Marine Policy xxx (xxxx) xxxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Key research priorities for the future of marine science in New Zealand

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A B S T R A C T

New Zealand's marine and coastal environments are of significant ecological, economic, cultural and social value. Yet a multitude of threats, disjointed legislation, and considerable knowledge gaps continue to limit the country's ability to effectively manage its marine ecosystems and resources. As such, it is important to identify the key research priorities that can best support progress towards more relevant and informed decision-making. Here we present the results of the New Zealand Marine Science Horizon Scan, which identified the ten highest priority research questions for the future of marine science in New Zealand across nine themes: 1) fisheries and aquaculture, 2) biosecurity, 3) climate change, 4) marine reserves and protected areas, 5) ecosystems and biodiversity, 6) policy and decision-making, 7) marine guardianship, 8) coastal and ocean processes, and 9) other anthropogenic factors. These key research priorities can be used to complement ongoing marine science activities, develop new and important areas of research, encourage opportunities for collaboration, and improve transparency around research and decision-making. Not only will answering these questions bridge existing knowledge gaps in marine science, but they can also be used to design research programmes that make the greatest contributions to the future of marine conservation, policy, and management in New Zealand.

1. Introduction

The health of our oceans is of paramount importance. Yet a multitude of threats, including global warming, ocean acidification, overexploitation, pollution, habitat destruction, and invasive species, continue to threaten our waters [1,2]. New Zealand (NZ) has the fifth largest exclusive economic zone (EEZ) in the world, with 96% of the country's sovereign territory underwater [3,4]. An island state, NZ's marine and coastal environments are of great ecological, economic, cultural, and social value [5,6]. However, disparate legislation and significant knowledge gaps continue to limit the country's ability to effectively conserve and manage its resources [7–9]. As such, identifying the research questions that will help bridge these gaps and enhance NZ's marine science, policy, and management is vital.

Horizon scanning is an established method for identifying emerging issues and priorities in the sciences. The horizon scanning approach was developed by Sutherland and Woodroof [10] to provide a systematic search for, and examination of, medium- and long-term threats and opportunities for environmental science and conservation around the world [11,12]. Such an approach can be used to identify important topics and priority research questions at national and international scales [13–15], and for specific topics of interest such as biosecurity, ecosystem services management, and marine biodiversity [16–18].

A modified prioritisation exercise was recently conducted which identified five main strategies for effective marine science in NZ [19]. These strategies included the importance of managing for cumulative impacts, enabling integrated management, balancing long- and short-term benefits, building appropriately resourced networks, and effectively translating knowledge into practice. Developing and nurturing these overarching principals within NZ's ocean governance framework will transform the way marine management and conservation is undertaken. While these cornerstone principles are envisioned to become the foundations of NZ marine science and planning processes, the provision of specific research questions is also needed to help drive ecological, economic, social, cultural, and policy-based research of utmost relevance. Therefore, we developed the NZ Marine Science Horizon Scan to identify key research questions considered most important for the future of marine research in NZ.

Our objective was to compile a list of priority research questions that could be used to inform the future direction of marine science in NZ, and guide focused investigation. These specific questions are those that could be pursued by individuals or research teams to bridge critical knowledge gaps, and ensure we can adequately conserve and manage our marine environments and resources. To achieve this aim, we invited the NZ marine science community to identify research questions they considered to be the most important, and collaboratively rank their relative significance. In doing so, we sought to draw together diverse knowledges, experiences, disciplines, and perspectives to identify the

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https://doi.org/10.1016/j.marpol.2019.103539
Received 27 November 2018; Received in revised form 3 April 2019; Accepted 10 May 2019

most pressing questions and priorities for the future of marine science in NZ. Not only will answering these questions progress marine science, policy, and practice in NZ, but they may provide important insights that can contribute to achieving our global ocean goals (CBD [20]; SDG14 [58]), and drive momentum towards the upcoming United Nations Decade of Ocean Science for Sustainable Development (2021–2030 [57]).

2. Materials and methods

2.1. Participants

The NZ marine science horizon scan invited contributions from researchers and decision-makers across the NZ marine science community. This community includes marine scientists working across a variety of disciplines, in addition to individuals from academia, conservation, research institutes, government, and non-governmental organisations. An initial list of 773 emails was collated via a search of academic and grey literature, as well as reports, resources, and staff listings of relevant organisations online. Email invitations were sent out to every contact on this list, with a link to the horizon scanning exercise. The horizon scan was also promoted at the NZ Marine Sciences Society (NZMSS) conference, and distributed via NZMSS and NZ Coastal Society (NZCS) mailing lists to further maximise reach and uptake. Both the initial gathering of questions, and later prioritisation exercise, were completed through online surveys. Individuals and institutions were not identifiable in this research. This research was approved by the Auckland University of Technology Ethics Committee (AUTEC:18.249).

2.2. Gathering the initial list of research questions

Participants were invited to submit up to three research questions that they believed to be the most important for "informing the future direction of marine science in NZ to ensure we can adequately conserve and manage our marine environments and resources". Submitted questions were required to meet the following criteria to be included in the final list: (i) be relevant to marine science in NZ; (ii) address an important gap in knowledge; (iii) be formulated as a research question (rather than general topic or priority area); (iv) be answerable through a realistic research design; (v) be of a spatial and temporal scope that could be addressed by a research team (criteria adapted from [13]).

The online survey was launched on 4th July 2018, and was open for eight weeks, with three email reminders following the first invitation to participate. A total of 322 questions were submitted by 244 participants. Checking these submissions against the inclusion criteria, and combining similar entries to avoid replication, provided a final list of 264 questions. These questions were then classified into nine major themes (e.g., fisheries, climate change, guardianship), based on similarity of topics across the questions submitted and the ease of use of the final results. The final list of questions is available as supplementary material.

2.3. Prioritising questions for the final list

At the end of the initial question gathering survey, participants were offered the opportunity to indicate whether they would like to take part in prioritising the final list of research questions. As a result, a total of 106 individuals were invited to participate in this second stage. The prioritisation exercise was open for three weeks from 6th November 2018, with three email reminders following the first invitation to participate. A total of 49 participants contributed in the prioritisation exercise, scoring questions from zero priority (0) to highest priority (6) across a seven-point Likert scale (zero priority, low, medium-low, medium, medium-high, high, highest priority). Responses were collated and averaged across participants to identify the ten highest priority questions for each of the nine themes.

3. Results

3.1. Fisheries and aquaculture

Fisheries and aquaculture are vital sources of food, nutrition, income, and livelihoods. However, harvesting wild stocks and farming aquatic organisms can impact marine ecosystems, and it is crucial that we find the best management approaches to ensure that these industries are ecologically, economically, and socially sustainable. In NZ, the seafood sector currently generates around NZD $1.8 billion per year, with various strategies in place to substantially increase revenues through the development of higher-value products and improved operational efficiencies [21,22]. Fisheries and aquaculture in NZ face similar pressures as many other regions, including challenges due to overfishing, habitat loss, carry-over effects caused by historical governance structures, threats imposed by anthropological factors such as climate change and pollution, spatial limitations, and introductions of marine diseases [23–27]). Safeguarding food security whilst protecting marine ecosystems underpins a successful blue economy, but there are still some important knowledge gaps which require closing in order to develop a comprehensive management strategy which can achieve this sustainable future. The key research questions identified are:

1. What new tools and technologies can be developed as alternatives to bottom-trawling that would allow this practice to be phased out?
2. How can fisheries management be improved to reduce impacts on marine environments and species?
3. How can we design an integrated management system that includes networks of marine protected areas (MPAs) to enable commercial, customary, and recreational fisheries to be sustainable?
4. What is the impact of fishing on coastal marine biodiversity and ecosystems?
5. How are commercial interests in fisheries influencing the ability to put in measures that adequately conserve and manage our marine environments and resources?
6. How does trawling and dredging affect productivity on continental shelves, and benthic habitats of significance?
7. What are the factors preventing wild shellfish stocks from recovering to historic levels?
8. What can be done to optimise fishing catch while minimising bycatch and incidental mortality?
9. How do terrestrial coastal processes, and human activities on land and the coast, impact shellfish populations and shellfish bed recovery?
10. How will multiple stressors impact and interact to affect the food security of marine resources in the future?

3.2. Biosecurity

Biosecurity manages risks to the environment and economy caused by pests and diseases entering, spreading, and/or establishing in marine systems. Primary vectors and invasion pathways of unwanted marine organisms involve ballast water, hull fouling, floating debris, and movements of marine farming equipment and products [28,29]. In NZ, recent incursions of invasive marine species are highlighting the difficulties associated with managing aquatic pests once they arrive, with a range of biosecurity issues emerging at both national and regional levels [30–32]. In 2015, 351 non-indigenous species were identified in NZ marine waters, of which 187 had become established [33]. Substantial efforts are currently underway to transform NZ's biosecurity system through development of the government's 'Biosecurity 2025' initiative [34]. Answers to specific biosecurity questions would greatly enhance our ability to protect our marine environment, and future-proof our natural and cultural heritages. The key research questions

identified are:

1. How can we better mitigate the impact of invasive species?
2. What new molecular techniques can be developed to improve the early detection of invasive species?
3. How can we identify and monitor the impact of marine pests on native biodiversity?
4. How do marine introduced species and climate-change-induced range shift alter ecological structure?
5. How can biodiversity be increased to ensure marine communities are resilient to the impacts of pests?
6. What are the impacts of current and future marine biosecurity risks?
7. How can we use genomic-scale DNA taxonomy to identify where alien species came from and when they arrived in NZ?
8. Which newly invasive toxin-producing microalgae might establish in NZ waters due to future expansion of the subtropical latitudes?
9. What is the reproductive potential of biofouling species on commercial and recreational ships arriving into the NZ Exclusive Economic Zone (EEZ)?
10. How do invasive marine invertebrates get distributed over long distances?

3.3. Climate change

There is compelling evidence for rapid climate change, with an overwhelming consensus that global warming is largely being driven by anthropogenic emissions. Associated effects of increasing ambient temperatures and atmospheric CO_2 levels include changes in precipitation patterns, increased frequency and intensity of storms, altered air and ocean circulation, sea-level rise, and ocean acidification. Over the past century in NZ, the country-wide average air temperature has increased by 1.0 °C, marine heatwaves have become more frequent, sea level has risen by around 20 cm, and the ocean has likely increased in acidity by around 25% [35]. Predictions for the next century include NZ sea levels rising 10% more than the global average, frequent coastal inundations and erosion of vulnerable coastal areas, increased rainfall and volume of sediment being discharged to the coast, changes in biodiversity, favoured conditions for exotic species, greater incidence of marine diseases and harmful algal blooms, and continued reductions in ocean pH [2,36–38]. Ecosystem-level implications stemming from climate-driven shifts in species composition and distribution is a core area of concern, with uncertainty around resilience and adaptability. The key research questions identified are:

1. How will primary production that supports coastal and ocean food webs respond to future change?
2. How will the increasing frequency of marine heatwaves affect marine ecosystems and the distribution and abundance of marine biodiversity?
3. What impacts will climate change and ocean acidification have on marine resources and how can this best be managed to ensure sustainability?
4. How resilient are marine species to changes in water temperature, and what impact will this have on local biodiversity?
5. How can we improve and prioritise our coastal restoration efforts to ensure we can adapt to climate change?
6. How will climate change affect the spatial patterns and extent of marine species, food webs, and their interactions within and across ecosystems?
7. How does the changing climate, and its impacts on our waters and the Southern Ocean, affect the oceanography around NZ?
8. How will the different factors of global change (temperature increase, ocean acidification, eutrophication, plastic pollution, etc.) act synergistically upon coastal and ocean ecosystem functioning?
9. How will ocean ecosystem services be affected by, and respond to, climate change?
10. How will global change affect biophysical interactions and ocean processes?

3.4. Marine reserves and protected areas

Marine reserves and protected areas are widely recognised as important tools for marine conservation, fisheries management, and environmental preservation [39,40]. As such, the need for improved marine protection has been recognised as critical in the NZ Biodiversity Strategy [41] and the country's international commitment to protect 10% of its marine and coastal areas by 2020 [20]. Yet NZ's 44 marine reserves currently protect less than 1% of the country's marine area. The Government is now reviewing our marine policies and protection [42] with the goal of creating a national network of marine protected areas (MPAs) in the near future. This network would help NZ achieve its 10% protection target, while providing representative cover of NZ's unique and diverse ecosystems. Strategic research is needed to maximise the conservation value of this expanding protected area network, while coordinating these efforts with other interests and priorities in the marine environment. The key research questions identified are:

1. What are the spatial requirements for an effective, national marine reserve network?
2. Where and how should we implement more marine protected areas (MPAs)?
3. What additional areas could be designated as marine protected areas (MPAs) or reserves in order to protect ecosystems that are not currently represented?
4. How effective are mixed-model marine protected areas (MPAs) (e.g., taiāpure, mātaitai, some rāhui) at protecting and restoring marine system function?
5. What are the environmental, social, cultural, and economic values of marine reserves?
6. What is the protection value of different marine protected area (MPA) tools (e.g., no-take, partially protected, etc) for different species and habitats?
7. How can we integrate NZ's marine protected areas (MPAs) into a wider Pacific network that maximises biodiversity conservation while allowing for multiple use?
8. Should an expanding marine reserve network focus on many small or few large reserves to deliver the most benefits while ensuring representation, adequacy, and effectiveness?
9. What are the benefits and impacts of marine reserves and marine protected areas (MPAs) that are currently designated?
10. Can a traditional ‘no take’ rāhui that is well-enforced locally provide benefits that are equivalent to a nationally designated marine reserve?

3.5. Ecosystems and biodiversity

Biodiversity refers to the variety of plant and animal life in our marine and coastal environments, while ecosystems are the interacting systems of living species and non-living components such as water, substrate, and nutrients. The NZ seascape is particularly rich and complex due to the country's waters extending across 30 °C latitude, from the subtropical to the subantarctic [43], and on an active plate boundary, between large water masses and ocean currents [44]. Scientists estimate that as much as 80% of NZ's indigenous biodiversity may be found in the sea [41], yet less than 1% of the NZ marine environment has been surveyed [43]. While over 17,000 species are known to scientists, research indicates that there may be as many 65,000 marine species in NZ, with an average of seven new species identified every fortnight [43]. However, human-induced impacts, climate variability, and a lack of information continue to threaten the future of NZ's marine ecosystems and biodiversity, and more research is

needed to understand how we can better conserve and protect them. The key research questions identified are:

1. How can degraded benthic habitats be restored to resume critical ecosystem functions?
2. What is NZ's current baseline of biodiversity and species abundance across its different marine habitats?
3. What are the most cost-effective techniques for restoration of degraded coastal ecosystems?
4. What are the factors hindering the recovery of depleted marine species, and what are the factors required to counteract depletion?
5. How can we identify and assess the biggest threats to marine habitats to inform their management?
6. How will multi-stressor impacts affect coastal species?
7. How can we quantify change and risk to ecosystem function and integrity associated with multiple stressors and cumulative impacts?
8. How can we best predict tipping points in marine ecosystems?
9. How do coastal, benthic, and pelagic ecosystems respond to natural and human-induced perturbations?
10. What are the key indicator species that demonstrate healthy or unbalanced marine ecosystems?

3.6. Policy and decision-making

Effective marine policy and decision-making helps balance the diverse priorities and objectives of different stakeholders in the marine environment, while enhancing sustainable management of the ocean. The marine environment around NZ is of tremendous ecological, economic, social, and cultural value, but existing legislative frameworks were developed in response to particular interests and sectoral needs, rather than the current and future needs of the ocean. As a result, NZ's policy landscape is complicated, and at times contradictory [5,7]. These complex governance issues are further compounded by a lack of data that could be used to inform management, which makes transparent and legitimate decision-making difficult [16]. There is no overall decision-making framework to guide the country forward, and a new approach to marine policy and management is urgently needed. Researchers play an important role in bridging these knowledge gaps, while providing answers to questions that would greatly enhance NZ's ability to develop equitable and effective evidence-based decision-making. The key research questions identified are:

1. How can cumulative effects and multiple stressors in coastal marine environments be better accounted for to ensure robust decision making for regional councils?
2. What is the best approach to manage the cumulative effects of multiple activities occurring in the marine environment?
3. How can we improve the processes between science, decision-making, and action to improve our conservation and management outcomes?
4. How do we encourage more sustainable practices in the utilisation of marine resources?
5. How can uncertainty and risk be better incorporated into effective ocean governance and policy-making?
6. How can we better navigate the distribution of power in decision-making across multiple and diverse stakeholders?
7. How might a voice for the ocean be empowered, and an integrated ocean policy be advanced?
8. What policy, legal, or institutional arrangements are required to effectively integrate the management of terrestrial watersheds and adjacent coastal environments?
9. How does NZ form a coherent marine research policy when are there so many different disparate pieces of legislation that cover the oceans?
10. What are the most effective methods, approaches, and outcomes for developing marine spatial planning in a NZ context?

3.7. Marine guardianship

Marine guardianship (kaitiakitanga) means enhancing individual and collective stewardship of the oceans to protect the environment, while safeguarding marine resources for future generations. Recent years have seen increasing interest in understanding how different people value NZ's coasts and oceans, with targeted funding directed towards projects that actively engage society in monitoring and managing the marine environment [19,45–47]. Combining different ways of knowing (mātauranga, local, experiential, and scientific) is critical for such efforts, and strong relationships between agencies, communities, and tangata whenua (the indigenous Māori people of NZ) has never been more important. Carefully targeted research is needed to better understand how we can effectively build such partnerships, enhance kaitiakitanga, and strengthen Māori, community, and citizen guardianship of the marine environment. The key research questions identified are:

1. How could we improve public awareness of, and compliance with, sustainable use of our marine resources?
2. How knowledgeable are the general public about their personal impact on the marine environment, and what level of knowledge makes people want to protect it?
3. How can we give the wider community a better awareness and understanding of what's happening beneath the surface of our waters, to inform better behaviour, management, and decision making?
4. How can citizen science be utilised to maximise observations of changes in the marine environment?
5. Can local and/or community monitoring detect changes in the environment to inform local marine management and behaviour change?
6. How can outreach and engagement efforts be developed to better connect New Zealanders with their marine heritage?
7. What are the impacts of poor environmental condition on mātauranga Māori and iwi place-based interaction?
8. How best to achieve a partnership of inquiry between Western science and mātauranga Māori?
9. How can we better understand and account for the social perceptions of marine environments and resources to improve conservation and management?
10. What is the spatial distribution of marine social, ecological, economic, and cultural values?

3.8. Coastal and ocean processes

Coastal–ocean processes involve different physical phenomena over a large range of temporal and spatial scales that co-exist and interact. Erosion, transportation, and deposition of terrigenous sediments are coastal processes controlled by hydrodynamic patterns. Important exchanges with the open ocean influences primary productivity, habitat structure and quality, community composition, the availability and mobility of trace elements, nutrient cycling, and geomorphology [48,49]. NZ has a large extended continental shelf area (ca. 1.7 million km^2) with a variety of seascapes, and 15,000 km of variable coastline vulnerable to erosion [1,50]. Receiving inputs from three major water masses (Tasman Front, Subtropical Front, and Subantarctic Front), different thermal, chemical, and biological features creates a unique marine environment. Predicting coastal and oceanic change is difficult, but it is expected that future changes in wind, wave, sea level, and precipitation will substantially affect sediment movement and coastal upwelling of nutrient-rich ocean waters, which are essential for coastal productivity [51,52]. The key research questions identified are:

1. How do long-term changes in ocean water masses around NZ impact the marine ecosystem?
2. What are the impacts of suspended sediment on primary production and carbon pathways in coastal waters?
3. What is the impact of sedimentation on nearshore ecosystems and species?
4. How could coastal inundation forecasting help us manage low-lying and vulnerable coastal areas?
5. How do current impacts of terrigenous fine sediment on key coastal processes and ecosystem services vary nationally, and how are these likely to change in the future?
6. What else do we need to know to accurately forecast biophysical transport and transformation in shelf seas at the space and timescales sufficient to aid conservation and management?
7. How is the increase of sedimentation affecting the behaviour and survival of benthic and non-benthic organisms in offshore sites?
8. What is the baseline for biophysical transport and transformation in NZ's shelf seas, and how will these processes change in the coming century with changing climate and land-use practice?
9. What are the greatest barriers to accurate quantification of physical and biogeochemical processes, and how do we overcome them?
10. What approaches can be used to better determine the loading of nutrients and sediments into estuaries?

3.9. Other anthropogenic factors

Coastal ecosystems are complex and species-rich, and are vulnerable to degradation from a variety of anthropogenic factors other than climate change and fishing. Movement and interactions of water through the landscape ultimately mean that oceans are the repository for multitudes of contaminants associated with different land uses and human activity (agriculture, forestry, mining, urban development) [53]. Surface runoff and stormwater discharges are major sources of sediments, nutrient loading, chemical pollutants, and floating debris – mounting pressure on marine and coastal resources through deteriorating water quality and impairment of ecosystem health [53–55]. Data on marine waste and pollution in NZ is limited, but threats derived from human activities in catchments that discharge into the coastal environment are of considerable concern [56]. Identifying sources of contamination, assessing impacts, and developing mitigation strategies to protect NZ's marine environment are areas that require focused investigation. The key research questions identified are:

1. How can we better mitigate the impacts of land-use on the coastal ocean?
2. What are the impacts of runoff from terrestrial farms on marine environments?
3. What are the combined effects of very low levels of multiple contaminants (e.g., pesticides, natural resource extraction contaminants, salinity, pharmaceuticals and personal care products, endocrine disrupting chemicals) with different modes of action on aquatic organisms and ecosystems?
4. What are the impacts of land-use change and future development on coastal ecosystems and the marine environment?
5. What are the relative effects of different land-use types and activities on coastal water quality and biodiversity?
6. How can we best monitor river plumes and their pollution burden on coastal waters?
7. What are the ecological and social impacts of deep sea mining?
8. How do we develop appropriate regulatory guidelines and standards specifically for contaminants of emerging concern that account for multiple modes of toxicity and multi-generational sublethal effects?
9. How do the interrelated and interacting effects of human activity on land and resource use in the sea affect marine ecosystems?
10. What are the fates and impacts of microplastics, nanomaterials, and other marine debris?

4. Discussion

The NZ marine science horizon scan invited contributions from researchers and decision-makers across the NZ marine science community. This community included marine scientists from a variety of disciplines, in addition to individuals in academia, conservation, research institutes, government, and non-governmental organisations. This collaborative approach was chosen to draw on the diverse knowledge and experience of the science community, while maximising participation, inclusivity, and relevance in identifying and prioritising the final research questions. The inclusion criteria required all questions identified in the horizon scan to address important knowledge gaps, be answerable through a realistic research design, and be of a spatial and temporal scope that could be addressed by an individual or research team (see Methods; [13]). These questions can also be broken down into components with sets of specific objectives, and/or aligned with existing projects to facilitate uptake and ease of applicability.

Many of the questions posed are also highly relevant at global scales, and the research required to answer some of them may prove to be challenging and complex (see [16]). It will be important to bring together the diverse experiences and expertise of natural and social scientists, tangata whenua, policy-makers, practitioners, legal specialists, and community groups to find effective solutions. The development of new inter- and trans-disciplinary approaches to answer these questions will enhance NZ's ability to bridge existing knowledge gaps across the marine sciences and identify new opportunities to translate marine science into policy and practice. Doing so may help provide a mechanism to align existing complicated, and sometimes contradictory, marine policy and legislation, and move NZ towards a more integrated and effective decision-making framework. Researchers answering the questions here will play an important role in this process, driving the country forward towards a cohesive approach that will ensure NZ can adequately conserve and manage its marine environments and resources.

We believe the questions identified here will be of great interest to the NZ marine science community and a variety of other stakeholders in NZ and around the world. These research priorities can be used to complement ongoing marine science initiatives, identify new and important areas of research, encourage opportunities for collaboration, and improve transparency around research and decision-making. We also hope that funders and donor organisations find this information useful for determining how they might target their future investments (e.g., [13,14]), to seed innovative new science programmes aimed at pursuing some of the questions considered to be high priority but under-researched. Ultimately, attention towards answering the priority questions identified here will bridge significant knowledge gaps in marine science, and provide important new insights that will support the country's progress towards effective marine conservation and management. In doing so, marine science in NZ can deliver greater environmental, social, economic and cultural benefits for the future of its seas and society.

5. Conclusion

The NZ horizon scan identified important questions that have the potential to address key knowledge gaps across the marine sciences. These questions can be pursued by individuals and research teams, and are important for the future of our marine species, ecosystems, and resources. The questions identified here also provide new opportunities for enhancing collaboration and building the inter- and trans-disciplinary research teams required to align disjointed legislation and translate marine research into policy and practice. Not only will such work improve NZ science, seas, and societies, but answering the research questions identified here is also relevant for the future of marine

science, policy, and practice around the world (CBD [20]; SDG14 [58]). The upcoming United Nations Decade of Ocean Science for Sustainable Development (2021–2030) has announced an urgent need for bridging priority knowledge gaps in marine science and developing new science-informed approaches to ocean policy and management. The ocean community is invited to plan for the next ten years of marine science and technology, and the NZ marine horizon scan may be an important opportunity to work together to effectively manage our marine systems and resources "for the ocean we need and the future we want" [57].

Declarations of interest

None.

Acknowledgements

We acknowledge the Institute for Applied Ecology New Zealand (AENZ) and the School of Science at Auckland University of Technology (AUT) for their funding and support. We would like to thank the NZ Marine Sciences Society (NZMSS) and NZ Coastal Society (NZCS) for their help in distributing the horizon scan across the marine science community. We are grateful to everyone who participated in the horizon scan, including all of those who submitted research questions, and those who helped prioritise the final questions in each theme. You all helped identify the key research priorities for the future of marine science in New Zealand.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2019.103539.

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