Office of the Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

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The Future of Commercial Fishing in Aotearoa New Zealand

A report from the Office of the Prime Minister's Chief Science Advisor, Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia.

Key Messages

February 2021

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Back cover: *Pāua fishing vessel on Rēkohu Wharekauri the Chatham Islands.*

Ka pū te ruha, ka hao te rangatahi

FOREWORD FROM THE PMCSA

Kia ora koutou

This report was prepared at the request of the Prime Minister in late 2019 and has had a difficult gestation, having been rudely interrupted by a pandemic response which called on the time and energy of the team here in the Office, and the many participants on whom we relied for expertise and input. It has also had a difficult birth, as we strived to digest a deluge of feedback and listen to wildly different opinions on our early drafts. As such, it is worth emphasising at the outset that the views in this foreword are personal.

Beyond the foreword, the recommendations we present are those of the Office of the Prime Minister's Chief Science Advisor (OPMCSA). These have drawn heavily on the expertise of our panel and the large number of contributors and peer reviewers, but few would endorse the report in its entirety. As well as this 'key messages' short report, a full report is available in long narrative form and also forms the basis of a web resource, which is easier to browse. But first, some reflections on our foray into commercial fishing:

Scope of our report – science advice on commercial fisheries

The stakeholders we talked to during this project all shared a remarkable passion for the ocean. We thank them for their enthusiasm to share this passion with us. Many had deeply held views and it was a significant challenge to stay within our scope without straying into fraught relationships and decades-old feuds.

To be clear, the scope of this report is *to provide science advice to the Prime Minister on commercial fisheries (excluding aquaculture)*, which sounds simple. It is not. Some stakeholders were placed offside from the start simply by the scope and the framing – an indication of the poor relationships and lack of trust that characterise this sector. So at the outset, it is worth acknowledging that science advice on commercial fisheries won't solve all the many problems faced by an increasingly challenged marine environment, globally and locally.

Solving these problems will need people to work together on a system change, as partners not adversaries. Such a system change needs to address not just commercial fishing, but recreational fishing too. It needs to address not just fishing, but the many other environmental stressors on the marine environment – climate change, land-based impacts such as sedimentation, and pollution. To acknowledge these sector challenges, we have tried to place our recommendations within a broader context. We stray beyond our scope in the first three themes of our recommendations, in our general call for overarching leadership in the ocean realm. That said, the specific recommendations in this report are within the scope of commercial fisheries and, if implemented, will make a difference.

Irrespective of individual – sometimes widely divergent – views of how environmentally sustainable commercial fisheries are in 2020, nearly every stakeholder we talked to agreed we could do better in at least some areas. There are many differences that can be made in the short term to help the pendulum swing towards a greater emphasis on the environment in which we fish, and away from emphasising just the fishing itself. There are conversations around innovation in data management, technology, policy, and collaboration that can pilot good practice to catalyse change. This benefits everyone, including commercial fisheries, which have everything to gain from a healthy marine environment.

Context and framing – the QMS is in place, but we can do better for our environment

The context in which our science advice is provided is important. Since our scope was restricted to commercial fisheries, we have placed our recommendations within the framework of the Fisheries Act 1996 which provides the legislation for the Quota Management System (QMS). Those seeking to completely revolutionise the management of fisheries need not read on – a review of the QMS was outside our scope.

Over the course of this work, many stakeholders identified the parts of the Fisheries Act 1996 that are under-used. These can enable protection of special marine habitats and an ecosystem approach to fisheries

management (EAFM). The most striking example is perhaps Section 9(c), which enables the protection of habitats of particular significance for fisheries management – but has never been used. These provisions can be used in the short term and enable immediate action. We challenge the Minister and the regulator to strengthen their arm and use these provisions to catalyse change.

Many argue that the protection tool that should be used is a Marine Protected Area (MPA), under the purview of the Minister of Conservation, and some that the Resource Management Act should be more often used to protect the inshore environment and marine life. These conversations often run parallel, creating indecision and hostility.

A shared understanding of our environmental bottom line and collective aspirations for our environment are needed to harmonise these conversations and bring all voices to the table. This was beyond the scope of our work, but we highlight some local examples where a collaborative approach has made progress in setting up a framework improving environmental outcomes. The single biggest challenge to progress is the lack of trust and shared vision between stakeholders – in stark contrast to our last project (on rethinking plastics), there is little evidence of widespread social and cultural license for change.

The need for a partnership approach with iwi to respect the Treaty and the Māori Fisheries Settlement was emphasised throughout and needs to be fully understood by scientists seeking change.

"The facts"

There is no accepted single source of truth in the fisheries sector and this report does not claim to be one. Passionate debate arises from (over-)interpretation of uncertain data sets by all sides, which supports conflicting narratives of 'what the evidence says'. We have tried to highlight where particular points of contest lie in interpreting data and were saddened by the number of incidences of 'alternate facts' that we navigated in this project.

The inherent uncertainty in fisheries management is very easily manipulated to support a particular narrative. From an agreed percentage of how many of our stocks have been assessed, to the size of the original non-fished biomass, to a percentage of this biomass that can be sustainably harvested, to whether our trawling footprint is increasing or decreasing – the very basis of our fisheries management is often fiercely contested. Where possible, we have tried to explain the alternate interpretations of uncertain information. In other places we highlight where data, the interpretation of data, or both, are contested.

Data, data, data – it is dark down there, but we must make decisions anyway

We do have a lot of data about the ocean but in many ways, we also know frighteningly little. What we do know is often uncertain, creating error bars in measurements which foster the differences in interpretations that fuel dissent. The data we do have is poorly integrated across different stakeholders. The mountain of electronic and other data collected for compliance purposes could be better mined for environmental, commercial and social outcomes. New tools can support this if the data is shared. Aggregation of non-sensitive data from industry sources and integration with data from a wider range of scientists from different disciplines and regulators could radically change the amount of information available on which to base decisions, and the decision-making processes must be open to incorporate this data in a transparent way. Deep local knowledge and mātauranga Māori are also under-used and we could listen more to on-the-ground expertise.

In the meantime, lack of data is used by many to excuse lack of action – this must change. Data is expensive to collect and information will never be perfect. Transparency in what we don't know, our levels of uncertainty, and how we manage this, is as important as sharing what we do know.

Research, science and technology efforts could be better coordinated across the sector

The industry levy funds vital data gathering and research for significant commercial species. It does not pay for basic public good research or research that would be valuable for other fished species. This creates a resourcing shortfall, unreasonable expectations on this funding, a lack of trust and perverse incentives. There are many

new high-tech tools and cool new ideas that could change the way we fish, but public good funded research is not always well connected to industry questions or environmental challenges. Fishers understand the issues better than anyone and have many great ideas – we should empower them to innovate and try them out. Many fishers would love to more fully understand the basic biology of the commercial species, to inform better fisheries management decisions taking an ecosystem approach – but this research is often not prioritised.

Relationships between researchers looking at different aspects of the marine environment, housed in different institutions, mirror the poor relationships in the sector as a whole. A lot of energy is wasted trying to deconstruct an opposing narrative, which could be better spent coming to a shared understanding.

We need to ensure the regulator is nimble, trusted and well placed for success

This contested environment presents our regulator with formidable challenges. More resource is needed to enable the regulator to keep pace with the ever-changing stocks. Plans are critical for success, but an agreed fisheries management plan is the beginning of a solution, not the end. Despite big strides in the introduction of electronic monitoring and initial cameras on vessels, we found that there is sometimes a lack of confidence that plans will be implemented. Making data and information more accessible will help improve transparency of prioritisation and decision making. This will benefit everyone by allowing more independent scrutiny, which will build trust.

Slow processes and high data requirements can provide unnecessary hurdles to innovators to try new fishing practices. A higher-trust, more permissive environment to trial and optimise new equipment could enable our innovators to flourish and address the many challenges in this environment.

But above all, we need overarching leadership

Although beyond the bounds of science advice, the need for leadership across the many different strands of oceans governance was clear. Science can support the journey, but the governance of the oceans needs to provide a framework in which to do so. We were delighted to see the Oceans and Fisheries Minister and Under-Secretary appointed after the recent election.

Our report – fishing today, fishing beyond 2040

This key messages report presents our recommendations in seven themes, with a short supporting summary of the evidence upon which the recommendations are based, and links to the full report for a richer discussion and bibliography.

Our full report begins by clarifying our Terms of Reference and outlines detailed recommendations in seven themes, which represent the conversations in our panel meetings.

We then provide the challenging context in which commercial fishing takes place and lay out the many stressors which the marine environment faces, in addition to those posed by all types of fishing.

To help understand how to make progress in this complex area, we try to capture the complexities of fishing in 2020. This is the most contested section of our report in that impressions of the status quo vary a great deal.

Finally, with the context set, we outline ideas and innovations that could help us fish smarter in the future. There are no silver bullets. Not all the ideas are new, and not all of the new ideas will be successful. But we think they offer hope that challenging current thinking about how, where, and when we fish can move the conversation forward to create a future that is better than the past. We end with an aspirational vision of the future to challenge old thinking and encourage new.

Ngā mihi nui

I'd like to give my heartfelt thanks to our hard-working panel for their collegial spirit and painstaking explanations of the complexities of this field to us novices in the OPMCSA. Particular thanks to my co-chair Craig Ellison for his deep knowledge, enthusiasm for science, patient expertise, and for connecting us to the sector.

To the hard-working team in the OPMCSA who did a mountain of work in a gruelling year – thank you. Celia Cunningham led the project ably supported by Rachel Chiaroni-Clarke, Ellen Rykers, George Slim, Susie Meade, Manmeet Kaur and Daksha Mistry-Surti. Thanks all for all the hard yards. Ka pai.

Thanks to the fishing industry for letting us march into your world uninvited and sharing your thinking and expertise, introducing us to your members, and hosting us on vessels, in factories and in boardrooms. The depth of knowledge and ideas to protect your environment in your midst is under appreciated and I hope that we have helped to tell some of your success stories to balance the darker ones.

Thanks to the many researchers, officials, fishers and environmentalists who supported our kaupapa from within our limited Terms of Reference and scope, even though your frustrations with these in terms of addressing the wider problems in the marine environment were palpable. Your input was incredibly valuable, and we hope that you feel heard, especially in the first three themes of our recommendations.

And a final thanks to everyone involved for their energetic engagement. Even for those who were unable to contain the occasional outbursts of anger, hostility and despair, your commitment to our marine environment was clear and has earned my respect.

He moana pukepuke e ekengia e te waka

Juliet Gerrard

Professor Dame Juliet A. Gerrard DNZM HonFRSC FRSNZ
Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

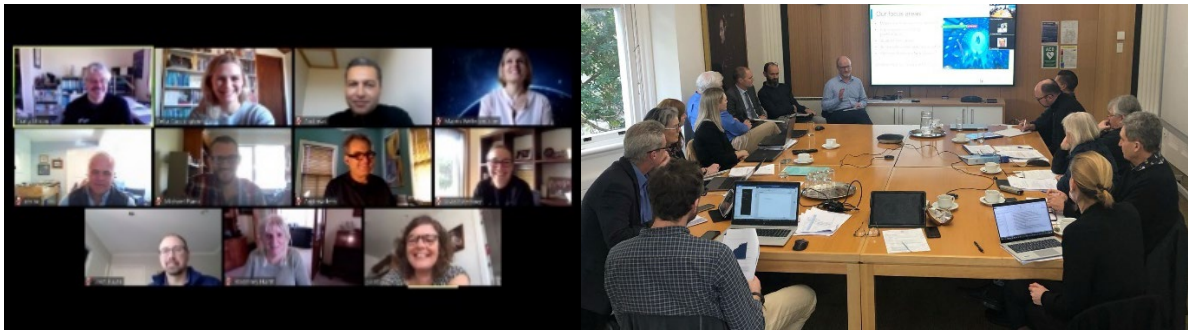
OUR PANEL

We convened an expert panel to create a diverse and balanced group that could guide the OPMCSA and the PMCSA in preparing this report.

- **Juliet Gerrard, Co-Chair**
- **Craig Ellison, Co-Chair**, Seafood New Zealand
- Dr Chris Cornelisen, Cawthron Institute
- Livia Esterhazy, World Wildlife Fund
- Dr Rosemary Hurst, NIWA
- Dr Andrew Jeffs, University of Auckland
- Andrew (Anaru) Luke, Cawthron Institute
- Raewyn Peart, Environmental Defence Society
- Professor Michael Plank, University of Canterbury
- Dion Tuuta, formerly Te Ohu Kaimoana
- Dr Maren Wellenreuther, Plant & Food Research

We are incredibly grateful to the support and hard work that the panel has put into this research. The values below reflect the views of the project's expert panel and framed our work:

- **Retain what has worked** – build on strong foundations to enhance outcomes for commercial fishing, the community and the environment, and remain open to new ways of doing things.
- **Challenge and inspire** – use knowledge and science to challenge, inspire and guide a better future for commercial fisheries and Aotearoa New Zealand.
- **Responsibility** – to be good ancestors and ensure we maintain and enhance the resource for those generations to come.
- **Te hā o Tangaroa kia ora ai tāua** – protection of the environment (and ecosystem) so that utilisation is possible and sustainable.
- **Respect** – respect for the oceans, the people, and the products we produce and share. We reflect on what sustains us, the contributions made, and the high value of our products.
- **Crown obligations** – have respect for the agreements made between the Crown and iwi in relation to fisheries and the marine environment, such as Te Tiriti o Waitangi and the 1992 Fisheries Settlement.



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We thank the many researchers, stakeholders and interested parties who agreed to be on our reference group, met with the team, provided introductions, generously contributed time, energy and suggestions to this project through conversation, consultation, peer review or high-level comments on the report. We are particularly grateful to those who hosted the team to give us the necessary insights into the setting of commercial fisheries on which we were providing advice. Though we have incorporated as much feedback as possible, we acknowledge that this is an area with highly contested views and that as a result not all suggestions could be actioned. As such, **our acknowledgement of people who helped us with this project in no way reflects endorsement of the project itself**. We have done our utmost to keep track of everyone who has contributed and they are recorded below. Please accept our sincere apologies for any inadvertent errors.

We'd also like to acknowledge those who chose not to be listed in these acknowledgements.

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Alaric McCarthy, Cawthron Institute
Alex Rogers, Hauraki Gulf Forum
Alice Rogers, Victoria University of Wellington
Alison Collins, Ministry for the Environment
Alison Greenaway, Manaaki Whenua
Alistair Jerrett, formerly Plant & Food Research
Amanda Leathers, World Wildlife Fund
Anastasija Zaiko, Cawthron Institute
Andrew Hill, Fisheries New Zealand
Andrew Peti, New Zealand Coastal Seafoods
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Anna Yallop, Seafood Innovations
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Ashley Rowden, Victoria University of Wellington
Balam Jimenez, Victoria University of Wellington
Barry Torkington
Barry Weeber, ECO NZ
Becky Shanahan, Hawke's Bay Regional Council
Beth Fulton, CSIRO, Australia
Beth Hampton, Ministry for Primary Industries
Brendan Flack, East Otago Taiāpure Committee
Bronwen Golder, Stanford Centre for Ocean Solutions
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Carolyn Lundquist, University of Auckland
Carolyn Walker, Ministry for Business, Innovation and Employment
Cath Wallace, ECO NZ
Ceri Warnock, University of Otago
Charles Heaphy, Sealord
Charlotte Austin, Fisheries New Zealand
Chris Battershill, University of Waikato
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Chris Rodley, SnapIT
Chris Tyler, SnapIT
Christina Stringer, University of Auckland
Cliff Law, NIWA
Conrad Pilditch, University of Waikato Constance Nutsford, Ministry for the Environment
Dan Bolger, Fisheries New Zealand
Dan Hikuroa, University of Auckland
Dana Briscoe, Cawthron Institute
Danette Olsen, Ministry for Business, Innovation and Employment
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Dave Jose, Foodstuffs
Dave Kelbe, Xerra Earth Observation Institute
Dave Kellian, Fisher, Leigh
Dave Woods, Precision Seafood Harvesting

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David Howes, Fisheries New Zealand
David Jones, Sanford
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Jonathan Peacey, The Nature Conservancy
Josie Crawshaw, Bay of Plenty Regional Council
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Karl Warr, Better Fishing
Karli Thomas, Deep Sea Conservation Coalition
Katherine Short, Terra Moana
Katina Conomos, The Noises Marine Protection and Restoration Project
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Mike Taitoko, Takiwā
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Richard Wells, Resourcewise
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SOME KEY TECHNICAL TERMS AND HOW WE USE THEM

A report of this breadth is necessarily cross-disciplinary, incorporating input from a wide variety of people with different expertise, who may use terms in very specific (and sometimes rather different) ways. Here we lay out definitions of some key terms and how we use them in this report. A full glossary of technical terms and abbreviations with definitions, and approximate translations of all Māori words and phrases, are provided in the full report.

This report is about **commercial fishing**: taking fish, aquatic life or seaweed in circumstances where a fishing permit is required as per section 89 of the Fisheries Act 1996. We use the term 'commercial fisheries' to refer to wild-caught marine life that is harvested to sell. We did not include seaweed in this report.

In this report, **sustainability** or **sustainable use** usually refers to sustainability as defined in the Fisheries Act 1996 – that is, (a) maintaining the potential of fisheries resources to meet the reasonably foreseeable needs of future generations, and (b) avoiding, remedying or mitigating any adverse effects of fishing on the aquatic environment. Sometimes, we use a narrower definition referring to the long-term maintenance of a single fish stock without considering the wider ecosystem impacts. At other times, we use a broader meaning of sustainability that encompasses ecological and social factors, including but not limited to biodiversity (genetic, species and ecosystem diversity), environmental and ecosystem impacts.

In this report, a **stock** or **fish stock** usually describes a management unit of a species as defined by Fisheries New Zealand. A stock may be a discrete biological population, with little to no reproductive mixing with other stocks of the same species. In other cases, there may be migration or mixing between stocks.

Biodiversity refers to the variety of life. It pertains to the variety of *different* species present, the variability of ecosystems themselves and diversity *within* species. Biodiversity is a critical part of ecosystem and planetary health but not the major focus of this report.

An **ecosystem approach to fisheries management** (EAFM) and **ecosystem-based fisheries management** (EBFM) are different terms used widely in the literature. Both involve moving beyond single-species measures to incorporate wider ecosystem effects into management. We generally use EAFM, unless referring to specific literature which uses EBFM. They differ from **ecosystem-based management** (EBM) which refers to management of the ocean more broadly – not just fisheries.

Threatened species are those assessed according to the New Zealand Threat Classification System as facing imminent extinction because of their small total population size and/or rapid rate of population decline. This includes three sub-categories: 'Nationally Critical', 'Nationally Endangered' and 'Nationally Vulnerable'. **Protected species** are defined under the Wildlife Act 1953. In the marine environment, all marine mammals, seabirds (except black-backed gulls), all sea turtles, some corals and some fish are protected species. A species may be protected but not threatened, or it may be both protected and threatened.

People from different disciplines use the term marine protected area (MPA) as an umbrella term for spatial areas in the marine environment where restrictions exist in order to conserve nature or maintain biodiversity values. There are a range of legal tools that offer differing levels of protection in the marine environment. Protected areas in the marine environment include marine reserves (as defined in the Marine Reserves Act 1971), benthic protection areas (BPAs), mātaitai and taiāpure reserves, and others. Different marine protection tools are discussed in detail in section 4.2 of the full report. The term MPA is often conflated with 'marine reserve' in everyday use but is used more widely in this report.

ORGANISATION OF THE FUTURE OF COMMERCIAL FISHING IN AOTEAROA NEW ZEALAND

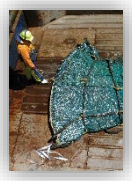
The Future of Commercial Fishing in Aotearoa New Zealand focuses solely on commercial fishing of wild fish stocks, with aquaculture, customary and recreational fishing outside of scope.

THIS SHORT 'KEY MESSAGES' REPORT

This report contains a summary of the key messages that emerged from the detailed analysis in the full report, based around the seven themes of our recommendations (see next page).

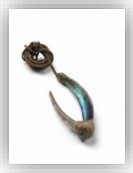
THE FULL REPORT

The full report provides a detailed evidence synthesis relating to commercial fisheries. It has six parts:



Part 1: Introduction

The introductory chapter outlines the Terms of Reference as agreed at the beginning of the project, details of the panel and other acknowledgements, recommendations, the aim and scope of the report, and key technical terms used in the report.



Part 2: Context:

We briefly introduce the historical and current state-of-play for commercial fishing and ocean research, highlight key work that we build upon, outline motivations for improving the sustainability of the commercial fishing industry, and describe the guiding frameworks and exemplars for this project.

Part 3: Challenges for the marine environment

To provide context for the stressed environment in which fishing takes place, we describe the range of non-fishing stressors acting on the marine environment, including climate change, land-based impacts, diseases and invasive species, plastic pollution, and their cumulative effects. We then provide an evidence synthesis on how commercial fishing challenges the marine environment, focusing on the ecosystem.

Part 4: The regulatory space is complex

In this part of the report, we outline the complexity of the regulations in the marine domain and demonstrate the resulting challenges at local, national and international levels.

Part 5: Commercial Fisheries in 2020

We provide a brief overview of the key tools used for fisheries management in Aotearoa New Zealand, synthesise the evidence on the state of our commercially fished stocks, highlighting data and information gaps as well as contested information, and describe various initiatives underway in the sector.

Part 6: A future focus: Science, technology and innovation

We take a future focus and introduce innovative ideas and scientific solutions to address sustainability issues in the commercial fishing sector, concluding with a vision for fishing in 2040 to inspire action.

OUR WEBSITE

The detailed findings are available in an accessible format at https://www.pmcsa.ac.nz/topics/fish/. The full report and key messages report, and all other content relating to this report are also available on our website.

RECOMMENDATIONS

The recommendations presented in this report aim to support movement towards 100% sustainably managed oceans, reflecting our aspirations for commercial fishing in 2040. They were developed through a consensus process with our panel with open sharing of a wide range of views. Alongside the recommendations we provide considerations for supporting their implementation.

Not every panel member fully supports each individual recommendation and consideration but, taken together, the recommendations are a fair representation of the collective view of the group.

The first three themes of the recommendations acknowledge that our Terms of Reference were limited to one part of the marine environment only – commercial fisheries – but that there are issues to solve beyond our narrow scope.

These themes cover:

1. Strengthened leadership.
2. A bold Oceans Strategic Action Plan.
3. Te ao Māori | A connected worldview in 2040 and beyond.

The remaining themes focus on commercial fisheries and can be achieved within the Fisheries Act 1996 – facilitating urgent action.

These cover:

4. A refined set of regulatory tools.
5. A data platform that enables informed commercial and environmental decision making.
6. An ecosystem approach to fisheries management (EAFM) is embraced within the current regulatory framework, including the Fisheries Act 1996.
7. Research and innovation are maximised.

The series of the recommendations could form part of a multi-year programme, but individually many can be implemented right away to make a start.

THEME 1: STRENGTHENED LEADERSHIP

Aotearoa New Zealand benefits from its commercial fishing industry for a number of reasons – it upholds Treaty obligations, contributes to the economy and provides thousands of jobs, while supplying food for people here and overseas. However, these benefits from the industry will only be maintained if our fishing practices are environmentally, economically and socially sustainable.

The challenge with managing our commercial fisheries is that there are competing demands to use and protect the ocean. Even within central government, there are a range of relevant agencies who regulate the marine environment.[1] Different stakeholders have divergent and often conflicting priorities. Recent government reports such as *Our Marine Environment 2019* by the Ministry for the Environment and Stats NZ, *Focusing Aotearoa New Zealand's environmental reporting system* by the Parliamentary Commissioner for the Environment, and *Te Mana o te Taiao – Aotearoa New Biodiversity Strategy 2020* by the Department of Conservation have highlighted that different departments are often pulling in different directions with regard to managing the marine environment. There is a lack of connection in the way that land-based impacts on oceans are regulated and how fish stocks are managed, though there is a strong link between land-based issues and outcomes in the marine domain.

Different departments are often pulling in different directions with regard to managing the marine environment.

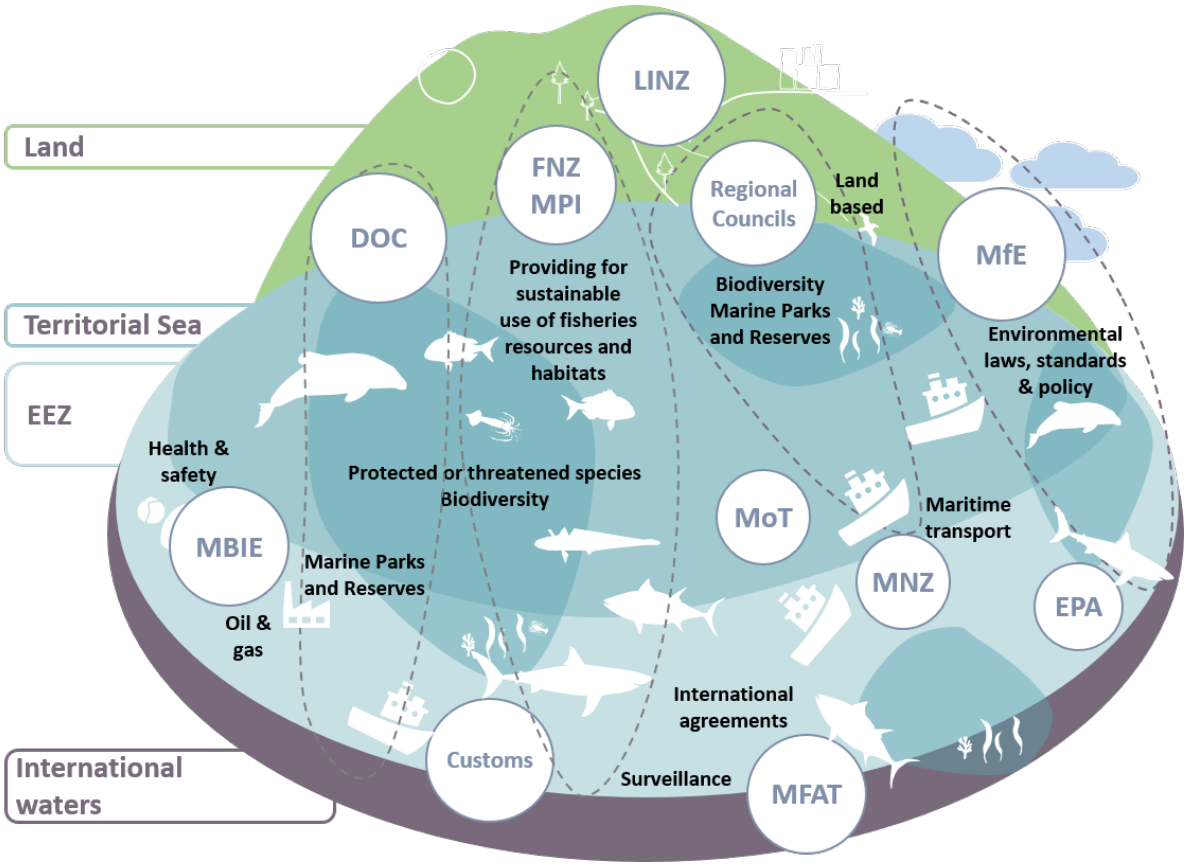


Figure 1: Major marine actors in the Aotearoa New Zealand marine regulatory space in 2020.

[1] Some government organisations do already work together through the Marine Hub (a policy development and advice group).

Given the complexity of managing the marine space and the large number of regulators (see figure 1), there are likely to be issues of both regulatory overlap (particularly where there may be conflicting statutory obligations) and gaps (where there is no regulatory lead).

Figure 2 illustrates some of the areas where there is overlap and the potential for gaps between four of the key regulators. There are significant overlaps in the regulation in areas of conservation – protected or threatened species, biodiversity, and marine parks and reserves. This can create tensions, for example where legal definitions do not align, as is the case with the term 'biodiversity'. To illustrate:

- **Fisheries New Zealand**, through the Fisheries Act 1996, has the dual objectives of ensuring sustainability, while providing for utilisation. This must be done within the context of environmental principles regarding the impacts of fishing on the marine environment and information principles regarding best available information and uncertainty.
- **The Department of Conservation** is the key regulator for species protection and biodiversity in the marine environment, which includes marine reserves and parks, mammal sanctuaries, protection of protected or threatened species, and protection of biodiversity, and developing the *New Zealand Coastal Policy Statement*. This role is undertaken through a number of legislative instruments.

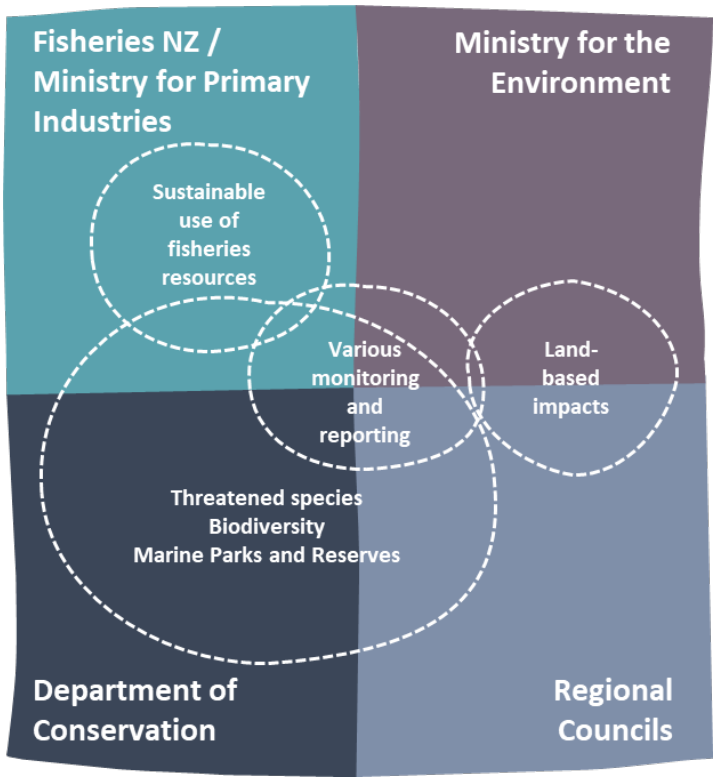


Figure 2: Four of the key regulators in the marine fisheries space and some of their overlapping roles in the marine environment.

- **Regional councils**, through the Resource Management Act 1991, can enact protections for the purposes of maintaining Indigenous biodiversity (within the territorial sea).

Fisheries management cannot focus solely on changes to fishing, but the poor integration of the Fisheries Act 1996 with conservation legislation makes this challenging. There are also regulatory tensions at the local scale between the Resource Management Act 1991 and the Fisheries Act 1996, as demonstrated by recent case law (Motiti Protection Area decisions of 2019) (see figure 3). The *New Zealand Coastal Policy Statement* provides higher-level direction for how regional councils manage the coastal environment, but has been criticised as not fully capturing the "temporally dynamic, spatially heterogeneous, and physically and socially complex region which characterises the interface between terrestrial, marine and lacustrine processes."[2]

[2] Scott, K. N. (2016) The evolution of marine spatial planning in New Zealand: Past, Present and Possible Future, *International Journal of Marine and Coastal Law*, 31(4). 652-689.

Effective management requires these efforts to be integrated and overarching leadership is important to ensure that this is achieved. Cohesive oversight of all marine activities is required to facilitate the necessary multi-party conversations, improve the culture, and build trust between stakeholders. More integration and oversight would enable a conversation to harmonise definitions across stakeholders and legislation. For example, there is currently no agreed definition of sustainability.

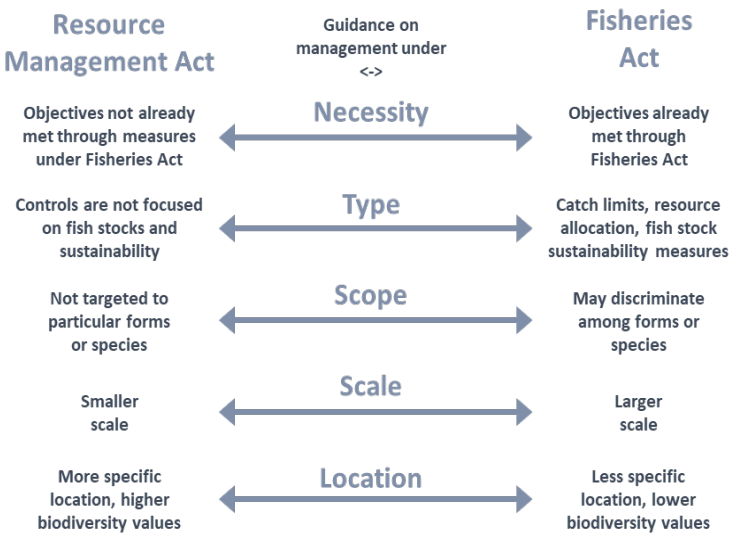


Figure 3: Five indicia identified by the Attorney General for how a council may decide to implement a control that impacts on fisheries management from Court of Appeal (2019) Attorney-General vs the trustees of the Motiti Rohe Moana Trust & Ors. - CA408/2017 [2019] NZCA 532.

There is currently no agreed definition of sustainability.

The enduring rights of Māori to fish are of particular importance with regard to leadership in the marine domain. The introduction of the Quota Management System (QMS) in 1986 with the Fisheries Amendment Act was not fully inclusive of Māori. It triggered a protracted legal process in which a forced accommodation of the QMS within the Treaty was eventually agreed by mutual consent of both partners. Thus our fisheries system has Māori Treaty rights fundamentally built into it, resting on the Treaty of Waitangi and embodied in the 1992 Fisheries Settlement. As per the Treaty, Māori have perpetual rights to fish and to exert rangatiratanga over their fisheries – maintaining the sustainability of fisheries and their surrounding environment. Sustainability of the fisheries resource is a pillar of these agreements and, to uphold the fundamental rights of Māori, there needs to be a sustainable resource for future generations to fish. As part of the Settlement, Māori endorsed the QMS. Changes made to fisheries management, including those that shift the focus further towards an ecosystem approach to fisheries management (EAFM), should be made in partnership with Māori. The principles of EAFM are often in harmony with traditional approaches. The importance of a partnership approach to management changes cannot be overstated if we are to facilitate the continuation and strengthening of an effective, legally sound, and authentic co-management approach to improving the sustainability and strengthening the resilience of our fisheries.

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Perhaps the fundamental challenge faced by all those focused on the goal of sustainable fishing is to translate an incomplete but increasingly sophisticated understanding of the complex interactions and cumulative pressures on our ecosystems into effective and actionable policies and regulations, along with robust indicators to monitor progress. This ambitious goal is likely to take some time to achieve and demands strong leadership by the fisheries management agency, and a connected community of stakeholders with a shared vision of the future. However, it offers an opportunity for Aotearoa New Zealand to be world leaders in managing commercial fisheries.

The fundamental challenge faced by all those focused on the goal of sustainable fishing is to translate an incomplete but increasingly sophisticated understanding of the complex interactions and cumulative pressures on our ecosystems into effective and actionable policies and regulations, along with robust indicators to monitor progress.

This ambitious goal is likely to take some time to achieve and demands strong leadership by the fisheries management agency, and a connected community of stakeholders with a shared vision of the future.

While beyond the scope of science advice per se, these issues inform our overarching recommendations on the system changes that are required to enable science to make a difference, particularly those in Theme 1.

The following sections of the full report expand on these issues:

- 2.4: Recent relevant government reports
- 2.5: Why fisheries are important
- 2.6: We can build on the QMS to improve sustainability
- 2.7.1: Te ao Māori
- 4.1: The complex domestic regulatory system can create gaps and overlaps
- 4.4.3: Case study: The establishment of the Motiti protection areas sets a new precedent for local coastal management
- 5.9: We need a plan for our oceans

THEME 1 RECOMMENDATIONS: STRENGTHENED LEADERSHIP

Recommendations	Considerations
1. We welcome the appointment of an Oceans and Fisheries Minister and Under-Secretary to ensure cohesive oversight of all marine activities within Aotearoa New Zealand's territorial sea and EEZ. This will allow holistic management of the marine domain and productive, sustainable fisheries. a. The Oceans and Fisheries Minister might lead development of an Oceans Strategic Action Plan to provide ongoing strategic oversight for the marine domain (see Theme 2). b. The Oceans and Fisheries Minister might facilitate multi-party conversations to build a culture of trust and collaboration in the marine domain, taking a Treaty-based approach that is inclusive of all Māori and non-Māori (essential for Theme 2). c. As a first step, the Oceans and Fisheries Minister might prioritise immediate evidence-informed actions to protect the marine environment within the provisions of the Fisheries Act 1996 (see Themes 2 and 6).	• All actions relating to Theme 1 must reflect the special relationship between the Crown and Māori, particularly relating to Article 2 of the Treaty of Waitangi, the Māori Fisheries Settlement 1992, and section 5 of the Fisheries Act 1996. • The Oceans and Fisheries Under-Secretary can support co-partnership with iwi, respecting rights embodied in the Treaty of Waitangi, the Māori Fisheries Settlement 1992 and section 5 of the Fisheries Act 1996. • The Oceans and Fisheries Minister might work collaboratively with other key Ministers in the marine domain in developing an Oceans Strategic Action Plan to allow synthesis and prioritisation of varied responsibilities within a cohesive framework, including: ○ Minister of Māori Crown Relations: Te Arawhiti ○ Minister for Māori Development ○ Minister of Conservation ○ Minister for the Environment ○ Minister of Research, Science and Innovation. • The Oceans and Fisheries Minister might work collaboratively with other relevant Ministers, including: ○ Minister for Climate Change ○ Minister of Local Government ○ Minister for Land Information ○ Minister for Biosecurity ○ Minister of Transport ○ Minister of Foreign Affairs ○ Minister of Energy and Resources ○ Minister of Statistics ○ Minister of State for Trade and Export Growth ○ Minister of Treaty of Waitangi Negotiations ○ Minister for Food Safety.

THEME 2: A BOLD OCEANS STRATEGIC ACTION PLAN

THE LACK OF OVERARCHING STRATEGY FOR THE OCEAN INTENSIFIES TENSIONS

There are ongoing tensions between the management of fisheries and supporting ecosystem resilience. The connection between numerous documents and workstreams in terms of an overarching strategy or coherent governance structure is poorly understood. This makes it difficult to identify gaps in management and opportunities for reducing management overlap, and doesn't support a high level of public confidence in management of our fisheries and ocean ecosystem, an environment where data and its interpretation are highly contentious.

The connection between the numerous documents and workstreams in terms of an overarching strategy or coherent governance structure is poorly understood.

Our legislative environment has advantages in providing multiple tools that can be used in management and this is critical to manage a complex biological system at the appropriate management scale. However, overarching policy to drive how and when these tools are used could allow Aotearoa New Zealand to fast-track decisions about how to utilise and protect our marine resources, maximising the opportunities afforded by our large and non-overlapping exclusive economic zone (EEZ), and helping to reduce future conflict.

In the Aotearoa New Zealand context, the basis for what an overarching strategy or plan for the oceans would look like has already been developed through legislation and policy statements, including the Resource Management Act 1991, EEZ Act 2012, Marine and Coastal Area (Takutai Moana) Act 2011, *New Zealand Coastal Policy Statement*, *Te Mana o Te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020*, and the Ministry for the Environment's environmental goals published in 2015. Future work could build on these foundations and further guidance can come from the obligations Aotearoa New Zealand has through international agreements.

A CLEAR FRAMEWORK TO COORDINATE PLANS IS NEEDED

The complexity of the regulation and management of fisheries, and the variable implementation of management plans, has led to some people having limited trust in the regulatory system – although key decisions are made publicly.[3] The need to provide certainty to tangata whenua and other stakeholders around fisheries management was recognised as important during the development of the Fisheries 2030 Strategy released in 2009, which is still referred to occasionally, but does not appear to be widely referenced and is not readily available through the Fisheries New Zealand website. The 2009 Fisheries 2030 Strategy followed a number of previous attempts to establish an Oceans Policy in Aotearoa New Zealand, which began some useful thinking.[4]

As part of Fisheries 2030, fisheries plans are described as an integral component of the wider strategic context. They are key for increasing transparency and putting into action longer-term strategy. Fisheries plans are provided for under Section 11(a) of the Fisheries Act 1996 (and are approved by the Minister) and can apply to a stock, multiple stocks, fishing years, or areas, or any combination of these. The provision gives flexibility for the regulator to provide a rapid and highly customised response to emerging issues. However, there appears to have been a lack of consistent use and update of fisheries plans. For example, the deepwater and middle-depth fisheries plan from 2010 was to provide an overarching framework for management of deepwater fisheries for a five-year period, though was not formally updated until 2019. In the inshore fisheries, a plan was developed

[3] For example, see The Decision letter – Minister of Fisheries and Review of Sustainability Measures for selected stocks for 1 October 2020: Final advice paper.
[4] See full report appendix 11: Some history surrounding an Oceans Strategy in Aotearoa New Zealand.

in 2011 and reportedly trialled but never finalised (i.e. never approved by the Minister). Consultation on a new inshore fisheries plan was underway in 2020, but does not include shellfish. The extent to which finalised (or un-finalised) fisheries plans actually inform fisheries management and are implemented is unclear, particularly in a medium-to-long term view. Making this information more explicit and accessible would help build trust in the system.

There appears to have been a lack of consistent use and update of fisheries plans.

A clear integrative framework to coordinate and implement more specific localised plans would better enable stakeholders to develop and implement their own fisheries plans (subject to approval by the Minister). While development and approval of a fisheries plan has been achieved by the pāua industry, the processes to enable future initiatives could be streamlined.

COMPETING INTERESTS NEED TO BE MANAGED

There are a range of stakeholders with competing interests that need to be managed to prevent excess demand depleting the resources. As well as those within the commercial fishing industry, many others have an interest in the health of our shared marine environment. This includes recreational and customary fishers, the general public, researchers, government representatives, tourism operators, those interested in mining the seabed, environmental groups, iwi, community groups and future generations (see figure 4).

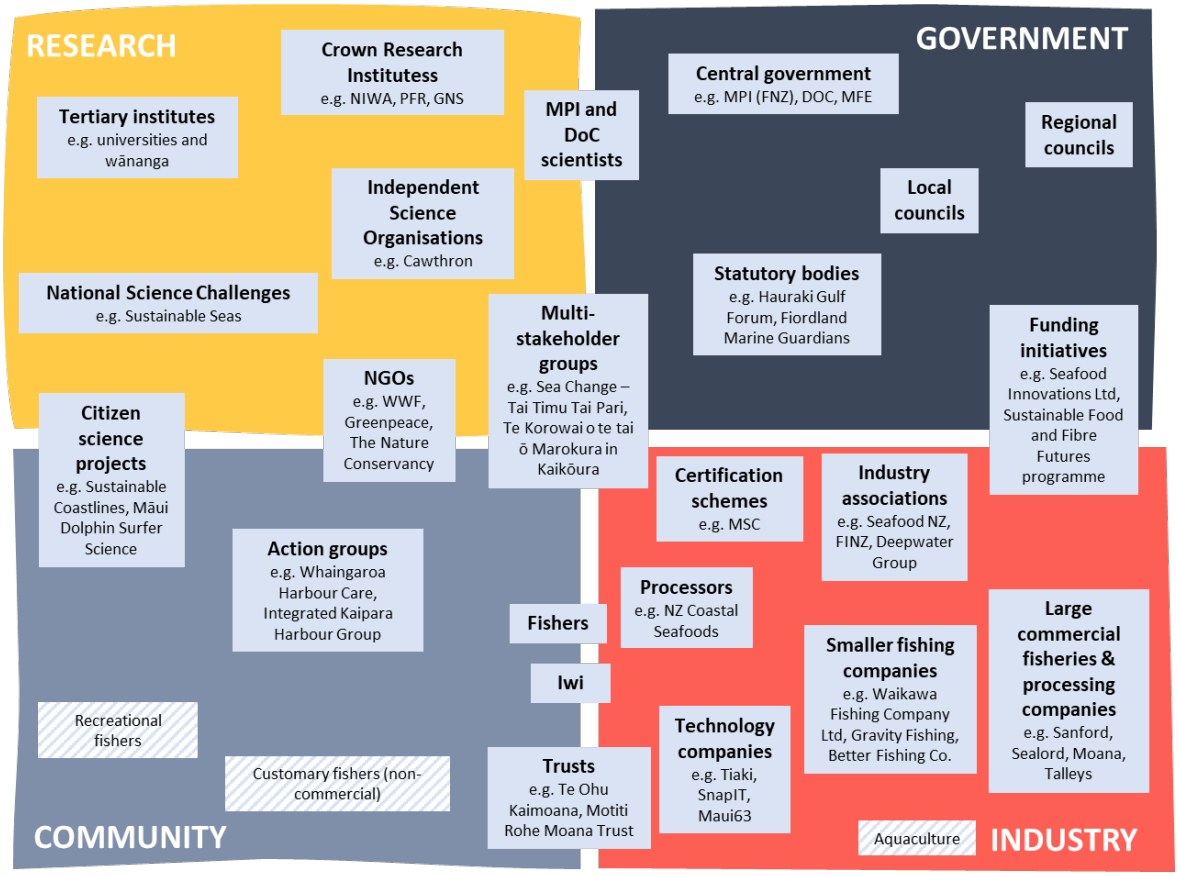

Figure 4: Some of the many stakeholders with interests in Aotearoa New Zealand fisheries.

Tensions between commercial and environmental priorities often surface, but new multi-stakeholder approaches show that, with a shared vision and goal, people can come together to address complex issues in our marine environment. Local marine environments are often managed in a specific way, drawing on local knowledge to manage context-specific issues. Several different approaches to managing the marine area are

underway throughout Aotearoa New Zealand, with each having unique processes and outcomes. There is no one-size-fits-all approach but there are examples of long stakeholder negotiation processes resulting in a bottom-up design of how the area should be managed, as shown in Ata Whenua Fiordland and Kaikōura. Consensus building is a particular strength of the approach, but the approaches are not necessarily outcome-based, require bespoke acts, and their effectiveness varies. Currently, these localised management solutions are relatively few and cover particular, remote areas, but they provide inspiration for a way forward.

A key limitation of taking a collaborative, multi-stakeholder approach to region-specific management is that progress can be slow, despite action sometimes being urgent. These approaches are also resource intensive. However, there are many provisions within the current Fisheries Act 1996 that could be better used to enact immediate change, in parallel with the broader conversation.

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RESEARCH AND REGULATORY INITIATIVES RELATING TO FISHERIES COULD BE MORE INTEGRATED

Through the Fisheries Change Programme, the regulator has introduced mandatory electronic catch and position reporting, has commenced rolling out on-board cameras, and has proposed changing some fishing rules, among other workstreams. The Government has signalled an intent to reform marine protected area (MPA) legislation (through the Ministry for the Environment, Department of Conservation and Ministry for Primary Industries), and the Department of Conservation has developed *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020*.

The industry sometimes takes its own approaches to manage catch, independently verify the sustainability of their fisheries, and improve their gear to reduce impacts on the environment. In certain situations, the commercial fishing industry has changed how fisheries are managed without regulatory changes (e.g. voluntarily lowering catch, fine-scale catch reporting in advance of regulatory requirements, enhancement and translocation, area closures, increasing the minimum size of fish that can be harvested, and developing and implementing harvest control rules). The industry has also gained certification from sustainability schemes – with eight species, which account for over half of the volume of Aotearoa New Zealand's wild caught seafood and nearly three-quarters of deepwater fisheries, currently certified to the Marine Stewardship Council Fishery Standard (though some question the credibility of these schemes). The industry-led Gear Innovation Pathway has successfully driven innovation with fishing gear.

Iwi and hapū have comprehensive mātauranga about their local marine environment, a responsibility to manage the oceans as kaitiaki, and a significant stake in the commercial fishing sector. There are examples of iwi managing their rohe moana through rāhui, reserves and protection areas. Various iwi and hāpu have been key members in collaborative processes that have sought to improve the conditions of their rohe moana. A growing number of research projects involve iwi to draw on mātauranga, and in some cases interweave this knowledge system with western science.

The National Science Challenge, Sustainable Seas/Ko ngā moana whakauka, is a 10-year research program (2014-2024) that brings together around 250 biophysical scientists, economists, social scientists, and experts in mātauranga Māori and policy from across Aotearoa New Zealand. This research programme has been an important start to address the need for a long-term, strategic, collaborative and integrated approach to research in the marine environment, including fisheries. There is significant room to build upon this work, undertaken with co-funding from industry and government, to fill the knowledge gaps about our marine environment and support more sustainable uses of this resource into the future. Sustainable Seas has recognised the importance of bringing in the very many stakeholders in the marine environment, but the fraught relationships within the marine realm make this very challenging. Sustainable Seas is working with government (central, regional and local), businesses, Māori partners, and communities to identify and develop the tools needed to enable

ecosystem-based management (EBM) and a blue economy. Opportunities to work more closely with the fisheries industry would strengthen the potential of this research to address the sector's biggest challenges.

Current initiatives underway by various groups might be better coordinated to support a more cohesive and integrated approach to fisheries management, and could sit within a broader plan for the oceans.

FISHERIES MANAGEMENT COULD DRAW ON INTERNATIONAL BEST PRACTICE

As part of a larger plan for the oceans, we can look to parts of international fisheries management systems for inspiration to improve the sustainability of our fisheries, with the caveat that no place is universally accepted as gold standard by all parties.

Figure 5: Norwegian fishing boats. Image credit: Javier Rodríguez/Flickr (CC BY-SA 2.0).

- **Iceland**: The Icelandic fishing industry has focused heavily on the use of fish by-products. While the volume of fish caught in Iceland has decreased over the past few decades, their export value has increased. Trust is built through independent fish surveys and fisheries data is widely accessible.
- **Alaska**: Fishers have come together to share data in order to allow real-time identification of hotspots to avoid for bycatch. The National Oceanic and Atmospheric Administration has developed an Integrated Ecosystem Assessment initiative to guide effective EBM which Alaska is beginning to apply, starting with conceptual models.
- **British Columbia**: British Columbia in Canada implemented an innovative bycatch quota system for bycatch in the Trawling Groundfish Fishery (Area 2B) in 1996. On top of the individual transferrable quota (ITQ), this fishery has also had an individual vessel bycatch quota system paired with a 100% mandatory observer programme. This allows a specified proportion of their total allowable catch (TAC) to be comprised of bycatch.
- **Norway**: A new Marine Resources Act came into force in Norway in 2009 representing a paradigm shift in fisheries management for the country by mandating the application of an EAFM. An Atlantis ecosystem model of the Norwegian and Barents Sea has been developed and, although there is a long way still to go, some of the management takes into account multi-species fisheries and interactions between species.
- **Australia**: Some fisheries activities are defined as 'threatening processes' under the Environment Protection and Biodiversity Conservation Act 1999.
- **Faroe Islands**: Fisheries management reform that came into effect in 2018 recognises all living marine resources in the Faroese waters as the property of the Faroe people. However, it is worth noting that the historical and cultural context of the Faroe Islands is very different than Aotearoa New Zealand.

Managing fishing sustainably requires international collaboration. This is not explored in depth in our work.

A PLAN IS NEEDED

Resolving long-standing issues in the marine environment, making the most of the many workstreams underway, and maximising on the opportunities afforded by our marine resources will require an overarching strategic approach to managing the oceans. A plan that provides a clear framework for annual reporting, decision making, future planning and lead agency responsibility could be used to coordinate all efforts in this space and guide collaborative, localised plans. This could improve the clarity, transparency and future focus of Aotearoa New Zealand's fisheries management system.

Figure 6: A local fisher unloads his catch of snapper on Auckland's waterfront in the mid-1970s. Image credit: photographer unknown/NIWA.

A plan will be essential for the necessary coordination and integration of workstreams underway by a range of stakeholders. Collaboration between different groups such as researchers and industry will support the sustainable use of our marine resources. It could enable the development of high-value by-products and the development of more sustainable harvesting approaches which can attract a price premium, therefore supporting economic growth without necessarily increasing catch. Setting expectations of best practice through a plan may also be useful to support international market access.

A clear, overarching and transparent strategic action plan would be beneficial to guide long-term planning and action in the marine domain, making the environmental bottom line clear and setting our aspirations for the marine environment. The need for such a plan informs our recommendations in Theme 2.

A clear, overarching and transparent strategic action plan would be beneficial to guide long-term planning and action in the marine domain, making the environmental bottom line clear and setting our aspirations for the marine environment.

The following sections of the full report expand on these issues:

- 2.7.2: International best practice
- 2.7.3: Case study: Integrated ecosystem assessments to inform ecosystem-based fisheries management
- 4.3: Aotearoa has international obligations in the marine space
- 4.4: Regions have varying approaches to management within the territorial sea
- 5.2.3: Fisheries plans
- 5.5: Regulator initiatives and data transformation
- 5.6: Industry initiatives
- 5.7: Iwi initiatives
- 5.8: Research programmes, funding and prioritisation
- 5.9: We need a plan for our oceans
- 6.7: Using the whole fish to develop high-value by-products

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THEME 2 RECOMMENDATIONS: A BOLD OCEANS STRATEGIC ACTION PLAN

Recommendations	Considerations
2. Develop a bold Oceans Strategic Action Plan for 2040 to protect and manage Aotearoa New Zealand's territorial sea and EEZ, with a clear integrative framework to prioritise, coordinate, implement and measure outcomes to achieve 100% sustainably managed oceans. *The panel recognised that such a plan is beyond its Terms of Reference. The following recommendations pertain to the commercial fisheries aspects of such a plan and could be enacted ahead of a larger look at the oceans:* a. Through a Treaty-based and multi-stakeholder approach, develop an evidence-informed action plan that agrees upon the definition and role of an ecosystem approach to fisheries management in Aotearoa New Zealand and how it can be achieved within the context of the Quota Management System (QMS) and a changing climate (see Theme 6). b. Provide a clear framework for annual reporting, decision making, future planning, and lead agency responsibility to coordinate all efforts in this space, including providing clarity around the roles of local and central government, Treaty partners and kaitiaki in fisheries and biodiversity management (see Theme 6). c. Set an expectation that any fisheries-related plans, when created or revised, must specify how they will progress the objectives of the Oceans Strategic Action Plan and demonstrate progress against this in annual review reports (see Theme 6). d. Include actions to support the move from volume to value in commercial fisheries through full product utilisation and a premium brand associated with Aotearoa New Zealand (see Theme 7). e. Clearly prioritise actions across a multi-year programme, starting with those that can be achieved in the short term in an evidence-informed manner to protect the marine environment within the provisions of the Fisheries Act 1996 (see Theme 6).	• Develop the shared Oceans Strategic Action Plan through a co-design process with iwi, respecting rights embodied in the Treaty of Waitangi, the Māori Fisheries Settlement 1992 and section 5 of the Fisheries Act 1996. • Review the detailed thinking in previous iterations of Oceans Policy development. • Consider implementing international targets, including those related to percentage coverage of coastal and marine protection, within Aotearoa New Zealand's context, particularly relating to Article 2 of the Treaty of Waitangi and the Māori Fisheries Settlement 1992. • Facilitate discussions between the regulator and other central government agencies, local government, iwi, industry, environmental organisations, and marine guardians to build a shared understanding of the most effective way to manage the marine domain through the Oceans Strategic Action Plan. • Informed by multi-stakeholder discussions, the Oceans Strategic Action Plan might: ○ Operationalise increased application of an ecosystem approach to fisheries management (see Theme 6). ○ Be based on a true co-partnership model and a dual framework of mātauranga Māori and western science (see Theme 3). ○ Enable tangata whenua to exercise kaitiakitanga. ○ Enable local knowledge and connections to be maximised (see Theme 5.h; Theme 7). ○ Reflect the level of national consistency that is desirable, while acknowledging local context, including the willingness and capacity of stakeholders to undertake management actions. ○ Explicitly address tensions and conflicts in the objectives of stakeholders and regulators in the marine domain. ○ Explicitly address environmental decline to achieve ecosystem resilience in the marine domain (see Theme 3). ○ Address environmental impacts of fishing (see Theme 6.f, g). ○ Aim to reinvigorate Aotearoa New Zealand's global reputation for innovative and effective fisheries management. ○ Consider international exemplars of strong Indigenous leadership in fisheries management (see Theme 3).

	○ Uphold and build on Aotearoa New Zealand's international obligations and commitments. ○ Consider how trade agreements might facilitate more sustainable commercial fisheries. ○ Improve consistency across the marine domain by: harmonising discrepant definitions; agreeing high-level principles; defining environmental outcomes and targets, with an environmental bottom line and clear aspirations. ○ Be implemented through use of all necessary regulatory and non-regulatory levers (see Themes 3, 4, 6). • Define the relationships between the different legislative requirements and strategic visions across Ministries, Departments and Agencies to provide clarity to stakeholders, including but not limited to the: ○ Fisheries Act 1996 ○ Marine Reserves Act 1971 ○ Resource Management Act 1991 ○ Wildlife Act 1953 ○ Marine Mammals Protection Act 1978 ○ Maritime Transport Act 1994 ○ *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020,* especially objective 12. ○ Prosperity Sustainability Protection: Ministry for Primary Industries Strategic Plan 2019 ○ Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. ○ Animal Welfare Act 1999. • Work collaboratively with other ministries when developing the Oceans Strategic Action Plan, feeding into and responding to ongoing relevant work, for example: ○ The 2020 review of the Resource Management Act 1991. ○ The reform of marine protected area (MPA) legislation reform, including how it relates to Section 9 of the Fisheries Act 1996. ○ Recent case law (such as Motiti Protection Area decisions of 2019).

THEME 3: TE AO MĀORI | A CONNECTED WORLDVIEW IN 2040 AND BEYOND

THERE ARE MULTIPLE STRESSORS INTERACTING IN THE MARINE ENVIRONMENT

The marine environment is under enormous stress, with environmental degradation and worldwide declines in biodiversity. Some of these impacts are also seen here in Aotearoa New Zealand. Fishing is one of many stressors on fisheries stocks, marine ecosystems and the marine environment. All forms of fishing are, in turn, impacted by the other stressors on our marine environment. The challenges faced by commercial fisheries therefore need to be understood and addressed in the context of other environmental stressors and their cumulative effects.

Fishing is one of many stressors on fisheries stocks, marine ecosystems and the marine environment.

FISHING EFFORT HAS WIDER ECOSYSTEM IMPACTS

The stress imposed by fishing is not uniform – the relative importance of fishing as a detrimental impact on the ecosystem depends on location, target species, size of catch and the methods used. There are many clear and well-studied environmental impacts of fishing activities, but there are also significant data and knowledge gaps.

One of the most obvious impacts of fishing on habitat is when bottom trawling – the method used for 46% of our catch volume in the 2019-2020 fishing year[5] – is undertaken (discussed further in Theme 6). Even decades after bottom trawling has been halted, there can be little to no recovery in some benthic communities. Diverse habitat is needed to support diverse species, but fishing activities like trawling and dredging can cause habitat homogenisation.

Even decades after bottom trawling has been halted, there can be little to no recovery in some benthic communities.

There is significant bycatch of non-target species every year, some of which are protected species and much of which is dead on recovery or killed by predators if returned to the ocean. Catching protected or threatened species may also impact the industry's social licence to operate. Non-governmental organisations have advocated for a zero-bycatch goal, with gear innovations to reduce seabird capture a key component of achieving this.[6] The variety and variability of bycatch means it's difficult to know the ecosystem impacts and these are likely to differ significantly for each fishery.

Overfishing can result in significant changes to community structures. Research suggests that ecosystems with greater biodiversity may be more resilient to ecosystem changes. Maintaining biodiversity should be a priority for fisheries management in Aotearoa New Zealand to ensure ecosystems are resilient to stressors, including fishing.

CLIMATE CHANGE IS A HUGE THREAT TO OUR OCEANS

A changing climate is inevitable and threatens the stability of our oceans and fishing as we know it. Changes in climate are already happening and further changes are imminent. Mitigation and adaptation are both needed

[5] Information from Fisheries New Zealand. This includes 'bottom trawl', 'precision bottom trawl' and 'bottom pair trawl' categories. The number rises to 84% of our catch if mid-water trawling is included.
[6] https://www.forestandbird.org.nz/resources/call-zero-bycatch-after-mpi-admits-2016-bad-year-seabirds; https://www.wwf.org.nz/what_we_do/marine/sustainable_fisheries/bycatch/

for our fisheries industry to manage change. However, Aotearoa New Zealand will not be the worst affected country and this may provide a competitive advantage. The ability to rely on fisheries resources as we do today is not a given, and evidence-based management will play a crucial role in future-proofing our fisheries to withstand climate change impacts. Staying at the leading edge of fisheries management in a changing climate will require: being responsive, adaptable and flexible; ongoing monitoring to inform actions; taking a holistic approach to managing our oceans; and mitigation efforts and innovation to transition to a zero-carbon way of fishing.

The ability to rely on fisheries resources as we do today is not a given, and evidence-based management will play a crucial role in future-proofing our fisheries to withstand climate change impacts.

LAND-BASED ACTIVITIES IMPACT COASTAL FISHERIES

Linkages between the land and sea are of critical importance for our fisheries and coastal fisheries are under increasing pressure from land-based activities. With some of the highest sediment run-off in the world, the adverse effects from sedimentation such as smothering bottom-living organisms, changing habitats on the seafloor, reducing water clarity in coastal areas, clogging the gills of filter feeders, changing fish gill structure, loss of amenity value, and poisoning marine life, are a significant risk to our coastal fisheries. Addressing sedimentation is difficult due to the large number of different sources that contribute, including conservation land, forestry, agriculture, earthworks and stream bank erosion. It will require removing pressures on the environment (e.g. replanting trees and changing land management practices) and active efforts to restore environments (e.g. replanting seagrass or transplanting bivalves). Alone, neither is sufficient because even if no further sediment affects an area, it may still have lasting damage from sediment to date. Restoring a habitat will have limited benefits if further sedimentation will occur in that area.

Figure 7: Aotearoa New Zealand has some of the highest sediment run-off in the world. Image credit: Geoff Reid NZ.

With some of the highest sediment run-off in the world, the adverse effects from sedimentation are a significant risk to our coastal fisheries.

Compared to sedimentation, contaminant issues such as pollution from vehicles, discharge of waste products, use of fertilisers, and run-off from materials and paints tend to be more localised and are less likely to impact the whole ecosystem, but are still important and may require localised approaches to mitigate harms.

Fisheries management and land-based regulations are not integrated. Despite a strong evidence base showing that land-based activities affect our marine environment and fisheries, there has been limited work to incorporate this knowledge into management decisions or to manage land-based activities. There are increasing localised efforts to do so, but progress is slow given the challenges of balancing impacts of the sectors using the land. This does not necessarily indicate a legislative gap, but may represent a failure in implementation. Improving the sustainability of our fisheries requires better management of land-based activities. This currently

falls outside the realm of fisheries management but highlights the need for an integrated approach to both monitoring and management.

DISEASES AND INVASIVE SPECIES THREATEN THE MARINE ENVIRONMENT

Invasive species are widely recognised as one of the greatest threats to marine biodiversity, having already transformed many marine habitats around the world. The most harmful of these displace native species, change ecosystem structure and food webs, and alter fundamental processes, such as nutrient cycling and sedimentation, all of which can trigger a loss of ecosystem services. Increasing pathogens and invasive species will make marine ecosystems less resilient to other stressors and the establishment of invasive species and introduction of disease could have major consequences for the commercial fishing industry. Actions to reduce the risk from invasive species and diseases will be important to maintain a sustainable commercial catch.

The establishment of invasive species and introduction of disease could have major consequences for the commercial fishing industry.

PLASTIC POLLUTION IS BUILDING IN THE OCEAN

Most plastic that enters the environment ultimately ends up in the ocean. Of the 86 million tonnes of plastic thought to be in oceans worldwide, it is estimated that 80% came from land and the remaining 20% from activities at sea – with commercial fisheries being a large contributor. Plastic is known to impact commercial fisheries stocks or the ecosystems that they rely on through physical harm (e.g. entanglement) or through other physiological impacts that occur after ingestion. Plastic in the marine environment may also help spread pathogens and invasive species. The plastic pollution crisis has a significant negative impact on the marine environment and the organisms within it, so poses a direct risk to the sustainability of our fisheries. The cumulative effects of plastic causing physical or physiological harm to species, disruptions to ecosystems and habitats, and introducing invasive species to new environments, will have negative impacts on our commercial fish species and the ecosystems that they rely on.

Figure 8: Ghost gear and other waste made of plastic and other materials washed ashore on Te Hauturu-o-Toi Little Barrier Island. Image credit: Simon Thrush.

The plastic pollution crisis has a significant negative impact on the marine environment and the organisms within it, so poses a direct risk to the sustainability of our fisheries.

CUMULATIVE EFFECTS MEAN THE STRESSES COMPOUND

Species' responses to different stressors can be non-linear and can cause cascading effects within an ecosystem. Understanding cumulative impacts is key to predicting and preventing irreversible tipping points. Aotearoa New Zealand's coastal and marine systems are vulnerable to rapid changes or tipping points because our disconnected management frameworks currently do not take an approach focused on cumulative effects. Taking a cumulative effects approach acknowledges that commercial fishing isn't the only stressor on an ecosystem,

while also recognising that a more precautionary catch limit may be necessary because of reduced resilience in that system caused by multiple stressors.

Aotearoa New Zealand's coastal and marine systems are vulnerable to rapid changes or tipping points because our disconnected management frameworks currently do not take an approach focused on cumulative effects.

The activities that affect the marine environment are multifaceted and varied. Their consequences are too. This makes it complex to study and model the outcomes. Multiple methods to assess cumulative pressures and impacts exist, but each are limited in some way. Mapping methods can reveal what species overlap with stressors, but this relies on assumptions about impacts being direct and additive. Experimental methods can delve into how different stressors interact – whether additive, indirect or cascading – but applying this to a large number at once is not feasible. Advances in systems thinking, methodological improvements, increasing access to big data, and integration of assessments into legislation and regulations are making the study and application of cumulative effects modelling more feasible.

We first need to overcome some practical obstacles in order to implement cumulative effects assessments more widely. Gaps in ecosystems and species data, or inaccessibility of data, will hinder meaningful interventions. We will never gather all the data needed to fully understand the cumulative impacts of stressors. A more realistic objective is to have sufficient information to allow more balanced decisions under unavoidable uncertainty. Use of more consistent definitions and methods will also help to standardise processes and facilitate comparisons across systems and studies.

We will never gather all the data needed to fully understand the cumulative impacts of stressors. A more realistic objective is to have sufficient information to allow more balanced decisions under unavoidable uncertainty.

A HOLISTIC APPROACH IS NEEDED

All of these stressors provide challenges for commercial fishers, who may need to harvest sustainably in a contaminated (and stressed) environment. Looking at issues in isolation fails to appreciate that these stressors can overlap in space and time and that a single activity can generate multiple pressures.

A move away from siloed approaches to more collaborative and connected structures that take a holistic approach to ocean management is needed, with fisheries management forming one part of a larger plan. Whether a particular fishery can cope with losing a proportion of its population each year depends on more than the amount taken. The fishery may be under stress from sedimentation occurring in the nursery ground and destroying the juvenile habitat, or may have to adapt to changing environmental conditions that reduce food availability. Neglecting to consider the wider pressure on the ecosystem may increase the risk of collapse because the population may be less resilient. On the flip side, acting on these stressors in a holistic way provides significant opportunities for future sustainable use of the ocean resources. Certainty that fishing will continue is also important for the wellbeing of fishers. Ultimately, even though it is complex and difficult to implement cumulative impacts assessments, fisheries management cannot afford not to do this.

Acting on these stressors in a holistic way provides significant opportunities for future sustainable use of the ocean resources.

The *Sea Change – Tai Timu Tai Pari* marine spatial plan is an example of how to integrate a range of stressors into a plan for managing the marine environment. That this is yet to be implemented illustrates the challenges in putting such plans into action.

Integrated management is necessary to maintain the health of the marine environment. There is enormous potential to draw on mātauranga Māori and foster kaitiakitanga to enhance the understanding of ecosystems and how to manage multiple stressors in a holistic and integrated way. Mitigation efforts and innovative ideas, if implemented in an appropriate and timely way, can help to curb the stresses on the marine environment. For example, the High Level Panel for a Sustainable Ocean Economy[7] estimated that ocean-based options might deliver up to one-fifth of the total emissions reductions required to limit warming to 1.5°C by 2050.

While detailed analysis and recommendations of the non-fishing stressors are out of scope, the need to take a holistic approach factoring in cumulative effects informs our recommendations in Theme 3.

The following sections of the full report expand on these issues:

- 2.5.4: The wellbeing of our fishers matters
- 3.1: Fishing is one of many stressors on our oceans
- 3.3: Fishing effort has wider ecosystem impacts
- 3.3.5: Case study: Managing land-based impacts through a multi-sector marine spatial plan

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Figure 9: Effective management of fisheries and the ocean requires consideration of cumulative impacts: from the land to the sea, *ki uta ki tai*.

[7] The Ocean Panel included members from 14 nations and developed a set of recommendations and actions to advance a sustainable ocean economy, see: https://www.oceanpanel.org/. Note, Aotearoa New Zealand was not a member.

THEME 3 RECOMMENDATIONS: TE AO MĀORI | A CONNECTED WORLDVIEW IN 2040 AND BEYOND

Recommendations	Considerations
3. Building on the other Themes, acknowledge that successful application of an ecosystem approach to fisheries management must take a holistic, long-term approach that considers future generations. a. Explicitly address cumulative effects and the interconnected nature of ecosystems and mitigate other stressors on fisheries, beyond commercial fishing including: i. Land-based impacts, especially sediment from forestry and land-use changes ii. Climate change iii. Plastics iv. Disease and invasive species v. Recreational fishing vi. Aquaculture vii. Population pressure and growing population viii. Mining and the energy sector.	• Support the wellbeing of the people who fish to ensure a sustainable workforce. • Consider using existing concepts to embed te ao Māori within policy, including '*He Awa Whiria*', building on the work undertaken in developing *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020* (Department of Conservation), and *Vision Mātauranga* (Ministry of Business, Innovation and Employment). • Develop principles for assessing and responding to cumulative effects in Aotearoa New Zealand, with flexibility for local application e.g. Hauraki Gulf Forum. • Analyse existing methods, tools and data to identify and assess cumulative effects. • Foster connections between high-tech tools and community knowledge. • Support regional plans combining land-based, coastal, marine and other impacts, to reflect the 'transboundary' nature of issues (see Theme 2). • Increase responsiveness within the Fisheries Act 1996 and related policies to climate change impacts on distribution and movement of species within and outside of the EEZ (see Theme 4). • Consider research and incentives into reducing the carbon footprint of the fishing fleet (see Theme 7). • Marine Protection Area strategy and planning could create a framework that gives consideration to stock resilience against the impacts of climate change and provide policy that is flexible enough to account for movement of species distribution due to climate change, where this is relevant (see Theme 2). • Undertake analyses to model the economic, socioeconomic and environmental benefits of changing to more sustainable plastic use in the fisheries sector. • Facilitate an active dialogue around rethinking plastics and other waste by setting targets and identifying opportunities to keep materials in circulation or shift to more sustainable alternatives with the fisheries sector. • Align with the Parliamentary Commissioner for the Environment's recommendation in *Managing our Estuaries* to manage estuaries as a single entity from the mountains to the sea.

THEME 4: A REFINED SET OF REGULATORY TOOLS

A RANGE OF TOOLS IS AVAILABLE

Fisheries New Zealand is the key regulator tasked with guiding the sustainable use of fisheries resources to the greatest overall benefit to New Zealanders. They do so under the Fisheries Act 1996. This focus includes the sustainability of Aotearoa New Zealand's wild fish stocks, marine biodiversity, and the wider aquatic environment.

A central and significant part of fisheries management is the QMS, but this is only one element of the overall approach that Aotearoa New Zealand takes to managing fisheries. The key parts of this system include:

- **Setting catch limits and allocating catch allowance:** A high-level decision is first made between conservation and extractive use (this is the total allowable catch or TAC), and then the extractive use is divided between commercial, customary and recreational sectors. Within the commercial sector, the QMS allocates shares in each fish stock as quota. Quota generates an entitlement to catch a proportion of the total allowable commercial catch (TACC) each year (annual catch entitlement or ACE) within the relevant quota management area (QMA). The Minister for Oceans and Fisheries sets the TAC, guided by the *Harvest Strategy Standard*. A summary of the process is shown in figure 10.

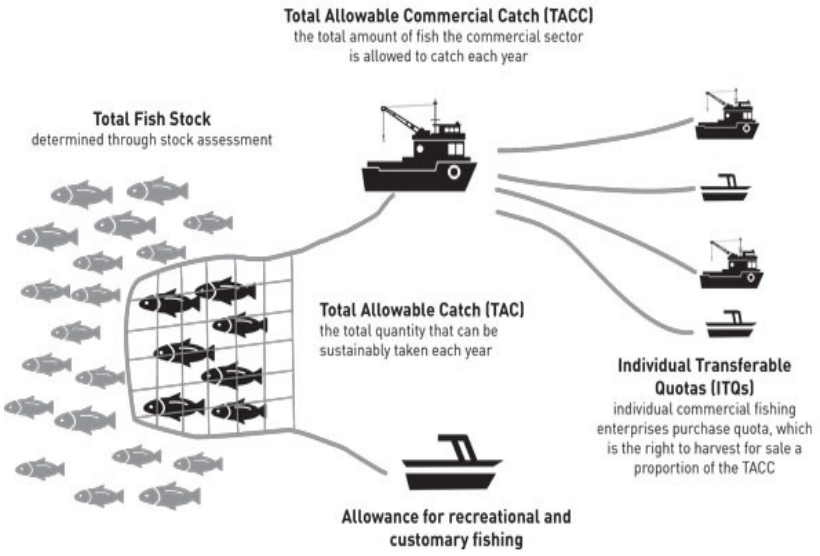


Figure 10: Summary of catch allocation. Image credit: Fisheries New Zealand.

- **Environmental principles:** These are present within the Fisheries Act 1996 and could be more widely implemented. Opportunities to do so are discussed further in Theme 6.
- **Integrated fisheries plans:** Fisheries plans are a tool used to bridge the different pieces of legislation, policies, strategies, and regulating authorities to guide action at a more refined scale and measure progress. They are provided for under Section 11(a) of the Fisheries Act 1996 and can enable stakeholder-led management (where a plan is approved by the Minister of Fisheries). Fisheries plans provide overarching frameworks (over a five-year timeline), from which (non-statutory) Annual Operational Plans are developed and Annual Review Reports produced. The limitations of the plans developed to date were discussed in Theme 2.
- **Targeted management of fisheries through action plans or strategies:** Fisheries New Zealand works in collaboration with others to develop management plans to provide targeted support to fisheries that are not meeting sustainability expectations and need closer management or to outline management frameworks for protected species impacted by fisheries.

- **Managing impacts on marine species through management plans:** Fisheries New Zealand works in collaboration with others to develop management plans or strategies to provide targeted support to provide protection for species impacted by fishing.

THERE ARE SIGNIFICANT CHALLENGES FOR THE REGULATOR OF FISHERIES

LIMITED DATA AND SIGNIFICANT KNOWLEDGE GAPS FORCE DECISIONS TO BE BASED ON UNCERTAIN DATA AND INFORMATION

The framework for setting stock targets and limits is contested. The *Harvest Strategy Standard* applies to all fish under the QMS and guides the way that fish stocks are managed (illustrated in figure 11). It is how the statutory requirements for stock sustainability, provided in Section 13 of the Fisheries Act 1996, are implemented in practice (but does not itself have statutory recognition). Stock management decisions are required to be made on the best available information and consider any uncertainty in available information, in accordance with the information principles required by Section 10 of the Fisheries Act 1996. The *Harvest Strategy Standard* states that stock targets and limits should be set more conservatively for stocks where information is sparse or uncertainty is higher. Not all stocks have had a target set and the key aspects of the standard are all contested.

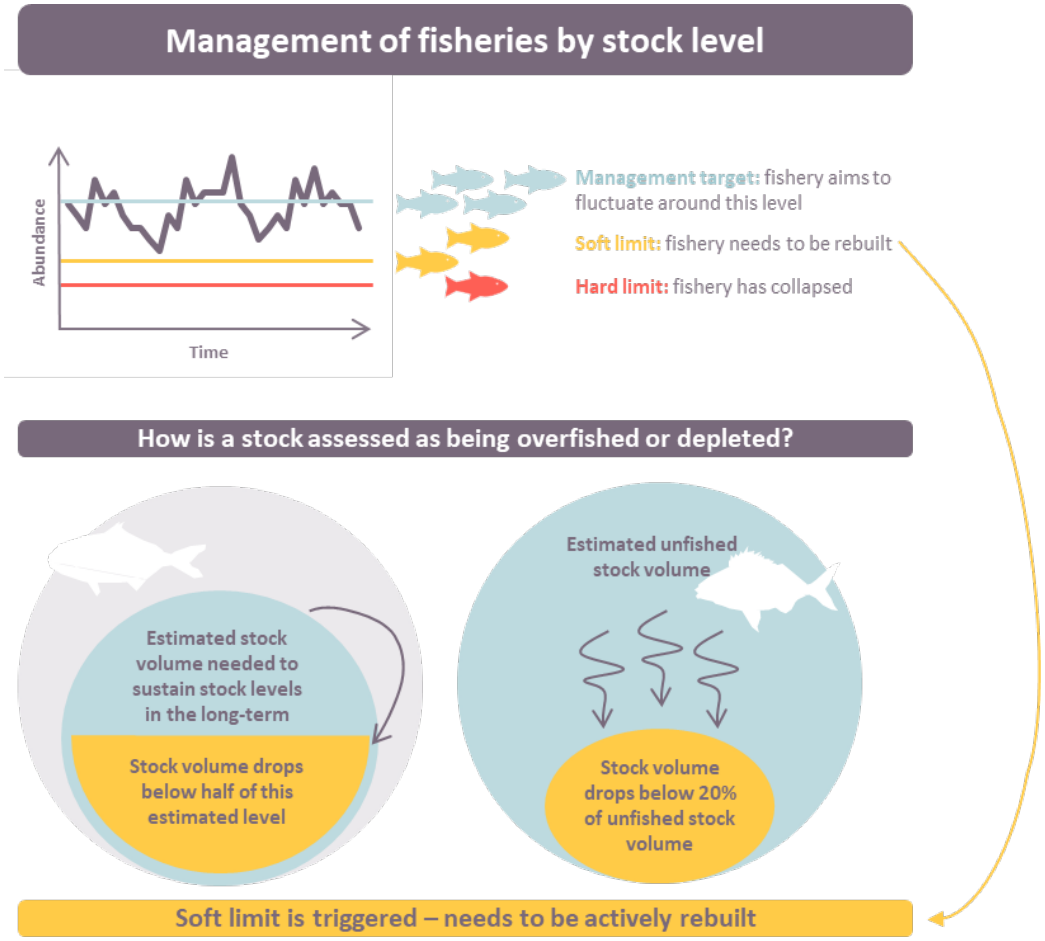


Figure 11: Summary of how fish stocks are managed based on the *Harvest Strategy Standard*. Note these are the default proportions and may vary by stock.

Once targets and limits are set, assessing the stock relies on science that is inexact and uncertain. The stock assessment process is not uniform across each stock – the availability of data is highly variable and the approaches used also differ. All of the key inputs for stock assessment are hard to measure and understand, which underpins both how challenging the fisheries management field is, and how much it is challenged.

- **How many individual fish there are currently in each stock is uncertain.** It is extremely difficult to gain accurate measurements of the total number of fish in each stock to determine current biomass. This means that proxy measurements must be used, such as catch per unit effort (CPUE), and these are often contested. Measuring effort is not straightforward and so the CPUE may not reliably reflect abundance (see spotlight on CPUE, page 34). The relationship between CPUE and abundance is difficult to validate because of the difficulty of collecting consistent catch and effort data over a long enough period to compare CPUE. There appears to be consensus that in many situations CPUE data may not accurately represent stock abundance, but if appropriately measured it can be a useful input into understanding abundance trends in a given fishery, in the absence of alternative measures. The credibility of CPUE indices varies greatly between stocks. It is therefore crucial that stock assessment working groups operate in a way that builds trust in the independent scientific assessment process.
- **How many fish there would be if none had been harvested is uncertain.** The calculation of original biomass is incredibly important because it is against this calculation that sustainability is measured. A variety of models can be used, depending on the available data. Uncertainty lies in both the underlying data and in the complex modelling approaches available. Different models with different methods and different assumptions may produce significantly different estimates of biomass, with high uncertainty. This presents a management challenge as it can lead to dissent, especially if the margin of error straddles the soft or hard limits.
- **The portion of the current stock that can be sustainably harvested is uncertain.** Maximum sustainable yield (MSY)[8] is defined as the greatest yield that can be achieved over time while maintaining the stock's productive capacity. MSY is related to several contested parameters described above, specifically original biomass, current biomass, and how soft and hard limits are calculated. The inexact and uncertain nature of these inputs therefore limits the certainty relating to MSY.
- **The degree of damage removal of these species does to the wider ecosystem is uncertain:** see Theme 6.

All of the key inputs for stock assessment are hard to measure and understand, which underpins both how challenging the fisheries management field is, and how much it is challenged.

There is dissent about the state of rock lobster stock CRA2. According to the official stock assessment, CRA2 is 'virtually certain' to be experiencing overfishing but 'very unlikely' to be below the hard limit, whereas the New Zealand Marine Sciences Society describes it as 'functionally extinct' and their estimates suggest it may be below the hard limit. This is discussed in case study 5.3.5 in the full report.

[8] See figure 61 in the full report.

Many stocks are not assessed due to limited data. There are numerous stocks that are not assessed due to a paucity of data – half of our stocks have too little information to be scientifically assessed. When stocks are not assessed, it is not possible to comment on their sustainability under our fisheries management regime. Of the stocks that are assessed, the time since last assessment also varies widely. While many have been completed in the last few years, others have not been assessed in over ten years. Aside from almost 300 'nominal' stocks, around one third of the commercial catch volume is made up of stocks that have never been assessed (see figure 12). Where further information is not available on a stock to either validate or refute assumptions relating to biomass, it leaves high uncertainty around the size of the stock and the level of impact that commercial fisheries may or may not be having.

Around one third of the commercial catch volume is made up of stocks that have never been assessed.

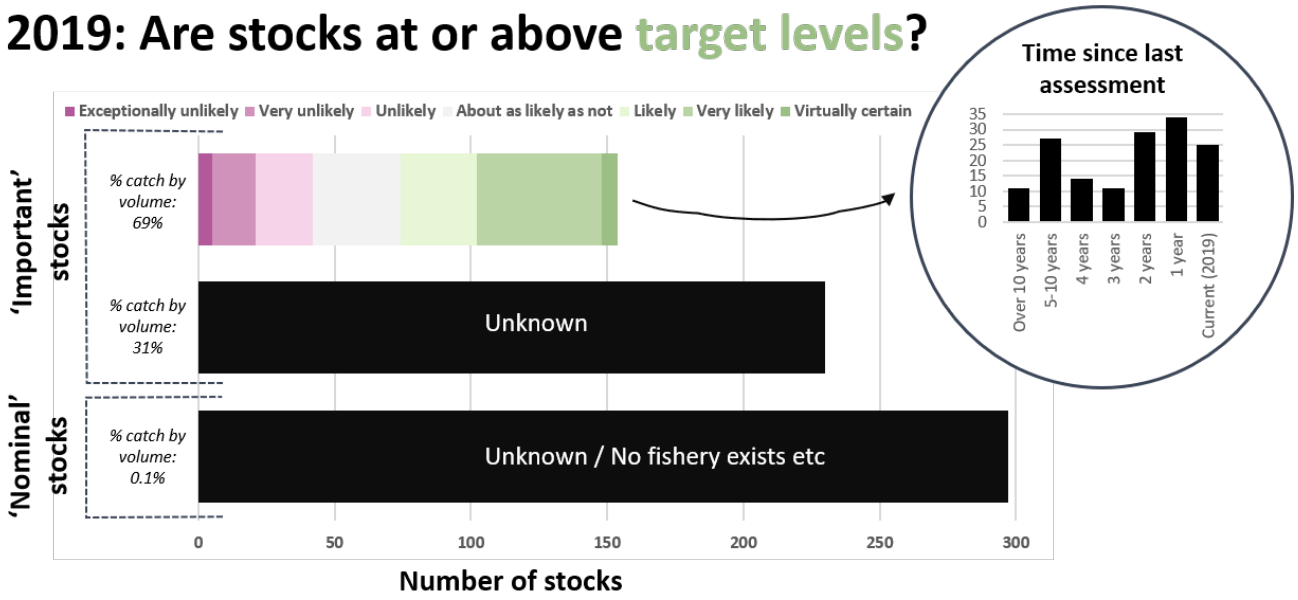


Figure 12: The status of fish stocks relative to the target level as reported by Fisheries New Zealand in 2020.

Spotlight on factors that impact the calculation of CPUE

- **Catch equipment used.** E.g. cod-end size and length, door spread and length of sweeping gear.
- **Experience and skill.** E.g. an experienced skipper may be able to more easily locate and catch fish than a newer skipper.
- **Practices used.** E.g. vessel speed: a net that is trawled more slowly will typically catch fewer snapper.
- **Locations fished.** E.g. seamounts and spawning aggregations can have dense aggregations of orange roughy.
- **Water temperature.** E.g. warmer surface waters may lead to deep-diving species like bigeye tuna avoiding gear, or species moving elsewhere.
- **Changes in weather.** E.g. an increase in storms and waves (and consequently water turbidity) can reduce hook and line catch rates.
- **Market.** E.g. the desire to avoid paying deemed values may lead to avoidance of some species (e.g. snapper) to minimise high deemed value payments.
- **Behaviour of the target species.** E.g. moulting and reproductive behaviour of scampi varies between the sexes and seasonally, impacting catch rates; aggressive species can be easier to trap as they tend to guard bait, increasing catch rates.
- **Interrelated fisheries.** E.g. fishers may change their fishing location to a less optimal area if a protected species would otherwise be present where the fish were greatly abundant. In practice this would decrease CPUE and indicate a lower abundance of fish, instead of reflecting fishers' behaviour in avoiding areas of greatest abundance.

Improvement in data collected on fishing gear and fishers experience could include information on areas such as door spread, ground gear rope length, sweep and bridle lengths, cod-end mesh size and orientation, and number of years a skipper has been involved in the fishery.

Incorporating these variables into CPUE models will make estimates of abundance more robust.

LIMITED RESPONSIVENESS OF THE SYSTEM TO CHANGES

In 2019, there were 160 stocks that were scientifically evaluated and 228 stocks (and almost 300 nominal stocks)[9] that were not assessed (see figure 13). In the same year, catch limits were adjusted for 29 stocks, which sits around the current capacity Fisheries New Zealand has to adjust catch limits each year of 30 to 40 stocks. Where changes to regulation are required, it can take far longer for adjustments to be implemented.

Too few stocks are assessed annually and many assessments should occur earlier than they do. The limited stock assessments and limited capacity to adjust catch limits are likely contributing to the collapse and overfishing of stocks that are evident in annual reporting. In 2020, nine stocks were reported as 'collapsed',[10] five stocks were virtually certain to be experiencing overfishing[11] and two stocks were very likely to be experiencing overfishing.[12]

[9] Nominal stocks are stocks that represent less than 1% of catch.
[10] Black cardinalfish/akiwa – CDL2, CDL3, CDL4; orange roughy – ORH7B West Coast South Island; pipi – PPI1A - Mair Bank, Whangārei harbour; scallop – SCA7 Golden Bay, SCA7 Tasman Bay; Southern bluefin tuna – STN1 Southern Hemisphere Stock; Pacific bluefin tuna – TOR1.
[11] Tarakihi – TAR1E, TAR2&TAR7 (east CS), TAR3; rock lobster – CRA2 Bay of Plenty.
[12] Pacific bluefin tuna (highly migratory species) – TOR1; Pāua – PAU7.

Another fundamental challenge of fisheries management that requires a responsive regulatory approach is bycatch. There is huge variation in the amount of bycatch according to the species targeted and the method used. For example, pāua is caught selectively through diving and has no bycatch, whereas scampi has up to 80% bycatch. The current rules that set out what commercial fish must be landed and returned are complex, open to interpretation, difficult to comply with and monitor, and do not always set adequate incentives.[13] Generally, fish that are managed under the QMS must not be discarded – but where bycatch forms a significant proportion of the catch it is difficult to manage discarding simply. Where the deemed value[14] is high, this can create an incentive to discard catch illegally to avoid these fees and is reportedly common in some fisheries. Although policy changes are currently underway, there is likely further work needed to reduce perverse incentives to discard illegally.

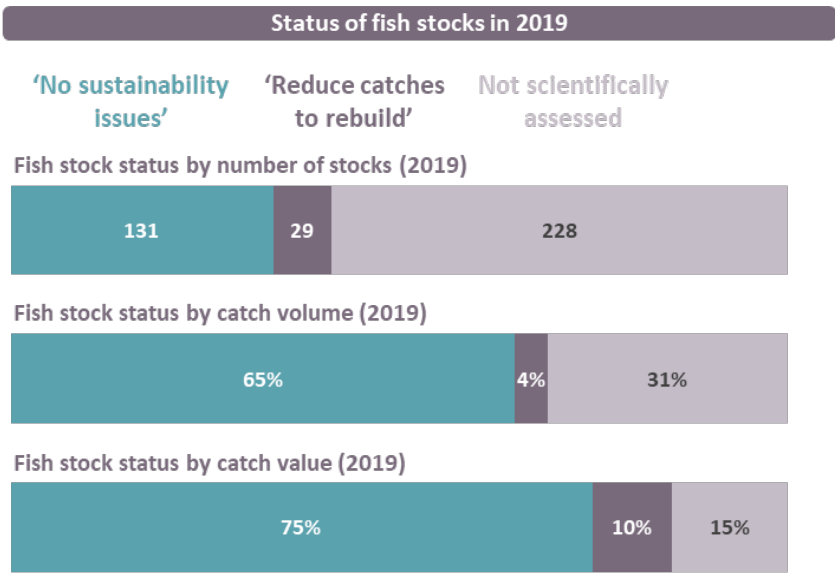


Figure 13: Fish stock status in 2019. Data from Fisheries New Zealand.

The mismatch in management scales between regional councils (limited to territorial sea within their region) and the QMAs (which may cross many regions and cover both the territorial sea and EEZ) can also create challenges in managing stocks at the appropriate scale.

THERE ARE OPPORTUNITIES TO REFINE THE REGULATION OF FISHERIES

INCREASED TRANSPARENCY AND ACCESSIBILITY

During this project, we heard calls for increased transparency around the stock assessment process and how decisions are made. Given the limited data for a significant number of fished stocks, and the lack of assessment for even more, it is crucial that how allowable catch is decided is clear. Providing accessible information around the assumptions made and knowledge gaps during decision making may drive the necessary research to enable better informed stock assessments and ensure stocks are being fished at a sustainable level. Increased transparency and accessibility will increase trust in the decision-making processes. This could help transition to a place where there is high trust that our fisheries are being sustainably managed in the context of their ecosystems.

Regulations and management decisions can also play a role in facilitating innovation and bringing good ideas to the fore so that they can be implemented as best practice across the industry. Clarity around high-level regulatory direction will provide reassurance to industry.

Despite the challenges, there are many opportunities to increase data, synthesise what we know, improve knowledge that could strengthen more reliable assessment of stocks, and make these assessments and their

[13] https://www.fisheries.govt.nz/dmsdocument/32761-your-fisheries-your-say-consultation-document-february-2019
[14] Commercial fishers who catch more fish than their ACE may be charged the 'deemed value' of the extra catch (if they cannot buy more ACE to cover it). The deemed value is calculated using a rate set by Fisheries New Zealand for each fish stock in the QMS and the deemed value is higher than the cost of buying ACE, to discourage intentionally fishing outside catch entitlements.

uncertainties more widely accessible. There is a wealth of data for both single-species assessment and ecosystem monitoring that could be more routinely used for stock assessment. Anecdotally, useful data that could be used in stock assessments is not accessed because it sits outside of the formal research system that feeds into these assessments. Clarity on the form in which this data needs to be presented to inform management decisions would be useful to researchers. While researchers who sit outside of the formal system are reportedly frequently invited to Science Working Group meetings and may also present at these, there seems to be a disconnect in how inclusive participants perceive this process to be.

There are many opportunities to increase data, synthesise what we know, improve knowledge that could strengthen more reliable assessment of stocks, and make these assessments and their uncertainties more widely accessible.

There can be disagreement between conclusions reached by the regulator compared to research undertaken by other researchers, given the data available to each differs. With different methods, models and assumptions used, and high uncertainties, estimates will differ. Where the regulator has less information about a stock or species, consideration of fisheries-independent research would be particularly valuable.

Fisheries New Zealand acknowledges issues in this area and is working to make information more accessible (e.g. by including summary tables at the end and start of chapters of the comprehensive Fisheries Assessment Plenary documents and the AEBAR reports and developing webpages) but this work in in its early stages.

Transparency and accessibility of the data used in fisheries management is vital to the scientific scrutiny of the management decisions. Improved transparency around data and uncertainty in decision-making processes will also build confidence in the system.

A MORE RESPONSIVE SYSTEM

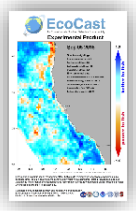
Changes in our fisheries require management that is flexible and adaptable to changing situations at pace. It is essential that Aotearoa New Zealand's fisheries management system accelerates rather than encumbers adaptation to a changing environment.

- **Changing fisheries demand nimble and responsive decision making.** The recent shift within the fisheries management system to use digital technology for electronic monitoring has enormous potential and provides a strong foundation on which to build a more responsive system. A key strength is that the timeliness, quality and reliability of commercially reported data has improved and is verifiable (if there are observers or cameras), which will support better and more nimble decision making by the regulator. As well as improving efficiencies and compliance, electronic reporting will drive improvement in stock assessment and sustainability, and environmental performance and outcomes. It also increases the potential of providing traceability information to consumers e.g. through labels.
- **Adapting to the appropriate management scale is important.** Information and knowledge from a range of different sources could be drawn on to trigger a stock assessment, including locally held knowledge from fishers and the mātauranga held by local iwi. Combining place-based evidence at an appropriate scale with a management framework that is agile and responsive will help to provide optimum management for each unique scenario.
- **Data-driven knowledge is the cornerstone of effective and sustainable fisheries management.** Improving how we collect, curate, use and share fisheries and marine science data is crucial to advance Aotearoa New Zealand's fisheries management system and enable research to answer critical questions in the marine environment. Both the regulator and industry need extensive data and information about fisheries changes to inform faster and more effective decision making (see Theme 5). For example, the

wealth of data from electronic reporting could allow the regulator to adjust deemed values at shorter time intervals based on on-the-ground experiences.

- **Artificial intelligence (AI) and machine learning have the potential to increase efficiencies.** Our ability to analyse data has not kept pace with the data collection explosion, resulting in an 'analysis bottleneck'. AI and machine learning can widen the analysis bottleneck and accelerate the shift to responsive data-driven fisheries management. For example, feasibility studies have shown there is significant potential for automating age estimation from otolith images using machine learning. However, most AI-related fisheries projects – both in Aotearoa New Zealand and overseas – are still at the proof-of-concept stage. The hurdles that are currently limiting implementation to small research projects and pilots include: transparency and privacy issues, the need to retain human touchpoints and build trust, cost and funding, the right data being available and useable (i.e. with labelling and metadata), the need for image libraries, data storage issues, limited AI expertise, and the risk of perpetuating biases.
- **Dynamic ocean management will help protect non-target species in real time.** The ocean is not a static environment so effective fisheries management needs to be fluid in space and time to respond to the changing locations of marine species and its users. A number of tools can help to monitor the patterns of movement of protected species to first predict, but ideally inform in real time, the areas to avoid while fishing. Methods and tools such as electronic monitoring, modelling, AI, genetic and acoustic technologies, and unmanned or autonomous vehicles (UAVs) can be drawn on to inform dynamic ocean management to protect non-target and threatened species. The challenge lies in rapidly collecting and pulling relevant data together to inform decisions.

EcoCast is an app for fishers that acts much like a weather forecast – it takes an array of live ocean conditions and known species distribution patterns for target and bycatch-sensitive species into account to generate a fluid map to guide fishing efforts. The app is now used to allow fishers exemptions to fish in certain marine protected areas in California. This is discussed in case study 6.5.6 in the full report.



The following sections of the full report expand on these issues:

- 5.2: Fisheries management involves the use of many different tools
- 5.3: Commercial fishing has impacts on target species sustainability
- 5.5: Regulator initiatives and data transformation
- 6.2: How we respond to changing fisheries
- 6.5.5: Dynamic ocean management will help protect non-target species in real time
- 6.7.5: Improving traceability to add a premium to products

THEME 4 RECOMMENDATIONS: A REFINED SET OF REGULATORY TOOLS

Recommendations	Considerations
4. Refine the regulatory framework for fisheries management to support more responsive and transparent decision making to improve fisheries and environmental outcomes. a. Improve the processes for input and engagement in fisheries management, particularly in regards to undertaking effective iwi and stakeholder engagement, public involvement, and adequate checks and balances. b. Improve transparency through increasing the accessibility of information used to inform decision making, including data collected by and for the regulator (see Theme 5). c. Enable the increased use of observational and localised community knowledge, mātauranga Māori and fishers' observations in regulatory decision making, ensuring there are appropriate processes to corroborate and validate data (see Theme 5). d. Develop a mechanism to ensure that all relevant research is incorporated into regulatory decision making (see Theme 5). e. Include a step within formal decision-making processes that ground truths quantitative modelling results against real-world observations as far as practicable. f. Support operationalisation of an ecosystem approach to fisheries management to improve environmental outcomes by utilising data from existing electronic collections and expanding data collection where practicable (see Themes 5, 6). g. Empower fishers to innovate to enable them to improve environmental outcomes (see Theme 7). h. Continue to update the process behind setting and updating the deemed value of species within the Quota Management System to make it more responsive to short-term changes in species abundance and distribution, to avoid either perverse incentives to discard catch or incentives to catch in spite of penalties. i. Develop a dashboard to present the Fisheries New Zealand Stock Assessment Plenary Annual Report and Aquatic Environment and Biodiversity Annual Review information to more clearly showcase new data and knowledge and important data and knowledge gaps. j. Support development of mechanisms to increase consumers' ability to access traceability information on fish and fish products.	• The regulatory framework could be aligned to ensure that it is fit-for-purpose to enact the Oceans Strategic Action Plan and to provide legislative backing to policy on managing the environmental impacts of fishing (see Theme 2). • Consider a 'traffic light' approach that could provide a transparent way to prioritise assessment of stocks (see Theme 7.a.iv). • Ensure Fisheries Assessment Working Groups have an inclusive culture and processes. • Improve transparency around the Fisheries Assessment Working Groups and what data is considered in their assessments to build confidence in independent scientific scrutiny. • Ensure there are adequate checks and balances on the decision-making process including provision for independent review. • Decision-making processes should not allow a paucity of data to prevent active management decisions to be made, and the decision-making process in these circumstances should be transparent. • Actively seek data and information as an integral part of the stock assessment process, including from fishers and non-Fisheries New Zealand funded scientists (see Theme 5). • Review labelling requirements for fish and fish products in relation to increasing transparency to inform consumer choice.

THEME 5: A DATA PLATFORM THAT ENABLES INFORMED COMMERCIAL AND ENVIRONMENTAL DECISION MAKING

DATA IS LIMITED, HARD TO GET, AND NOT FULLY UTILISED

THERE IS LIMITED DATA AND AVAILABLE DATA HAS LIMITATIONS

There are many gaps in data and information relating to fisheries management. Here we highlight a few select examples to demonstrate the issue.

- **Information to manage stocks.** For example, stock structure understanding is vital for assessing the sustainability of a fishery, but how stocks are defined and managed by the regulator may not always reflect natural fish stock delineation, especially with stock movement due to climate change. In Aotearoa New Zealand, fish stocks are allocated spatially to QMAs under the QMS and may not necessarily align with the natural boundaries of fish populations. More research to determine the relationship between genetically distinct populations and formal management stocks is required for many species. For example, there are currently discrepancies for hoki stock HOK1, which is comprised of two sub-stocks. Stock estimates predict high biomass but this doesn't match fisher experience of declining catch rates. These discrepancies may be arising because of uncertainty in the modelling assumptions due to knowledge gaps about how the sub-stocks' movements overlap in time and space.
- Most **ecological risk assessments** undertaken for Aotearoa New Zealand fisheries have been qualitative or semi-quantitative, which points to a lack of comprehensive or in-depth data being available, though this has been improving in more recent assessments.
- **Information on habitats.** There is a lack of understanding of resilience and recovery dynamics of deep-sea and coastal habitats impacted by benthic trawling. Little is known about how the functioning of our ecosystems is impacted by changes to seabed habitats, including productivity on continental shelves and benthic habitats of significance. There are extensive and significant data gaps on where biogenic habitats occur. While there are national databases for two types of biogenic habitat (seagrass and mangroves), there are another 13 habitats for which this national inventory is missing.
- **Bycatch and discards data** currently relies on observer coverage and may sometimes assume there is no difference in fishing practices between observed and unobserved fishing trips. Observed bycatch is consistently much greater than that self-reported by fishers, which needs to be accounted for when interpreting bycatch data. Digital monitoring is expected to substantively change how fisheries are monitored in Aotearoa New Zealand. Cameras can supplement observer monitoring by providing an alternative method of independent oversight (particularly when combined with electronic catch and position reporting). Long-term datasets on bycatch species, outside of landings, is an area that could be improved for many species and locations. Non-target fish species are less studied in general, so non-

Figure 14: Mixed species bycatch from a deepwater trawl. Image credit: MPI/NIWA.

direct impacts on stocks and sustainability are also not well understood. Discard data will also be improved through electronic reporting.

- **Information about how climate changes in the ocean influence fisheries.** There is very limited explicit data on these changes that can inform fisheries management decisions beyond the information already captured for stock assessments.
- At the global level, many of the benefits of an **ocean observing system** cannot yet be directly applied to fisheries management because data isn't localised enough, though there are wider benefits – for example, improving early warnings of severe weather events like floods, droughts and storms.

DATA ACCESS IS AN ISSUE

There are calls to improve accessibility of datasets held by Fisheries New Zealand, which would facilitate greater analysis of this data. Access to Fisheries New Zealand data is not an issue for those directly involved in the regulatory process of fisheries management, but this is not always the case for others, such as industry and researchers. Official Information Act (OIA) requests are sometimes needed to access data held by Fisheries New Zealand. This process does not foster trust or collaboration.

When data is held in multiple databases there are lost opportunities for combining and overlaying different datasets to identify patterns and trends. Marine data in Aotearoa New Zealand is siloed and fragmented, and hundreds of databases exist. There are many players in the marine data space, meaning that the best available knowledge on a particular issue is not necessarily held by the regulator. Relevant data may be held by other central government agencies, industry, research institutes, or local and regional councils.

Marine data in Aotearoa New Zealand is siloed and fragmented, and hundreds of databases exist.

Fisheries New Zealand makes some databases accessible through a contract with Dragonfly,[15] e.g. for seabird, marine mammal and turtle bycatch, and FishServe.[16] There is also limited data sharing through data.govt.nz and the Ministry for Primary Industries Open Data Portal. There is significant room to improve data access so that more research and analysis can be undertaken to inform fisheries management.

DATA IS NOT FULLY UTILISED

Some research is known about but is not incorporated into fisheries decision making. Research undertaken at universities and research institutes, and the knowledge housed within these places, may be relevant to fisheries management decisions but is not always designed to feed into the decision-making process. The motivations for the studies are not necessarily directly aligned with fisheries management needs or the format required for the data to be useful to the regulator is not clear to researchers. In particular, there are lost opportunities to incorporate a wide range of research into stock assessments rather than just the research commissioned for those assessments.

Data that could feed into stock assessments includes research on fishing impacts on benthic food webs, the role of fishers in the spread of disease in fisheries, catchability and abundance, how overfishing has led to major ecological shifts in coastal ecosystems, and the impacts of fishing on biodiversity. Data on observations of non-Indigenous species is held in tertiary institutes, as well as other technological institutes, regional councils, and other research organisations. This data is valuable at a national management level, so a system that allowed it to be shared between organisations would add value. When considering data held by regional councils there are also issues of scale (given data is generally confined to smaller boundaries than used in the QMS).

[15] https://www.dragonfly.co.nz/data/
[16] https://www.fishserve.co.nz/

Fisheries New Zealand is in the process of implementing a data transformation strategy, building its capability and maximising benefits from the increased volume and diversity of fisheries data arising from new initiatives.

There are lost opportunities to incorporate a wide range of research into stock assessments rather than just the research commissioned for those assessments.

IMPROVING THE DATA SYSTEM WILL BENEFIT FISHERIES MANAGEMENT

EXPAND DATA COLLECTION, BUT ACT AHEAD OF THE PERFECT DATASET

With such a complex and inaccessible system as the ocean, action cannot wait for the perfect dataset. Lots of data needs lots of resource, so filling all of the data needs in a short timeframe is not feasible. However, we can expand data collection efforts in a strategic way to fill in the gaps in order of priority, and technological advancements provide leaps forward in this area. The High Level Panel for a Sustainable Ocean Economy cited that in 2018, new technology platforms collected more data on the oceans than had been collected during the entire 20th century.

Figure 15: Snapper, Northland. Image credit: Icolmer/iNaturalist (CC BY-NC 4.0).

Action cannot wait for the perfect dataset.

Important information required to fully understand stocks includes:

- Age/size structure of population
- Stock size, number and distribution
- Age at maturation and reproductive output
- Growth rate including regional variability
- Genetic diversity and structure
- Natural mortality
- Ecological interactions within and between species
- Fisheries mortality (landings and incidental)
- Impacts on bycatch species populations.

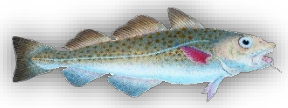
Technical and analytical advances will help stock assessments. Though the technologies themselves are not new, innovative applications, decreasing costs, and improvements in analytical capabilities will render these tools invaluable for fisheries scientists to assess the sustainability of a fishery in the years to come. As these analytical techniques become more refined and the cost declines over time they could be applied more widely.

Genetic technologies can potentially be applied to identify and assess fisheries stock structure and connectivity, resolve mixed-population fisheries, better understand population demographics and dynamics, and provide information about abundance, population biomass, and growth, as well as movement behaviour, and how these change through time (using genetic tagging of individual fish). The use of genomic technologies is not

commonplace in Aotearoa New Zealand fisheries management, but several workstreams are currently underway that will pave the way for such applications. Increasing demand for these technologies will also require more local capacity and capability. Barriers to use include the lack of genomic reference material, perception that genetic studies are expensive, lack of experience integrating genetic data into decision-making processes, invasive nature of genetic tagging, and the need to consider genetic data rights. Close collaboration between fisheries scientists and managers will be crucial for identifying the mixed stock fisheries where we should prioritise using genetic technology in active management.

The use of genomic technologies is not commonplace in Aotearoa New Zealand fisheries management, but several workstreams are currently underway that will pave the way for such applications.

A trial in Norway used a 'real-time' genetic management programme to actively manage Atlantic Cod stocks – one of which was stable and the other fragile. The researchers took samples from dead fish captured as part of the commercial catch, sent it off for sequencing and, based on the genetic markers, estimated the proportion of the stable stock – all within 24 hours. The regulatory body was able to use the findings to regulate the fishery in real time and to make longer-term decisions about where and when fishing for cod could occur to target the abundant stock and leave the fragile stock to replenish. This is discussed in case study 6.4.7 in the full report.



Acoustic technologies can be used for abundance estimates and to determine species composition and distribution. In order to broaden the application of acoustics in fisheries management some key challenges need to be addressed. An initial hurdle is classifying the acoustic properties of a species before active acoustic technology can be used to monitor or study it. This relies on studies to identify the species and its target strength.[17] This can be more difficult for some species or in particular habitats (e.g. deep water) but methods are constantly developing to improve in these two areas and validation steps are performed to ensure accurate data.

Biochemical technologies can potentially be used to delineate stocks, determine migration patterns, determine age and growth rates, and assess dietary patterns and shifts over time. Microchemical analyses are very powerful tools to use in fisheries science but they don't necessarily work every time. The extent to which various questions about a fish's environmental, ecological and life-history changes can be answered using microchemical analyses depends on the specific species, structure, and available technology. In order to apply these techniques to a species we first need a thorough understanding of its species-specific biology (e.g. details of bone remodelling and collagen turnover) and to validate the method in that species. For some species, these knowledge gaps may need to be filled before microchemical techniques can be used to their full potential and premature use of the method can result in a lack of trust in the data.

[17] Acoustic target strength is the amount of sound scattered by an individual fish and is the denominator in the equation used to estimate fish density (i.e. the total amount of sound scattering attributed to the species is divided by the target strength to calculate fish density).

Researchers used microchemistry to determine whether estuarine nursey grounds for snapper generated unique 'chemical fingerprints' and whether these could be used to match adult snapper in the open sea to their nursery ground in a west coast harbour of Aotearoa New Zealand. They found that 98% of the adult snapper were originally juveniles from Kaipara Harbour, showing clearly that ongoing and future efforts to manage this fishery and ensure sustainable stocks for years to come need to focus on keeping the Kaipara Harbour healthy. This is discussed in case study 6.4.11 in the full report.

MAKE A MORE ROBUST AND ACCESSIBLE DATA SYSTEM

The more connected the research community is, the more diverse knowledge can be shared and considered in decision making. Establishing and maintaining these connections can be achieved through multi-stakeholder and interagency networks. Well-developed networks can overcome fragmentation in the research community, and allow more proactive, flexible and collaborative approaches. Formalising collaboration can help to carve out a space for working through tensions around priorities and pace of work. Information sharing requires a strong focus on privacy and guidelines around the release of data, but with this in place, data from a range of sources could be made more accessible to improve transparency and build trust. Unless there are compelling constraints, the new default for Aotearoa New Zealand's ocean and fisheries data needs to be one of open data sharing. The data challenges for the ocean are global. Aotearoa New Zealand could lead in this space.

Aotearoa New Zealand's fisheries management system is currently on a journey towards a more high-tech system, having started to collect a lot of data electronically. Significantly more data will be generated using electronic monitoring and there are huge potential gains if its use is maximised in a timely way, but there are still obstacles to overcome such as the need for data collection standards and trust and buy-in from fishers. Improving the data system will also require:

- Large and secure data storage
- Improved analytical processes
- Effective data visualisation tools.

DRAW ON A WIDER RANGE OF DATA TO INFORM DECISION MAKING

Tackling the wealth of data that is needed to inform fisheries management can be easier if new ways of collecting data are adopted, with stringent processes embedded to ensure data meets the necessary standards. The government can also build on electronic reporting and expand use of the data for more environmental and commercial purposes.

New opportunities to collect data include:

- Drawing on mātauranga
- Engaging fishers more in data collection
- Opportunistic data collection, such as on non-fishing vessels
- Involving citizen scientists.

The real value of the data will then come from the interpretation and analyses of it, and the risk assessments and decision support tools that are driven by the data. An improved data system can help us move from data to information.

An improved data system can help us move from data to information.

Figure 16: Taruke kōura (crayfish trap), maker unknown. Taonga Māori collection, Te Papa Tongarewa Museum of New Zealand (ME003080).

The following sections of the full report expand on these issues:

- 3.3: Fishing effort has wider ecosystem impacts
- 5.3: Commercial fishing has impacts on target species sustainability
- 5.5: Regulator initiatives and data transformation
- 6.2: How we respond to changing fisheries
- 6.2.3: Case study: The Moana Project – arming vessels with sensors to help validate ocean models
- 6.2.4: Case study: Supporting the community to engage in science to protect Māui dolphins
- 6.4: How much we fish
- 6.6: How we ensure a healthy ocean

THEME 5 RECOMMENDATIONS: A DATA PLATFORM THAT ENABLES INFORMED COMMERCIAL AND ENVIRONMENTAL DECISION MAKING

Recommendations	Considerations
5. Cultivate a data platform that facilitates integration of data from a range of sources, compiles datasets in an accessible centralised platform, and turns them into information that can be readily applied in fisheries management and other areas of the marine domain, including state-of-the-art environmental reporting (see Theme 2). *Specific to commercial fisheries:* a. Work across government and with stakeholders to develop common data standards for the centralised data platform and reporting of ocean-related data and open data agreements. b. Aggregate existing datasets from within and outside government, determine data gaps, and provide detailed prioritisation of efforts to fill gaps for: i. Fish stocks (number of stocks and frequency of assessment) ii. Habitat, especially the seafloor iii. Biodiversity iv. Marine invasive species v. Protected marine species vi. Sedimentation vii. Ocean climate and acidification viii. Litter. c. Link and integrate relevant fisheries datasets to enable timelier, spatially explicit analysis of fisheries interactions with protected species. This will include linking and integrating fishers' electronic reporting with the protected species bycatch data from observers (data about seabird, marine mammal, shark, coral bycatch). d. Enable more timely monitoring and risk assessment of protected species bycatch by ensuring bycatch data flows into quantitative risk assessment models, so that managers can see bycatch hotspots and monitor impact on priority protected species in close to real time (see Theme 6). e. Engage with industry for the purposes of establishing an industry-wide agreement around sharing non-sensitive aggregated data with regulators, e.g. seafloor mapping (see Theme 6). Enable open and proactive use. f. Collaborate with and enable industry and others to fill data gaps where appropriate (see Theme 7). g. Increase opportunistic collection of data, e.g. through fishers, citizen science and ships of opportunity (see Theme 7.g). h. Include data, research and local knowledge gathered outside the formal government process in the centralised data platform, including from: i. Local and regional councils	• Align process with *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020* objective 4.2 'National, agreed common data standards and open data agreements are ensuring that everyone has access to a federated repository of biodiversity information' (see Theme 5.a). • Align the data platform with the *Fisheries New Zealand Science and Information Data Transformation Strategy*. • Coordinate development of the data platform with Stats NZ *Data Investment Plan*. • Current ocean monitoring efforts in Aotearoa New Zealand could be built on to establish an ocean observing system (see Theme 6). • Identify lead ministries for maintaining and updating specific ocean-related databases at a national level, integrated within an ocean observing system (see Theme 6). • Transition towards an increased number of stocks being reviewed annually (see Theme 4 and Theme 5.b.i). • Consider privacy concerns; future-proofing for emerging technologies (see Theme 7); initial investment cost; the need for back-end data support; transition; funding models; the sensitivity of data on taonga species. • Consideration of data issues can build on work already undertaken by the regulator, e.g. the matrix developed at the Ministry for Primary Industries. • Consider how research data that is publicly funded (including that held by research institutes, universities and other formal institutes) may be better stored and accessed (see Theme 5.e).

ii. Research institutes, universities, other formal institutes iii. Iwi and community groups iv. Citizen science v. Video vi. Emerging technologies e.g. environmental DNA (eDNA). i. Incorporate key trends from local government reporting within annual reporting (such as the Fisheries New Zealand Stock Assessment Plenary annual report and Aquatic Environment and Biodiversity Annual Review).	

THEME 6: AN ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT (EAFM) IS EMBRACED WITHIN THE CURRENT REGULATORY FRAMEWORK, INCLUDING THE FISHERIES ACT 1996

AOTEAROA NEW ZEALAND IS YET TO FULLY EMBRACE AN EAFM

THE STOCK ASSESSMENT PROCESS CURRENTLY HAS A SINGLE-SPECIES FOCUS

Fisheries management in Aotearoa New Zealand generally views each species of interest in isolation. Our current system primarily relies on measuring the stock sustainability of individual commercially fished species to determine how many can be caught. This provides a critical tool in fisheries management, and a certain level of reassurance of overall ecosystem health if all the stocks remain plentiful over an extended period of time.

But there are also limitations. There may be large uncertainties associated with stock assessments (see Theme 4). Beyond this, complex interactions are at play within an ecosystem. Commercial species are not necessarily good proxies for ecosystem health. Long-term resilience of stocks to heavy fishing might require a more complete set of data which reflects the capacity of the marine environment to sustain the fisheries stock. We need to measure and monitor more parts of the ecosystem and the interactions among them, across different trophic levels, to truly understand ecosystem health and mitigate the risk of ecosystem collapse.

THERE ARE LIMITATIONS IN OUR KNOWLEDGE ABOUT THE ECOSYSTEM IMPACTS OF FISHING – DEMONSTRATED THROUGH BENTHIC TRAWLING

In order to implement an EAFM, we need to understand how ecosystems operate and be able to identify indicators to protect their function as part of fisheries management. Currently, we tend to wait for adverse impacts to materialise before implementing management responses and often struggle to respond. This is demonstrated through our widespread use of bottom trawling but limited knowledge of the ecosystem impacts on those trawled areas. Ideally, we would pre-empt negative impacts via a thorough understanding of how ecosystems function, but we need to make decisions with imperfect data.

The impacts of bottom trawling are highly context dependent, and depend on variables such as location, substrate, presence of vulnerable biota, scale, frequency, duration, intensity, and how the trawl is deployed.

In 2007, around one third of Aotearoa New Zealand's deep sea benthic areas became protected from bottom trawling in an agreement between industry and government. The degree of protection afforded by these benthic protection areas is fiercely contested.

The total annual area of the seafloor that is bottom-trawled is not increasing and has remained under 100,000 km^2 per year over the last decade (see figure 17). However, each year new areas are trawled (schematic figure 18a). Over the last 20 years, the annual expansion of the cumulative trawl footprint in the deepwater fisheries has slowed, from around 1,000 km^2 in 2002 to under 100 km^2 in 2019. However, the overall 'cumulative trawl footprint' (the total area of our seafloor that has ever been trawled) is still increasing (schematic figure 18b). This is a concern given the long time for recovery of some fragile seafloor habitats. Understanding the extent and patterns of contact with newly trawled compared to previously trawled areas, the habitats and species

impacted, and the recovery time for the area trawled, are important factors in understanding the nature of benthic damage from trawling activities in our waters.

The total annual area of the seafloor that is bottom-trawled is not increasing and has remained under 100,000 km^2 per year over the last decade. However, each year new areas are trawled.

Figure 18 is drawn as a schematic to illustrate the principle and approximate scale, which are not contested. The precise figures for the annual increase in the cumulative trawl footprint are hard to measure.[18]

The way that areas that are 'newly trawled' are estimated can differ depending on the starting point of the data (e.g. how far back records go) and the level of information available (e.g. how precise location data is).[19] The resulting estimates can vary depending on how the analysis is undertaken. Where large areas have clearly been newly explored, these are generally highlighted in Fisheries New Zealand research and reporting (see for example, Black and Tilney, 2017).[20] In recent years, this has been mainly in the north and central areas of the Challenger Plateau. The use of electronic positioning reporting data in 2018 and 2019 has allowed for more precision in locating the start and end positions of tows, which has consequently affected standard reporting measures used by Fisheries New Zealand.[21] Further linking of observer data with electronic positioning reporting data will advance understanding of the habitats and species that are being impacted in the newly trawled regions.

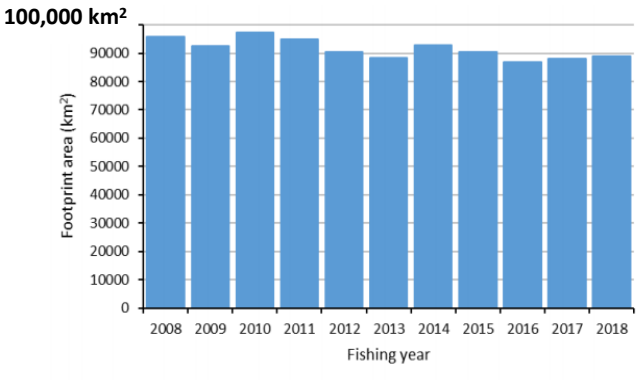


Figure 17: Figure taken from AEBAR 2020, see Figure 11.13 Annual footprint (km²) for bottom-contacting trawling for inshore and deepwater fish stocks, from TCERs, TCEPRs, and ERS, for the 2007–08 (2008) to 2017–18 (2018) fishing years. (From Baird & Mules (2021, in review))

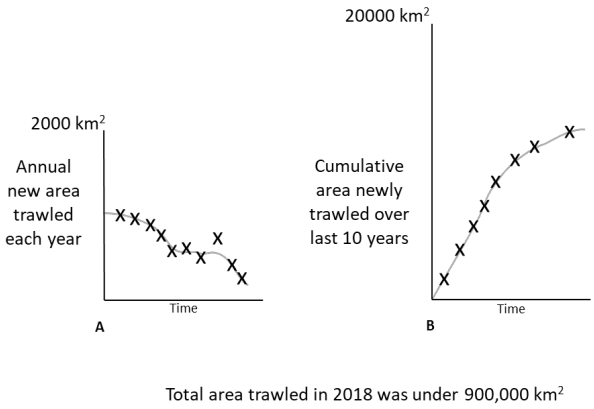


Figure 18: Schematic to demonstrate how a trend in decreasing amount of newly trawled areas (a) still increases the cumulative trawl footprint (b). (Schematic used as the data is disputed but the principle is not).

[18] The most recent data for both deepwater fisheries and inshore fisheries held by Fisheries New Zealand (Estimates from Baird and Mules, 2021, preliminary data, publication pending) are included in the full report appendix 3: Estimates for newly trawled data. Note that elements of the data remain a matter of dispute, for example from the WWF.

[19] For example, resolution of reporting can mean that new transects may be artificially aggregated and must be accounted for in analysis. Input from Fisheries New Zealand.

[20] Black, J. and Tilney, R. (2017) Monitoring New Zealand's trawl footprint for deep water fisheries: 1989 – 90 to 2011 – 2012 and 2012-2013, New Zealand Aquatic Environment and Biodiversity Report No. 176. Available at: https://fs.fish.govt.nz/Doc/24212/AEBR-176-trawl-footprint.pdf.ashx

[21] For example, number of contacted cells, aggregate area, and footprint are affected (see full report appendix 3: Estimates for newly trawled data). The effect of this is greater for inshore fish stocks than for deepwater data. Input from Fisheries New Zealand.

Further linking of observer data with electronic positioning reporting data will advance understanding of the habitats and species that are being impacted in the newly trawled regions.

There is a lack of agreement on the approach to assess impacts. Internationally, indicators for assessing impacts of trawling and dredging have been proposed by many but have not been evaluated or agreed upon. This is reflected in Aotearoa New Zealand where the approach to assessment[22] is not accepted by all stakeholders and opinions on the value of the assessments differ. Aotearoa New Zealand's assessment processes lag behind best practice and we are limited by our lack of data.

Protecting ecosystem structure and functioning is critical to ensure a sustainable future for the fishing industry. Understanding the extent of the local ecosystem impacts of bottom trawling occurring in Aotearoa New Zealand's fisheries, along with developing new technology that minimises damage to the seafloor (see Theme 7), will be fundamental to applying an EAFM.

LEGISLATIVE MEASURES ARE UNDERUTILISED

The concept of 30% marine protection[23] being a stated goal has emerged prominently internationally in recent years, aimed primarily at biodiversity conservation. Some international resolutions to which Aotearoa New Zealand is a signatory set targets for marine protection. One of the most well-known marine protection tools is the MPA, where fishing is significantly restricted, or not allowed. There is work underway by the government relating to MPA legislation and policy, led by the Department of Conservation and Fisheries New Zealand. There are many other types of marine protection tools. For example, Māori have traditionally and recently used rāhui – temporary protections in space and time. Mātaitai reserves recognise and provide for the special relationship between tangata whenua and their traditional fishing grounds and non-commercial customary fishing.

While much attention is focused on MPAs, less profile is given to specific provisions in the Fisheries Act 1996 for habitat protection. For fisheries management, the specific regulatory lever for habitat protection is through Section 9(c) of the Fisheries Act 1996. This states that, in relation to the utilisation of fisheries resources or ensuring sustainability, decision makers shall take into account the environmental principle that habitats of particular significance for fisheries management (HPSFM) should be protected. This supports the sustainability of fisheries, the environment, and our ecosystems as a whole.

However, according to Fisheries New Zealand, there have been no HPSFM defined or applied in the approximately 25 years the Fisheries Act 1996 has been in place. Work on preparing a guidance document for implementing Section 9(c) is described as ongoing in the AEBAR but is reportedly only at an early stage.[24]

There have been no habitats of particular significance for fisheries management defined or applied in the approximately 25 years the Fisheries Act 1996 has been in place.

Other MPAs or fishing restricted areas can be pointed to in lieu of progress in HPSFM – however, HPSFM relate to their significance for fisheries management, differing from marine reserves, which are set up to preserve, for the scientific study of marine life, "underwater scenery, natural features, or marine life, of such distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest."[25]

Despite decades of fisheries research, knowledge of habitats of significance is low due to our modest understanding of fish species' life histories, habitat usage and spatial structuring. Defining areas has been

[22] The current approach uses the overlap of trawl footprint with Marine Environment Classification, Benthic Optimised MEC, and depth classes.
[23] Note: this does not only refer to 'Marine Protected Areas' as defined in Aotearoa New Zealand legislation.
[24] Input from Fisheries New Zealand.
[25] Marine Reserves Act 1971.

purportedly difficult due to the specificity of significance of habitats to individual species and life-stages. The resulting situation is that the regulator specifies that most habitat is significant to at least one species, yet none are quantified. There is no prioritisation framework or formal quantification of the importance of different habitats. While there are definite data and knowledge gaps acting as barriers to identification and prioritisation, there is also a substantial body of research on areas of importance (e.g. juvenile nurseries). Work has been undertaken previously on habitats and areas of particular significance for inshore fisheries, and overseas there are references to build on, such as the National Oceanic and Atmospheric Administration 'Essential Fish Habitat' regulatory guidelines in the US.

THERE IS AN ACHIEVABLE PATHWAY TO IMPLEMENT AN EAFM

LOOK BEYOND SINGLE SPECIES TO INFORM DECISIONS

Incorporating measures of ecosystem health into fisheries management leads regulators down an EAFM path. EAFM can be defined in many different ways – Fisheries New Zealand has described it as an 'integrated approach to managing the competing values and uses of fisheries resources while maintaining the ecosystems that support them'.

Globally there is a move to an EAFM and this requires conservation of ecosystem structure and function. This in turn generates a need for long-term environmental and fisheries data. There are no 'off-the-shelf' measures to reassure regulators that ecosystems are well managed, and local knowledge is vital in translating these general principles into action. An explicit ecosystem approach builds on the best practice of experienced fishers who understand their environment after many years of observation.

There are no 'off-the-shelf' measures to reassure regulators that ecosystems are well managed, and local knowledge will be vital in translating these general principles into action. An explicit ecosystem approach builds on the best practice of experienced fishers who understand their environment after many years of observation.

Challenges in implementing an EAFM include:

- Having robust methods for recognising when an ecosystem is adversely impacted
- Understanding direct and indirect effects of fishing one species on other ecosystem components
- Reconciling multiple fisheries operating under different management systems
- Identifying indicators that can deliver useful information for these management systems.

Ecosystem indicators are crucial to understand ecosystem dynamics because it is impractical to measure every species to inform management decisions. Ecosystem structure and function is complex and there is scientific disagreement over which indicators can best measure the overall state of an ecosystem. Ecological indicators for the Aotearoa New Zealand ocean have previously been discussed in many papers and reports and there is local research in this area that could be built on.

The New Zealand Government has committed to taking an EAFM that integrates sustainable harvesting with wider biodiversity considerations. Local research to foster ecosystem thinking in Aotearoa New Zealand's fisheries management system is underway as part of the Sustainable Seas research programme, but more work is needed to integrate the research and policy intent with community knowledge, and to translate lofty goals to day-to-day decision making in the fisheries management system and practice in our oceans.

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Existing models used in fisheries management are limited by available data and improving data could open up opportunities to use better models. The growing recognition of the complexity of ecosystems and the need to understand dynamics within them has heralded a new era in modelling that expands beyond a single-species focus to the wider ecosystem. Along the continuum of complexity for models used in fisheries management, the mechanistic models used for stock assessments sit at one end, with models of intermediate complexity forming the bridge to full ecosystem models at the other end. Innovative ecosystem models can support sustainable fishing by improving system understanding, identifying major processes, drivers and responses of change, highlighting major knowledge gaps, and providing a way to test management strategies before implementation. Ecosystem models can be used to test the impact of management interventions, such as how balanced harvesting[26] or changing the size of individual fish that are harvested might impact ecosystem health. However, ecosystem models are extremely complex and resource intensive, depending on significant datasets for stocks and their environment over time. Some question whether these types of models are practical for wide deployment given how much funding would be required to fulfil the data needs. In the meantime, fisheries management decisions need to be made with imperfect models using imperfect data. This, in a nutshell, captures the uncertainty in the field.

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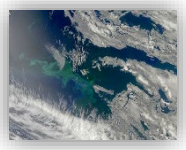
The Chatham Rise is a unique fishery with consistent, long-term data. The rich dataset has been used to develop a full ecosystem model – Atlantis – for the Chatham Rise, with a growing number of parameters. The model has been tested and validated. Scenarios could include varying levels of climate change impact, or alternative fishing approaches (exploitation level, spatial patterns, target species and gear changes), and single- versus multi-species MSY. The model does not account for seafloor damage and sensitive benthic habitats.



USE INNOVATIVE SOLUTIONS TO GROW THE KNOWLEDGE BASE

There is a need for ways to measure the broad ecosystem level effects of fishing as a whole, in order to implement an EAFM to sustainably manage fisheries. New tools can refine spatial and temporal knowledge about marine life to inform fisheries management.

New tools can refine spatial and temporal knowledge about marine life to inform fisheries management.

[26] Applying a moderate fishing intensity across as much of the ecosystem as feasible.

Genetic tools, including environmental DNA (eDNA) can grow ecosystem knowledge by providing a high-level overview of community composition (see figure 19) and offer a way to simply and non-invasively monitor ecosystems through species detection, determining species diversity, and determining further details about ecosystem function, including diet, pathogens and invasive species. The hope is that in the future eDNA sampling methods will enable further quantitative precision, which may enable the method to supplement research trawls.

Drones and UAVs can be used to track, count and measure marine mammals. Marine habitats are vast and can be difficult to access. UAVs can allow access to areas of interest from the air, sea surface or underwater, opening up new opportunities to map, assess and monitor habitats.

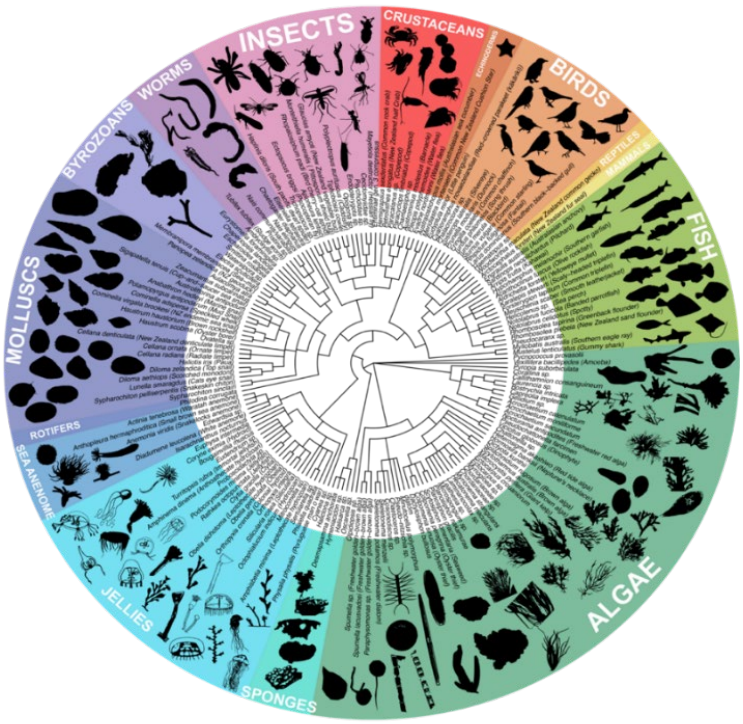


Figure 19: A biotic survey of Wellington harbour using eDNA metabarcoding. Such methods could play a role in baselining a variety of marine biota. Image credit: EPA's Wilderlab.

Satellite technology allows wide-ranging observations of movements around the ocean over various spatial and temporal scales. Improving and emerging satellite technologies have promising applications in fisheries management. Pop-up satellite archival tags have been used for nearly 20 years to track species movements and behaviours. Currently there is limited spatial resolution of satellite remote sensors, but developments in satellite technology are enabling more refined characterisation of the horizontal and vertical movements of individuals, populations and entire communities. There can also be temporal limitations depending on how the study or system is designed. Satellite tracking data can be coupled with oceanographic data to understand what drives movement and behaviour. Satellite tagging is labour intensive and tags are expensive, but it does offer some advantages over the more traditional 'mark-recapture' method[27] as species only need to be caught once and developments with batteries and hardware will continue to reduce the size of tags.

MAUI63 is developing and testing innovative drone and AI technology for monitoring distribution and habitat use of critically endangered Māui dolphins. The project is currently underway and aims to be able to model population abundance and spatial distribution, predict movements and track dolphins, and enable responsive fisheries management to avoid fishing where Māui dolphins are present. This is discussed in case study 6.5.2 in the full report.

[27] A portion of the population is captured, marked and released, then later another portion is captured and the number of marked individuals within the sample is counted.

USE LEVERS WITHIN THE FISHERIES ACT 1996 TO TAKE AN ECOSYSTEM APPROACH

The Fisheries Act 1996 does enable wider consideration of ecosystem impacts to be taken into account in fisheries management decisions. Some aspects have already been incorporated but implementation has been variable. An EAFM can be accelerated within the confines of the Fisheries Act 1996.

This view is also reflected in a report commissioned by Seafood New Zealand which explores whether our legislation enables an EAFM.[28] The research found that "there are no situations in which the Act does not require or enable a management approach that is consistent with the identified principles of EAFM" – in other words, there is nothing in the Act that prevents a shift towards an EAFM. The report also notes that "the existence of legislative provisions that require or enable EAFM does not indicate the extent to which our fisheries management processes, policies and decisions reflect EAFM in practice – either generically or on a fishery by fishery basis". Much could be achieved in the short term by implementing the provisions already in the Act.

An EAFM can be accelerated within the confines of the Fisheries Act 1996.

For example, progress towards an EAFM could be achieved through the operationalisation of HPSFM, research prioritisation, establishing ecological indicators, alignment with overarching strategy, and through implementation of other recommendations and considerations as described in some detail in the Fathom report.[28] Ultimately, an EAFM must focus on objectives, not only on the use of specific tools. Several sections of the Act could be applied in addition to Section 9(c): for example, Section 9 more widely covers environmental principles, Section 11 covers sustainability measures, and Section 15 covers fishing-related mortality of marine mammals and other wildlife.

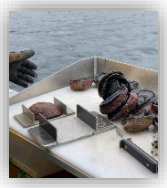
The use of HPSFM should be actioned. As our spatial information improves and there is finer-scale reporting of fishing locations and vessel tracking data – as is being presented in Fisheries New Zealand's electronic monitoring and compliance system – there are greater opportunities to monitor and manage interactions with HPSFM. First, these must be defined, identified and synthesised within a more integrated approach. Once HPSFM are formally identified and recorded, there can potentially be better understanding of impact and much more consistent management approaches. For example, quantification of benthic impacts on HPSFM, or as a first step, mapping of recurrent or new fishing events with areas of HPSFM could be achieved. In the meantime, the current lack of quantification should not prevent protective action from being taken. There are also benefits of taking this more formal HPSFM approach in terms of transparency, public trust, and industry confidence.

In many cases, the fishing industry may want to advocate for protection of a HPSFM as, depending on the species, this could have a substantial impact on both short- and long-term outputs and sustainability. Some sectors of the commercial fishing industry are demonstrably committed to identifying and protecting HPSFM. Declaring a HPSFM may help create a formal dialogue and expedite action from regional councils to mitigate land-based impacts on coastal habitats and also trigger action to restore damaged habitats. National guidelines to formally identify these sites, with scientific input, would support establishment of protection. The way that legislation is currently administered does not support these efforts.

Overall, there's clear opportunity to use the Fisheries Act 1996 to implement an EAFM in the short term. This can be supported by a range of new technological advances to grow our understanding of ecosystems and their response to fishing pressures and improvements in fishing gear which could be phased into our fisheries (see Theme 7).

[28] The Fathom report (2019) is available from the Seafood New Zealand website: https://seafood.org.nz/fileadmin/documents/PDFs/EAFM_and_the_Fisheries_Act_1996_-_Fathom.pdf. A summary is included in the full report appendix 1: EAFM principles and relevant Fisheries Act 1996 provisions.

The Pāua Industry Council is reviewing how they can strengthen their ecosystem approach to pāua management, building on current approaches and looking to implement HPSFM. While this is a niche industry, it provides a good example of applying principles of community-led management and a move towards an EAFM. This is discussed in case study 5.3.7 in the full report.



The following sections of the full report expand on these issues:

- 3.3: Fishing effort has wider ecosystem impacts
- 4.2: Managing impacts through protection tools
- 5.3: Commercial fishing has impacts on target species sustainability
- 5.9: We need a plan for our oceans
- 6.4: How much we fish
- 6.5: Where and when we fish

THEME 6 RECOMMENDATIONS: AN ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT (EAFM) IS EMBRACED WITHIN THE CURRENT REGULATORY FRAMEWORK, INCLUDING THE FISHERIES ACT 1996

Recommendations	Considerations

6. Within the current regulatory framework, transition Aotearoa New Zealand's fisheries management system to an ecosystem approach through supporting and resourcing the expansion and uptake of wider ecosystem monitoring and driving a shift towards more ecosystem-friendly fishing methods. In the longer term, the Oceans Strategic Action Plan should facilitate and define a shared understanding of what an ecosystem approach to fisheries might encompass and what this approach aims to achieve within the context of Aotearoa New Zealand's fisheries management (see Theme 2).
 	
In the shorter term:
a. Create a framework for prioritisation and protection of Habitats of Particular Significance for Fisheries Management (see 9(c) of Fisheries Act 1996) and review barriers to usage. Produce guidance documentation for the definition and identification of Habitats of Particular Significance for Fisheries Management (see 9(c) of Fisheries Act 1996) and required evidence base.
b. Support research that advances application of an ecosystem approach to fisheries management, such as how species, including bycatch, interact to form a functional ecosystem (see Theme 7).
c. Develop a set of national marine ecosystem indicators and establish long-term monitoring (including habitat, bycatch and taonga species) to better inform implementation of an ecosystem approach to fisheries management with clear goals.
d. Secure funding and commitment for the long-term monitoring to be established and maintained.
e. Review best practice international approaches to national marine ecosystem indicators and incorporate relevant learnings into the Aotearoa New Zealand context.
f. Define and implement an effective ecosystem protection regime in fisheries management.
g. Support the development of alternative fishing methods (see Theme 7).
h. In partnership with iwi, industry and environmental NGOs, develop approaches and incentivise innovation to minimise or eliminate adverse effects of fishing gear (e.g. full-contact
	• Investigate which species are suitable as indicators for ecological monitoring, referring to work previously undertaken, e.g. in Aotearoa New Zealand deepwater fisheries (see Theme 6.c).
	• Align work on an ecosystem approach to fisheries management with:
	  ○ *Te Mana o Te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020*, especially objective 12.
	  ○ The Parliamentary Commissioner for the Environment's report focusing on Aotearoa New Zealand's Environmental Reporting system, including recommendation 1(h).
	• Consider the range of tools available for protecting the ecosystem, including those that focus on species, habitat, flexible spatial and temporal management, as well as consideration of the use of buffer zones around no-take protection areas.
	• Fund gear innovation research designed to reduce impact on the benthic habitat (see Theme 7).
	• Ensure just transitions in any regulatory changes to preferred fishing methods.
	• Review the use of full contact bottom trawling and dredging methods for fisheries and ecosystem monitoring research; explore how other research methods could be used (e.g. estimating fish biomass with eDNA surveys) and how environmental impact of monitoring can be reduced.
	• Consider new approaches to the use of minimum and maximum legal sizes for species where research supports that this approach is beneficial to support sustainability (see Theme 7).

bottom trawling and dredging) on benthic habitats. E.g. further restrict the areas trawled, switch to less damaging gear when available, focus on developing new technology where less damaging gear is not currently available (see Theme 7). i. Review and prioritise restoration approaches for damaged habitats (see Theme 3 and Theme 7.a.iii).	

THEME 7: RESEARCH AND INNOVATION ARE MAXIMISED

THE PATHWAY TO IMPACT IS NOT AIDED BY THE COMPLEXITY OF THE RESEARCH LANDSCAPE

PRIORITIES FOR LIMITED FUNDING ARE HIGHLY CONTESTED

Tens of millions of dollars is dedicated to ocean research efforts every year, but this barely scratches the surface. Research in the marine environment is costly, which presents a particular challenge for Aotearoa New Zealand with our large EEZ and small GDP. Stakeholders generally agree that research into fisheries and the marine environment is underinvested. There is a diverse array of scientific researchers who all contribute to collecting, researching and analysing data in our marine environment and fisheries, delivering within a cluttered landscape of institutional structures and funding schemes. Data collection is undertaken for many different reasons, including environmental and sustainability purposes or economic and commercial ones. Our most extensive data collection efforts have a strong focus on compliance, which presents an opportunity to expand the use of this data for environmental and commercial purposes.

Though cost recovery aims to recover cost for research for all commercially exploited stocks, it does not currently achieve this. A consequence of how the cost recovery system functions is that limited, high-value species have been prioritised for scientific research. Concerns that in a cost recovery system, the research agenda would be dominated by industry voices were raised prior to implementation and remain.

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Between 2017 and 2020, Fisheries New Zealand spent on average $22 million per year on fisheries research, with approximately 80% spent specifically on research to determine the health of fish stocks and sustainable catch levels.

Limited funding and resources mean that prioritising and allocating funding to the most pressing issues is important. Within a low-trust sector with multiple competing interests, these priorities are highly contested. Further tensions arise regarding who is responsible for funding research and how much the funder should influence research prioritisation. The economic value of many inshore fisheries simply cannot sustain the best science and stock assessments and, with the current systems and limited resource, frequent, fully-informed stock assessments are only appropriate for high-value fisheries with high risk of collapse. A narrow research focus based on economic outcomes may lead to research and innovations that improve environmental or sustainability outcomes being overlooked, delaying the protection of vulnerable species and habitats.

When allocating scarce funding, the ocean sector would benefit from prioritising research that improves environmental or sustainability outcomes and fills critical knowledge gaps about species alongside research that promises short-term economic benefits.

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THERE ARE BARRIERS THAT SLOW INNOVATION TO IMPROVE THE SUSTAINABILITY OF FISHING

There have been successful funding initiatives for gear innovation where government and industry have come together to fund innovative projects on a large scale, such as the Precision Seafood Harvesting technology,[29] and success has also occurred on a smaller scale via Seafood Innovations Ltd. Recent experiences shine a light on the potential of gear innovation and some of the barriers that prevent good ideas becoming best practice.

Figure 20: Rigid cod-end with rectangular openings. Image credit: Karl Warr/Better Fishing Co.

- **The regulatory approval of new fishing technologies is a significant hurdle**. A key lesson from the experience of approving the Precision Seafood Harvester is that a permissive environment is required for gear innovation. Prescriptive regulations can hinder innovation when they are predicated on existing technologies. The current regulation precludes gear improvement as the regulation is framed so that new gear performs exactly the same as the current standard for a given fishery for indicators like selectivity. For some gear innovation it is expected that decisions will need to be made with uncertain evidence and regulatory requirements need to avoid creating a burden of proof – i.e. the proof needed for change shouldn't be greater than that for the status quo. These barriers to innovation could be removed by implementing a process that evaluates innovation based on desired outcome, taking a risk-based approach to evaluate the appropriate approval pathway for each innovation.

The proof needed for change shouldn't be greater than that for the status quo.

- **There's a tension between commercialising vs open-source tech.** The commercial approach to technological development is a barrier to wide uptake, but if the technology were open-source that would create a barrier to initial investment. There is reportedly interest from other countries in the Precision Seafood Harvesting technology, suggesting that there can be commercial benefits beyond the catch itself to be realised from investing in gear technology. This benefit is offset by the lack of access to the technology for other Aotearoa New Zealand companies.
- **Continued iteration must be supported to optimise results in different environments.** Some criticisms of the Precision Seafood Harvester relate to perceived limited improvement compared to the current standard. Acceptance of the iterative nature of development and testing of new technology in specific settings to improve outcomes will help to achieve the best results for gear innovation in Aotearoa New Zealand's fisheries.

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[29] https://www.mpi.govt.nz/funding-rural-support/primary-growth-partnerships-pgps/current-pgp-programmes/precision-seafood-harvesting/

- **Trialling gear can be cost prohibitive.** It can be expensive and time consuming to develop new gear and undertake studies to determine its effectiveness relative to the status quo. Further costs come from installing, optimising and using the new gear. Modelling and predicting the selectivity outcomes of changes in mesh sizes and openings to refine the proposed method until predicted selectivity is optimised, and using flume tanks to test systems before trialling at sea, can help to address these challenges.
- **It is particularly challenging for small-scale fishers to get their ideas off the ground** and a lack of resource makes it even harder. This is despite the best solutions often being those developed by fishers themselves.
- **Fishers aren't always connected to those who can accelerate their ideas.** Connections to and support from the wider industry, researchers and NGOs are crucial for fishers trying to innovate and can be facilitated by groups like Southern Seabird Solutions. Wider connectivity across the sector would lower the barriers to innovation. Improved access to funding for fishers to progress good ideas could have significant sustainability outcomes.

Another area that demands innovation but faces challenges is using the whole fish to develop high-value by-products. Because there is limited scope for harvesting more fish, adding value to the existing harvest through developing high-value by-products is an attractive path to increasing revenue for the commercial fishing industry. Ultimately, the goal is for companies to move up the value chain by developing a cascade of products for each species that can generate more value than they otherwise get by selling the fish whole or by generating low-value by-products. There is huge potential for large generators of fish processing by-products to extract more value. However, there are numerous challenges to overcome in order to process the whole fish into marketable products, with even greater challenges for developing high-value products. Some barriers are logistical, while others technical or social.

One industry representative articulated the opportunities and barriers clearly when they said: "We are sitting on a goldmine but we don't know how to tackle it."

"We are sitting on a goldmine but we don't know how to tackle it."

A significant challenge for Aotearoa New Zealand's industry is having over 100 commercial species with different potentially valuable components that cannot be processed in the same manner. In addition, our current marine-products processing infrastructure designed for manufacture of single products has no flexibility and often destroys one component when recovering another. Making our challenges into unique opportunities requires knowing exactly what is in any raw material in real time, then using this information to direct processing, choosing from a suite of integrated technologies to maximise raw material use and product value.

MAXIMISING RESEARCH AND INNOVATION IS KEY TO IMPROVING FISHING OUTCOMES

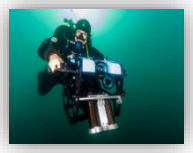
A FUNDING AND RESEARCH STRATEGY IS NEEDED

Choosing how we focus our data collection and research efforts is critically important. We need to have the right knowledge to progress towards a more sustainable fishing future, to measure whether we are moving in the right direction, and accept that decisions need to be made in the absence of complete information. This requires a reorientation from just focusing on stock assessments for limited high-value stocks to extensive support for research to inform responsive management of all stocks and the ecosystem more broadly. It also requires a shift from seeing science as a cost to seeing science as a value add. Continued training and development of a workforce with expertise in fisheries management science is essential to achieve these goals. The direction of travel needs to be clear as industry will require certainty to invest in an EAFM.

As highlighted throughout this report, some of the high priority issues that require further R&D include:

- **Making it easier to do stock assessments:** It is clear that there are significant improvements that could be made to increase the proportion of stocks that are scientifically assessed. Methods that improve the efficiency of these assessments could enable a far greater range of assessments (and expand beyond a single-species focus) to provide more certainty about the sustainability of our commercial fisheries and allow early intervention to prevent ecosystem or stock collapse.
- **Knowing more about target species:** Support for research to fill key data gaps, particularly the basic biology of commercial fish species, is needed. Research on how climate change will impact target species is also necessary. For gear design, understanding fish behaviour, including diet, school movements, and response to visual cues, sounds, and olfactory stimuli, is critical.
- **Reducing impacts from fishing methods:** Commercial fishing methods need to develop in order to reduce bycatch, improve selectivity, enable fishers to return unwanted catch live and unharmed, and eliminate the negative impact of fishing gear on habitats. Gear innovation and other new technology has the potential to radically reduce the negative impacts of fishing and support fishing to be humane, produce high-quality fish and be available just in time for market.
- **Gathering more data in a cost-effective way:** Data collection that's cost-effective and has a low fisher burden is necessary to inform fisheries management. Computers, cameras and AI could revolutionise catch monitoring. Scaling up AI for video review remains problematic. It is difficult to design a single AI solution that works across different fisheries and vessels, each with a unique set of species and environmental conditions. However, these challenges can be overcome over time. eDNA also offers huge potential to monitor biodiversity and deepen understanding of marine ecosystems using cheap non-invasive methods. Expanding data collection efforts, such as through citizen science projects, can also help to achieve this goal.
- **Real-time risk management**: Some of the issues relating to fishing sustainability – catching protected species as bycatch and damaging significant habitats – could be managed by changing where and when fishing occurs. Understanding the interactions of fisheries with species and habitats is important for three reasons: we can better estimate the magnitude of the impact of fishing on threatened species, and therefore better assess the conservation status of these species; we can understand the nature of the interactions and devise solutions to mitigate these impacts; we can determine which habitats to avoid and when. Better risk assessment tools are needed to achieve this, with the ultimate goal being real-time risk assessment.
- **Increasing value and adding a premium to products:** This can be achieved through innovations in processing and by-product development, or through traceability systems which can increase transparency and build confidence in the sustainability of the product, adding a premium that customers will pay for.

Local researchers have developed a machine learning approach to autonomously identify New Zealand scallops in visual imagery of the seafloor. This approach has the potential to underpin the future development of an innovative scallop harvesting system that does not damage the benthic environment, as well as a non-invasive camera-based method of surveying scallops and habitats. This is discussed in case study 6.3.6 in the full report.



THERE ARE KNOWN BARRIERS TO INNOVATION THAT CAN BE REMOVED

Regulators must keep up with innovators – to accelerate change we can bias the regulatory system towards innovation and accept the associated risk. A more permissive regulatory environment that maintains rigour is needed to enable controlled fishing trials of innovative gear with careful monitoring of the impact on stock numbers over time. This could be achieved through special permits to support innovation.

To accelerate change we can bias the regulatory system towards innovation and accept the associated risk.

New gear needs to be practical and rooted in the needs of fishers and their practices. Part of the way to address these challenges is through enabling fishers themselves to lead the innovation. Examples of collaboration in gear design, such as the development of rigid steel trawling cage with square mesh panels by Karl Warr and subsequent research into a video-guided active sorting device, highlights the opportunities when fishers and researchers come together to improve fisheries sustainability. Fishers know the requirements and practicalities of fishing operations and their markets and have many innovative ideas to address the range of issues faced on the water. Researchers are at the leading edge of technological advances and can help to progress ideas even further. There is an opportunity to strengthen the relationship between researchers and industry and expand funding opportunities for collaboration so that researchers can be more in tune to the needs and goals of fisheries management and help to fuel innovation and productivity through their research.

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A culture change is also needed to shift thinking from volume to value, which has been a long-term strategy across primary industries and a long-stated government goal. Policy could encourage innovation and reduce these barriers so Aotearoa New Zealand's industry as a whole can lead in this space.

Key ways to streamline commercialisation of fish by-products include:

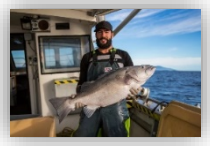
- Improving knowledge of demand and opportunities for supply
- Addressing issues in processing systems and supply chains
- Planning and support to establish infrastructure
- Improving access to technical expertise and applied science
- Making it easier to do clinical trials
- Supporting networks and connection.

The 2020 Cyber-Marine programme, which is investigating a path to transform the industry and make full utilisation and maximised value the norm, has made a start on this in Aotearoa New Zealand.

Iceland arguably lead the world in their use of fish by-products and we can look to them as an exemplar for how to unlock this potential in a national commercial fisheries industry. Strengths of Iceland's 'Ocean Cluster'[30] approach that could be drawn on in Aotearoa New Zealand's efforts to use more of the fish include:

- Taking a bottom-up approach to accelerate innovation and support start-ups in the seafood industry
- Welcoming ideas from within and outside the fisheries industry
- Incubating good ideas and offering a physical meeting space to provide networking and learning opportunities, knowledge spill over and economies of scale to reduce the risk of failure
- Focusing on local value add in fishing communities to restore opportunities to smaller fishing towns
- Expanding networks beyond borders to learn from other countries.

Gravity Fishing has a sustainable business model that adds a price premium to their products. It includes catching only what is wanted, using a precise and minimal impact fishing method, keeping the supply chain short, selling the whole fish, and letting people see their fishing practices for themselves. This is discussed in case study 6.7.7 in the full report.



The following sections of the full report expand on these issues:

- 3.3: Fishing effort has wider ecosystem impacts
- 5.3: Commercial fishing has impacts on target species sustainability
- 5.8: Research programmes, funding and prioritisation
- 5.9: We need a plan for our oceans
- 6.2: How we respond to changing fisheries
- 6.3: How we fish
- 6.4: How much we fish
- 6.5: Where and when we fish
- 6.7: Using the whole fish to develop high-value by-products

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[30] http://www.sjavarklasinn.is/en/

THEME 7 RECOMMENDATIONS: RESEARCH AND INNOVATION ARE MAXIMISED

Recommendations	Considerations
7. Take a more holistic and strategic approach to research and innovation in the marine domain to enable innovation to thrive and support more sustainable fishing (see Theme 3). a. Undertake a comprehensive review of fisheries research funding and establish a funding and research strategic action plan, including: i. Clear prioritisation of research questions to be answered, and technology to be explored, to inform and be informed by the Oceans Strategic Action Plan (see Theme 2). ii. Clarity on the role of industry levy funding and government funding. iii. Resource and incentivise the development and use of fishing methods that are more selective and reduce adverse impacts on the marine environment, particularly on benthic habitat and marine protected species (see Theme 6.i). iv. Investment in methods that improve the efficiency of assessment of fish stocks. v. Prioritisation of real-time risk management (e.g. avoiding protected species), increasing value through innovations in processing and by-product development, and innovations that support more cost-effective data collection at a lower fisher burden. vi. Support for research to fill key data gaps, particularly the basic biology of commercial fish species. b. Review the pathway to testing new fishing methods to reduce the barriers to enable innovation in trawl technology and other fishing methods. c. Invest in and incentivise innovation in environmental protection, prioritising research that enables bottom trawls to fish lighter (see Theme 6.i). d. Develop clear pathways and remove barriers for fishers to be involved in research and innovation, including support with applying for funding. e. Fast track the special permit processes to enable innovative new methods to be trialled, with key requirements to gather data and evidence of effectiveness of new methods (see Theme 5). f. Create and support a researcher/industry collaborative platform for accelerating innovation and its implementation, as well as innovation from existing companies. g. Support citizen science projects in the marine domain and guide data collection efforts to meet the Tier 1 standard so that data can feed into government reporting and decision making (see Theme 5).	• Consider continuing or reinstating 50% partnership funding for fisheries research and development through a fisheries-specific fund. • Consider funding support of industry transition to new technologies to encourage innovation. • Align strategic funding plan with commentary in the Parliamentary Commissioner for the Environment *A review of the funding and prioritisation of environmental research in New Zealand.* • Continue Fisheries New Zealand review of enabling innovation in trawl technology (EITT) and the barriers to innovation and implement changes (see Theme 7.b). • Continue work on Fisheries New Zealand real-time risk management initiative with the goal of producing a fisher friendly app (see Theme 4). • Consider mechanisms of sharing good practice while maintaining IP rights. • Support researchers to be partners in technological development not just providers. • Support climate change research that can inform fisheries management (see Theme 3). • Consider annual innovation showcase and awards to further encourage research and innovation.

h. Support development of tertiary training focused on fisheries management science.	

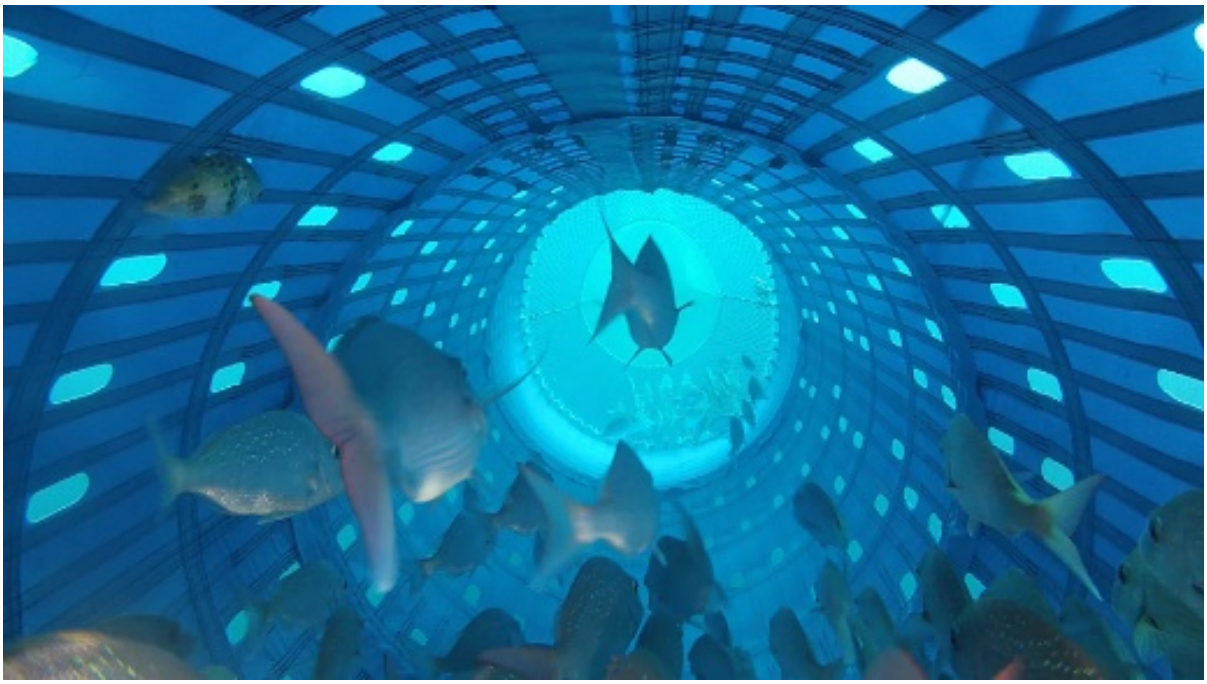

Figure 21: Tiaki modular harvesting system.

VISION: IMAGINING A DIFFERENT FUTURE. FISHING IN AOTEAROA IN 2040

When the panel that the Office of the Prime Minister's Chief Science Advisor reported on our Rethinking Plastics Project, we began with a vision from our panel in which we imagined a different future.[31] This proved helpful to capture how a new future might look if our recommendations were accepted. People were ready to imagine a different future because there was a social and cultural license for change. For this project, there has been a very different mood, with little consensus on the extent of the need for change, and an understanding that change would be dependent on many factors, only one of which is the role that science might play.

Nevertheless, to end this report, we present an imagined future – not a prediction – but a provocation to envisage a different way of harvesting from our oceans, which draws on some of the exciting research ideas presented in Part 6.

To end this report, we present an imagined future – not a prediction – but a provocation to envisage a different way of harvesting from our oceans, which draws on some of the exciting research ideas.

[31] https://www.pmcsa.ac.nz/topics/rethinking-plastics/our-vision-rethinking-plastics/

AN ASPIRATIONAL VISION FOR THE FUTURE OF COMMERCIAL FISHING BEYOND 2040 …

In a future Aotearoa, Amelia and Nikau are showing Amelia's grandad what they have done with his old trawler. The old girl looked the same as ever sitting on the wharf, so sitting in the galley with a cup of tea, grandad doesn't really see what all the fuss is about. They are heading out to catch snapper, just like they did twenty years ago, although the best fishing spots have shifted as the oceans have warmed, and the range of spots you are allowed to fish in keeps changing, to keep up with the moving fisheries.

The solar panels on the roof are the first clue that something has changed, and there are a lot more screens in the wheelhouse too. Amelia wanders in to show him how they all work after they drop the net. It's not actually a net to be honest, but it's still called a net in the same way that in 2020 we still 'dialled' a number on a smartphone screen – an affectionate nod to outdated technology. The 'net' no longer drags along the seabed, as computer technology ensures the fishing equipment gently glides through the water just above the bottom, keeping intact precious shellfish, sponge and coral beds with an acoustic tickler available for coaxing bottom dwellers towards the surface for those catching scampi and prawns.

The boat has slowed and is moving gently at the speed of a swimming snapper. The screens light up and the old wheelhouse develops a new vibe. Grandad watches with delight as live snapper enter the net and keep swimming calmly, while smaller fish dart in and then out, completely unharmed. Slowly but surely, the net starts to fill, almost exclusively with snapper. A second screen shows a catalogue of individual fish, all annotated with individual markings. Fishal recognition™ is a patented AI technology which can identify individual fish that are perfect for the very high-end premium fish market. Amelia has used the nickname function so that some of her favourites light up. FR2897, Daisy, is highlighted on the screen, confusing and delighting grandad in equal measure. The algorithm can identify the fish by the pattern of spots on its scales, and reports that this is the third time that Daisy has been located. This time she is the perfect size for the premium export harvest category, and will be harvested rather than left in the sea to mature further.

On a third screen, the numbers are being crunched. The fish have been filmed from multiple angles and are being ID'd, sized, counted and virtually weighed. Cameras under boats have proved much more popular than the ones on the deck, and the old privacy issues of the 2020s are forgotten as the fully automated electronic monitoring leaves the fishers themselves free from observation. Data is livestreamed to the central data hub and automatically processed before heading to the regulator for compliance purposes.

It is very rare that there are any breaches of fishing regulations these days, because the technology acts as a safeguard to fishing over quota, and selectivity is so high that bycatch is negligible and is recorded swimming away. In any case, most local management plans have set catch limits lower than quota limits to protect the marine ecosystems. The central data hub also enables electronic monitoring of the live bycatch; this is aggregated across fishing vessels to ensure commercial sensitivity is respected. This has led to a paradigm shift in environmental monitoring, with a deep understanding of ecosystem health at all trophic levels informing the detailed dynamic three-dimensional models of marine ecosystems.

Finally, on screen four, specific data for this vessel arrives back, copied to head office for commercial intelligence. The fish-to-order delivery times are estimated for the high-end restaurants at home and overseas; Daisy is heading to Sydney. And the local wharf sales, building on early Ministry for Primary Industries pilot schemes and implemented nationally as part of the 'Affordable Healthy Food Initiative' across Aotearoa's primary sector in 2025, are calculated for sale at local prices on return. These attract a government subsidy and a large crowd of locals. The robot-harvested scallops are a particular favourite.

Grandad is grudgingly impressed, but lurches into genuine excitement when screen five flashes an alarm. There is a large pod of dolphins nearby. The restoration of marine ecosystems is starting to lead to increasing challenges in avoiding the growing population of marine mammals. NewNetTech™ and the evolution of underwater bait-setting systems for longlines have completely solved the heartbreaking capture of seabirds

from the old days, but there are still challenges with dolphins and sea lions that need manual intervention. Nikau runs into the wheelhouse to respond to the alarm. The OOApp™ had predicted that the dolphins were in another part of the gulf, but there was a 10% chance they would encounter some today in this top snapper spot. Happily the dolphins have not yet entered the net, so there is no need to release the snapper. Nikau turns up the volume on the precisely tuned acoustic pinger, and grandad swears he sees the dolphins scowl as they turn away. The catch is saved, and they all stand on the deck watching as the dolphins head off.

Amelia explains that the central fisheries data hub is not just collecting data from nets. It also collects detailed information on the seafloor, aggregated appropriately so that researchers have full and ready access without jeopardising commercially valuable information. The majority of our seabed has now been mapped and we know where our most vulnerable and important habitats are. While the seafloor and all seamounts are now protected from the harms of bottom trawling, which was phased out ahead of target in 2035, many are still in the process of recovering and the decades-long process of seamount restoration has begun as a priority research area in which Aotearoa leads the world.

Extensive marine coastal habitats are protected and we know much more about the creatures that live there. From the Far North right down to Rakiura Stewart Island we are starting to see the return of majestic native kelp forests along our coastlines. Divers can swim among the large snapper and tarakihi that dart through these complex underwater forests. There are also numerous crevices full of large rock lobsters. Our thriving coastal areas help repopulate commercial fisheries both inshore and deeper at sea.

The Strategic Ocean Action Plan launched by the new Oceans and Fisheries Minister with Te Ohu Kaimoana and the Iwi Leader's Forum in 2022 represented a true Treaty partnership to care for the oceans. The QMS has evolved to better serve our fisheries system and the environment, while affirming the rights afforded by the Treaty of Waitangi. The agreed principles underlying the action plan brought congruence to the regulatory system across the fisheries and marine protection legislation, helped to coordinate specific localised management plans, and led to a shared sense of purpose to protect the oceans as a healthy environment with an abundance of fish nurtured by management at the appropriate spatial scale. The stalemate between those wanting to protect the ocean and those wanting to fish was finally broken during the process of community building that preceded the plan, and the agreed comprehensive network of areas protected by nuanced rāhui, informed at a local scale by local knowledge and mātauranga Māori, has allowed many of our marine habitats to recover and flourish.

The integrated fisheries research platform 'Ko moana tenei', which began in 2023, has increased our understanding of the basic biology of commercial species, food webs and ecosystems and means we have much greater confidence in the sustainability of our systems. The online dashboard has made it far easier to navigate the wealth of information and tunnel down into details of interest. Establishing ecological indicators back in the 2020s made a huge difference and ongoing refinement means that our ecosystem models are continually improving and have fewer assumptions every year. It's now routine that research surveys use trawl gear that skims over the bottom without contact, deploy autonomous vehicles to satellite tag fish underwater, use cameras to monitor benthic habitat, and collect genetic and biochemical data to feed into annual stock assessments.

This year will be the first that the new traffic light stock assessment system has completed its cycle for every commercially fished stock. And now that there's full transparency around commercial and non-commercial catch data, stock assessments and the decision-making process for reviewing stock status and catch allowance, the public are confident in the sustainability of fishing that takes place in Aotearoa. Community and local knowledge feeds more directly into decision making alongside industry data, at both a local and national level and communication is a two-way street. Not surprisingly, lots of our best ideas about new approaches to fishing have come from fishers, including the new ropeless acoustic pop-up pots that are used to harvest a now thriving rock lobster population, supported by scientific monitoring.

With the new Innovations Cluster and stronger relationships in the sector, it became much easier for fishers to engage in the research system and develop their ideas, with streamlined resourcing and minimal form filling. The annual showcase means these ideas spread far and wide. As Amelia and Nikau head to shore, an excited researcher contacts the boat – she was automatically alerted that one of the tagged fishes her team has been following is on board and wants a biopsy to check its DNA to inform genetic studies on the diversity of the stock and biochemical studies to confirm which nursery it had come from. She can also sample the seawater that has been automatically collected for eDNA giving a reliable and active measure of ocean biodiversity, which stabilised in 2030. They arrange to meet back at the wharf where the locals are already gathering for a fresh feed. Parallel innovations have taken place in the deep sea fishing sector, with multi-party ocean monitoring platforms supporting government and industry research, and innovations in fishing gear transforming the selectivity, efficiency and yield, while minimising damage to the seafloor.

There is one more piece of the puzzle to share with grandad. Many of the fish are now sold whole, and those that are filleted fetch nearly as high a price per fish. This too is a result of the research efforts to extract maximum value from the whole fish. Pure bioactives, fish oils, feedstock for cellular agritech and even fish leather are now manufactured and exported, often from the filleting factory sites themselves, to maximise the yield of the valuable marine-derived produce by processing while still fresh. The speed and responsiveness of our commercial fisheries has moved the industry to near-zero waste.

And then its home for a feed. We all have confidence in where and how our fresh fish caught, with a quick scan on an app telling the story of where and how your kaimoana was caught. Kaitiakitanga became part of an increased social environmental consciousness during the 2020s and means pollution has reduced through changes in materials used, our recycling abilities, and community initiatives that aim to clean up our environment.

Even though our population has increased, we have a better understanding of how land-based activities can be controlled to reduce the impact on oceans and have implemented many changes to reduce these impacts. These advances were made through the 2022 Oceans Strategic Action Plan which engendered greater cross-sector communication, relationships, and the acknowledgement of funding needs for cross-sectoral issues. In many areas previously impacted by land-based activities, ecosystems are recovering (like the return of subtidal seagrass and mussel beds) – some naturally and others with rehabilitative help.

While climate change continues to impact on our ecosystems, the ocean observing system established in 2022 has provided the vital information we've needed to understand the changing oceans and enable us to strengthen the resilience of many of our ecosystems to better withstand changes in ocean acidification, extreme weather events, and other issues current and future. The drive for community science in the marine space led to many recreational fishers and other non-commercial vessels adding sensors to their boats and collecting data for this system. We have already decreased the carbon footprint of our fisheries by moving to cleaner and more energy efficient means of fishing, along with our targeted technologies like the smart net and minimal biofuel waste.

Commercial fishing in Aotearoa is seen as word-leading and the Oceans and Fisheries Minister, along with all New Zealanders, is justly proud of the huge advances we have made in managing our ecosystems and fisheries in a way that benefits everyone. As well as providing affordable healthy kai for our communities, the reputation of our practices and our products around the globe, and the enormous growth in demand for seafood, has grown the industry to be a ten billion dollar contributor to GDP. Fishing is a sought-after career for our school leavers. We have led the use of sustainable practices in our trade agreements and the Comprehensive and Progressive Trans-Pacific Partnership (CPTPP) won an award from the World Sustainable Trade Organisation (WSTO) for its contribution towards international marine restoration as part of sustainable trade. Aotearoa is still on a mission to improve our knowledge and our systems, with commercial fisheries and scientists working together with the wider community to ensure that our industry and environment continue to thrive using ever more innovative tools and practices.

Ka pū te ruha, ka hao te rangatahi

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