authors contributed to the article and approved the submitted version.

Acknowledgments

All authors acknowledge the experience of being involved in the National Science Challenge Sustainable Seas. Sustainable Seas also provided a review of a draft of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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