Environmental management of New Zealand aquaculture: the science perspective

Hilke Giles
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Executive summary

The Environmental Defence Society (EDS) is undertaking a project to investigate potential future legal and policy arrangements for aquaculture in New Zealand. This report accompanies that project by exploring the environmental management of aquaculture in New Zealand from the science perspective. It provides insights into the role of science in environmental management processes, describes challenges, identifies opportunities and through the broad range of aspects covered presents ideas for improving the value and effectiveness of science in the environmental management of aquaculture as well as other activities and stressors.

This report aims to stimulate reflection, new ideas and discussions. It provides high-level recommendations to support improved decision-making in environmental management processes, suggestions in relation to aquaculture-specific matters and concludes with some thoughts on scientific considerations for proposed resource management reforms.

An important theme throughout this report is the importance of separating values- and facts-based contributions to environmental management and the importance of understanding what science can and cannot deliver. It is acknowledged that natural sciences are only one factor of environmental management within a wide range of social, economic, amenity and cultural considerations and values. Science can identify the effects, or potential effects, of an activity with a greater or lesser degree of precision and certainty. Whether those effects are acceptable depends on the viewpoint and values of the community, stakeholders, resource consent applicants and decision-makers. As all these parties will have a different point of view and perspective on the underlying issues, they are likely to judge the same effects differently, and it is this values-based difference that creates most conflicts within environmental management processes.

While these conflicts are relevant and often particularly visible for aquaculture developments, it is important to emphasise that they are not unique to aquaculture. Instead, they reflect the difficulties in dealing with complex environmental issues and conflicting interests and values, which are particularly prevalent in the public coastal space. Correspondingly, if we can find ways to improve the value and effectiveness of science in general environmental management processes, we will inevitably create benefits for the environmental management of aquaculture. In fact, some problems that manifest in aquaculture can only be addressed successfully by taking a broader view on environmental management processes in the coastal marine area.

To address the broader role of science in environmental management, part one of this report is not constrained to aquaculture. Instead, it explores the general role of science in environmental management by focussing on the intersection of facts- and values-based contributions to environmental management and the factors that influence the effectiveness of science in environmental management processes.

By examining the role of and expectations on science in environmental management from different perspectives, part one provided insights into various roles science can play and factors that facilitate or create obstacles for effective environmental management. While there have been examples of successful integration of science in environmental management processes in New Zealand, there remain challenges for scientists and non-scientists in ensuring that the role of science is better understood, trusted and more consistently and effectively implemented. To improve the effectiveness of environmental management it is recommend that improvement initiatives focus on three core goals: (1) Increase public confidence in science; (2) Clarify the role of science in environmental management; and (3) Increase the mutual understanding between scientists and non-scientists.
Part two of this report focusses on specific scientific considerations that influence the management of ecological effects of marine farming activities. Many challenges in and opportunities for more effective environmental management of aquaculture also apply to other activities in the coastal marine area; thus, some of the findings of this part can be transferred to other activities or used to inform wider environmental management questions.

Reoccurring themes emerged across the scientific considerations and led to some key recommendations that would have wide-ranging benefits. For example, fundamental challenges in managing environmental effects in the coastal marine area are related to the prevalence of secondary effects, far-field effects and cumulative effects. One recommendation made to improve effectiveness of environmental monitoring is to substitute the traditional notion of environmental monitoring as a stand-alone, compliance-focused activity, with an integrated regional environmental monitoring programme or framework that combines different monitoring and information gathering programmes.

Another important challenge identified in part 2 is that often insufficient focus is placed on identifying clear expected environmental outcomes. Instead, calls for “action on the ground”, monitoring, research, development of strategies or other activities are responded to without obtaining clarity and agreement of what type of effects are of concerns, what levels are acceptable and what management responses are appropriate for potential exceedances of acceptable levels. It is argued that only if we have agreed on what the most important ecological effects are, what levels of effects are acceptable and if we understand the trajectory of change from the current conditions to the limits set by thresholds from acceptable to unacceptable effects, we are able to strategically reduce and manage them, for example through the development of best management practices (BMPs) or staged development supported by relevant environmental monitoring. This part also emphasises the need for good communication and public information to manage potential public concerns about the environmental performance of New Zealand aquaculture.

Part three of this report explores challenges and opportunities for improvement in the way that effects of activities are assessed and managed through assessments of environmental effects (AEEs), environmental monitoring and adaptive management. Furthermore, the relevant considerations discussed in this report are combined into a proposed structure that could be used as a first step in developing a new framework for assessing and managing ecological effects of marine aquaculture.

This report recognises that specific solutions must fit organisational objectives, values, structures and processes. It therefore provides suggestions and ideas but does not aim to prescribe a set way forward. It encourages everybody involved in the environmental management of aquaculture to identify and strengthen effective processes and to identify opportunities for improvements. This entails challenging their own perspectives and reflecting on what they consider the role of science in decision-making to be right now and what it could be in the future. Most importantly, this report encourages open and constructive debate and reflection about the status-quo and established practises between and within organisations. It is acknowledged that this is not a trivial task. Through an objective exploration of the intersection of facts- and values-based contributions to decision-making processes, examples and case studies and a focus on practical aspects of environmental management processes, this report aims to stimulate positive and constructive conversations on how we manage aquaculture as well as other activities in the coastal marine area. By providing various suggestions, ranging from small shifts in mind-sets to complex decision-making frameworks, this report further aims to illustrates that there are opportunities for everybody to improve the role of science in the environmental management of aquaculture and thus help New Zealand maximise the benefits of a thriving and sustainable aquaculture industry.
1 Introduction

1.1 Background
The Environmental Defence Society (EDS) is undertaking a project to investigate potential future legal and policy arrangements for aquaculture in New Zealand. This report aims to add to that project by exploring the environmental management of aquaculture in New Zealand from the scientific perspective.

By describing current challenges in and identifying opportunities for improved environmental management of aquaculture activities, this report provides insights into the role of science in aquaculture management processes and how the value and effectiveness of science in these processes can be improved. Although focused on aquaculture, this report takes a wider approach and delivers insights into the management of other activities and stressors in the coastal marine area.

This report draws on the literature and the experience and ideas of the author and the many people who have kindly provided their time and insights on discussions of this topic and creative explorations of opportunities for improvements.

1.2 Report objective
At the heart of this report is the search for opportunities to improve the value of science in environmental management processes. The overarching aim of this report is to support improvements in science-related aspects of environmental management of aquaculture. It does not make judgment on the status-quo but works on the premise that there are opportunities for improvement in all science-related aspects of environmental management. Whether or not improvements are required, beneficial or meaningful in specific circumstances can only be determined on a case-by-case basis.

This report simply provides ideas to support the development and implementation of improvements where they are desired.

This report aims to stimulate reflection, new ideas and discussions. It provides high-level recommendations to support improved decision-making in environmental management processes, suggestions in relation to aquaculture-specific matters and concludes with some thoughts on scientific considerations for proposed resource management reforms.

It is hoped that readers feel inspired to reflect on the points made in this report, that they are motivated to evaluate the status-quo within their organisation or industry and that they feel encouraged to engage in suitable improvement initiatives.

1.3 Scope
The science perspective explored in this report focusses on natural sciences, including ecology, chemistry and physics and particularly on the management of environmental effects of aquaculture activities related to natural sciences. To avoid confusion with wider interpretations of environmental effects, which also includes aspects such as natural character or amenity values, and to ensure consistency with previous work, the effects considered in this report are those often referred to as "ecological effects".

It is acknowledged that natural sciences are only one factor of environmental management within a wide range of social, economic, amenity and cultural considerations and values. Without examining any of these factors in detail, the intersect between science-based and values-based contributions to environmental management is a key theme throughout this report.
This report examines environmental management of marine aquaculture in New Zealand. It does not provide a comprehensive review of ecological effects, nor does it provide species-specific guidance. Instead, this report illustrates scientific challenges of and opportunities for the management of ecological effects relevant for all types of marine aquaculture in New Zealand. Many findings of this report are not unique to aquaculture and can be transferred to the management of other anthropogenic activities in the coastal marine area and even broader environmental management contexts.

The challenges and opportunities discussed in this report are not specific or confined to the current New Zealand legislative context. Instead, they focus on illustrating core challenges and identifying opportunities that could be implemented under the current regime or used to inform the development of new or modified environmental management regimes. Where this report refers to specific examples under the Resource Management Act 1991 ("RMA"), it primarily aims to illustrate challenges and opportunities related to the underlying concepts and processes rather than focussing on specific RMA provisions.

1.4 Report structure

Following a brief overview of New Zealand aquaculture and its ecological effects, this report is structured into three parts:

**Part one** explores the role of science in environmental management. It focusses on the intersection of facts- and values-based contributions to environmental management and the factors that influence the effectiveness of science in environmental management processes. This section takes a general perspective on environmental management and is not constrained to aquaculture. The challenges and opportunities discussed apply to the environmental management of aquaculture, other anthropogenic activities and even broader environmental management issues.

**Part two** focusses on specific scientific considerations that influence the management of ecological effects of marine farming activities. Many challenges in and opportunities for more effective environmental management of aquaculture apply equally to other activities in the coastal marine area; thus, some of the findings of this part can be transferred to other activities or used to inform wider environmental management questions. Some ideas presented in this part of the report relate to or build on the general concepts of integrating science in environmental management decision-making processes discussed in part one. In those instances, this part illustrates practical applications of these concepts.

**Part three** explores challenges and opportunities for improvement in the way that effects of activities are assessed and managed through assessments of environmental effects (AEEs), environmental monitoring and adaptive management. It concludes by presenting a proposed structure that could be used as a first step in developing a new framework for assessing and managing ecological effects of marine aquaculture.

This report concludes with some thoughts on scientific considerations for proposed resource management reforms.

1.5 Case studies and examples

This report uses case studies and examples to illustrate concepts and ideas discussed and to showcase projects or initiatives that represent novel or effective ways of supporting the management of ecological effects of marine farming activities. Case studies were selected based on the author’s awareness of projects or initiatives and participants’ willingness to share ideas and provide input. It is
acknowledged that other projects or initiatives exist that also could have been chosen. By selecting or not selecting case studies, the author does not express any preference or opinion on the projects or initiatives.

1.6 The importance of perspective and interpretation

Environmental management is an elusive concept that means different things to different people, particularly depending on the context and objectives for which it is used. Importantly, environmental management is not management of the environment but, instead, aims to manage and regulate people’s behaviours and activities that have effects on the environment. Environmental management is a complex interplay of science, planning, politics, economics, sociology and psychology, involving diverse groups of people who often feel strongly about the activities and environmental aspects at stake.

The diverse backgrounds and perspectives of those participating in environmental management processes also influences the use of language and the interpretation of language used by others. Many terms and concepts used and referred to in this report are well-understood and frequently used by those involved in environmental management. However, the meaning assigned to them may reflect the individual’s perspective, perception and experience and thus may differ from the meaning held by others.

The following section provides a glossary of important terms and concepts used in this report. It is not possible to provide definitions for all terms used in this report that may have different interpretations or associations. Readers are encouraged to approach interpretations of terms and illustrations of concepts with a positive open-mind and focus on the general ideas presented rather than on potential narrow meanings or interpretations.

1.7 Glossary

Effect is any effect as defined in s 3 of the RMA, including:

a) any positive or adverse effect; and
b) any temporary or permanent effect; and
c) any past, present, or future effect; and
d) any cumulative effect which arises over time or in combination with other effects regardless of the scale, intensity, duration, or frequency of the effect, and also includes:
e) any potential effect of high probability; and
f) any potential effect of low probability which has a high potential impact.

All of these effects are relevant for aquaculture activities. Importantly, effects can be positive (for example increased water filtration by farmed shellfish in eutrophic waters) or adverse (for example increased organic loading of sediments beneath finfish farms). While environmental management of effects predominantly addresses adverse effects, the term effect is used in a neutral way. Where it is important to specify adverse or positive effects and this is not apparent from the context, the terms positive effect or adverse effects are used.

This report focusses on what is typically described as “ecological” effects of activities, for example, effects on water quality, sediment fauna and biogeochemical properties, marine mammals or birds. Importantly, this report does not address effects on natural
character, landscapes or amenity values. In this report the terms “effect”, “ecological effect” and “environmental effect” are used interchangeably.

Participants in environmental management

Environmental management involves many participants. For activities in the public coastal marine area, such as aquaculture, it attracts much interest and thus can involve participants from diverse backgrounds and roles. Some parts of this report distinguish simply between scientists and non-scientists. In these instances, “non-scientist” refers to a person whose role in environmental management is different from the provision of scientific information or advice. For example, a non-scientist could be an environmental manager, industry member or member of the public with an interest the matter discussed. In other parts of the report, specific groups of non-scientists are referred to, typically based on their role in the environmental management process. The main groups considered in this report are marine farmers, aquaculture industry representative bodies, regulators (including regional and unitary councils, government departments and agencies), iwi, NGOs and the public (including local communities, environmental groups and other interested people).

Research is used interchangeably with science.

Science refers to natural sciences, including ecology, chemistry and physics. Science can be described as providing reliable, objective and verifiable knowledge about what exists or what is possible (Gillespie 2017). Implicit in scientific processes are the concepts of systematic and repeatable methodology, evidence, objectivity and accountability, induction, critical analysis, learning, professional independence, critical exposure to scrutiny, quality control by peer review and transparency (Gregory et al. 2006).

Scientific advice is understood as described by Marc Saner (2016) as “a question and answer (Q&A) process between requesters [typically environmental managers] and providers [scientists] of evidence (either individuals or committees). Granted, the process may vary from being highly structured, like an expert panel process, to highly unstructured, like the process for scientific advice during crises and emergencies. Nevertheless, advice is an answer to a question, which may be written or unwritten, formally requested or anticipated”.

Scientist Scientists are those who gather and provide scientific information. Scientists may be based at Universities, research institutes, NGOs, private companies, regional councils, central government departments, private consultancies or a wide range of other institutions or groups. Importantly, scientists are identified through their functional role, not through the institution they are associated with. In this report the term scientist is used for anybody whose role in the environmental management process is the provision of scientific information. Based on their institution scientists may focus on different aspects of science and may have different motivations for conducting science.
2 New Zealand marine aquaculture and its ecological effects

The main New Zealand aquaculture species are green-lipped mussels (*Perna canaliculus*), Pacific oysters (*Crassostrea giga*) and King Salmon (*Oncorhynchus tshawytscha*). Marine aquaculture takes place along the New Zealand coastline, mainly in sheltered bays (Figure 1).

Mussels are grown on continuous rope (long-lines) that is suspended from back-bone lines. Backbone lines are suspended in, or on top of, the water column by buoys and anchored to the seafloor at both ends. Crop lines are seeded with mussel spat (juvenile mussels) that are predominantly sourced from Ninety Mile Beach. Mussels feed on naturally occurring plankton. Oysters are grown on wooden racks and baskets or sticks in sheltered and shallow intertidal bays. Seed is caught from the wild, predominantly from the Kaipara harbour. Salmon are reared in land-based hatcheries and transferred to sea pens to grow out until harvest. They are fed an artificial diet. While historically much of the protein and oil in fish feed was sourced from wild fisheries, increasingly, land-based proteins are being used to substitute wild fish in feed.

In addition to the three main species, New Zealand also has growing industries in pāua and seaweed and other species, including kingfish, eels, geoduck clams, sponges and Hāpuku have been farmed or trialled as possible species of the future.¹

![Figure 1. Major aquaculture areas in New Zealand. Source: Aquaculture New Zealand²](image-url)

² [https://www.aquaculture.org.nz/industry/farming-areas/](https://www.aquaculture.org.nz/industry/farming-areas/)
This report takes a broad view of marine aquaculture in New Zealand and focusses primarily on overarching aspects of the environmental management of aquaculture that apply to all farmed species and cultivation methods. It does not provide species-specific guidance; however, it does refer to specific species, trophic levels or farming methods where appropriate or beneficial to highlight specific ecological effects or to illustrate general concepts through examples.

A recent comprehensive review of ecological effects of aquaculture in New Zealand was commissioned by the Ministry for Primary Industries (2013). Subsequent reviews adopted (with minor modifications) the main effects categories described by the Ministry for Primary Industries. An informative recent summary has been provided by Forrest and Hopkins (2017; Table 1).

Table 1. Categories of ecological effects of marine aquaculture activities and potential mechanism of effect. Reproduced in abbreviated form from Forrest and Hopkins (2017).

<table>
<thead>
<tr>
<th>Categories of ecological effects</th>
<th>Potential mechanisms of effect</th>
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<tbody>
<tr>
<td>Water column effects</td>
<td>Filtration, and plankton depletion or altered composition</td>
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<td></td>
<td>Nutrient enrichment &amp; harmful algal blooms</td>
</tr>
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<td></td>
<td>Dissolved oxygen depletion</td>
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<tr>
<td>Benthic effects</td>
<td>Organic enrichment (biodeposits, waste feed, biofouling drop-off)</td>
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<td></td>
<td>Crop loss or shell accumulation</td>
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<td>Physical disturbance</td>
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<td></td>
<td>Increased sedimentation, erosion or accretion</td>
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<td>Shading</td>
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<td>Marine mammal interactions</td>
<td>Entanglement</td>
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<td>Habitat exclusion or modification</td>
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<td></td>
<td>Attraction (e.g. to fish, farm waste, structure)</td>
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<td></td>
<td>Noise and lights</td>
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<tr>
<td>Seabird interactions</td>
<td>Entanglement</td>
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<td></td>
<td>Habitat exclusion or modification</td>
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<td></td>
<td>Attraction (e.g. to fish, farm waste, structure)</td>
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<td></td>
<td>Noise and lights</td>
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<tr>
<td>Wild fish interactions</td>
<td>Habitat exclusion or modification</td>
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<td></td>
<td>Attraction (e.g. to fish, farm waste, crop, structure)</td>
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<td></td>
<td>Noise and lights</td>
</tr>
<tr>
<td>Biosecurity</td>
<td>Introduction and spread of pests</td>
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<tr>
<td></td>
<td>Introduction and spread of disease (pathogens or parasites)</td>
</tr>
<tr>
<td></td>
<td>Status of species farmed (i.e. indigenous or not)</td>
</tr>
<tr>
<td>Escapee and genetic effects</td>
<td>Ecological effects of escapees</td>
</tr>
<tr>
<td></td>
<td>Changes to genetic structure/fitness of wild populations</td>
</tr>
<tr>
<td>Effects from additives</td>
<td>Use or release of chemicals &amp; therapeutants, including trace metals</td>
</tr>
<tr>
<td>Hydrodynamic alteration of flows</td>
<td>Impede or alter water currents or water column stratification</td>
</tr>
<tr>
<td></td>
<td>Wave dampening</td>
</tr>
</tbody>
</table>
3  Part 1: The role of science in environmental management

3.1  Introduction

This part of the report explores the role of science in environmental management. It focusses on the intersection of facts- and values-based contributions to environmental management and the factors that influence the effectiveness of science in environmental management processes. This section takes a general perspective on environmental management and is not constrained to aquaculture. The challenges and opportunities discussed apply to the environmental management of aquaculture, other anthropogenic activities and even broader environmental management issues.

There is general agreement that science plays an important role in environmental management. However, what exactly is science, what is its role in decision-making processes and how can the value of science in environmental management processes be maximised? When it comes to complex environmental issues, these questions are not easily answered. This can create uncertainty and disconnects between scientists and non-scientists that can diminish the effectiveness and value of science in environmental management processes.

The factors contributing to the disconnects between scientists and non-scientists are complex. This part of the report presents and examines four premises derived from relevant publications on the role of science in environmental management, policy and politics. While there are some overlaps among these premises and their underlying concepts, this serves to clarify and strengthen the ideas presented and recommendations developed. The premises are:

1. Public confidence in science has been declining in the era of "post-normal science"
2. The role of science in environmental management is uncertain
3. There is limited awareness of what research can and cannot deliver for environmental management
4. Scientists must choose their role in policy and politics

These four premises are explored in section 3.2, followed by a summary and identification of opportunities and recommendations in section 3.3.

3.2  Premises

3.2.1  Public confidence in science has been declining in the era of "post-normal science"

The complexity of modern environmental management issues is unprecedented. The questions society needs answered and the solutions it needs to be offered are unlike anything it has ever had to deal with previously (Gillespie 2017).

For most of the 20th century, there were plenty of unambiguously dangerous environmental management issues for which low cost solutions could be identified by scientists and implemented by environmental managers without adversely affecting other objectives (Gregory et al. 2006a). It was easy to identify threshold levels that separated safe conditions from unsafe ones. In those circumstances, science-based environmental management was relatively simple and enjoyed both technical defensibility and widespread support (Gregory et al. 2006a).

In the last 30 to 40 years, environmental management issues and the subsequent demands of science have changed rapidly and substantially (Gillespie 2017; Gregory et al. 2006a; Pielke 2007). Challenges faced by environmental managers, such as ensuring safe drinking water, environmentally sustainable food production or mitigating climate change, have become increasingly complex, technically complicated, costly and often have strong emotional and ethical elements. Environmental
management decisions involve difficult and controversial trade-offs among competing ecological, health, and socio-economic objectives (Gregory et al. 2006a). Most improvements can only be achieved at the expense of other objectives, either because they are directly in conflict or because they take resources away from other needs (Gregory et al. 2006a).

Funtowicz and Ravetz (1993) were the first to assign the new state of science required in this context the term “post-normal science”. In the era of “post-normal science”, the leading scientific problems are thrown up by issues that are characterised by uncertain facts, disputes in values, high stakes and urgent decisions (Funtowicz and Ravetz 1993). This induced a shift in the role of science in environmental management. Sir Peter Gluckman, in his role as New Zealand’s Chief Science Advisor, describes post-normal science as:

...characterised by research in areas of high public interest and urgency meaning that it inevitably must intersect with diverse and often irreconcilable individual and societal values which are reflected in deeply entrenched debates in which these values are in dispute. (Gluckman 2015a, p.2)

While the era of post-normal science has seen the emergence of unprecedented scientific technological and methodological capabilities embracing uncertainties, complex systems and interdisciplinary approaches, it has also seen a decline of public confidence in science globally and in New Zealand (Gillespie 2017). The intersect of relatively values-free science and the values-rich use of science created challenges for scientists and the public they ultimately serve, creating major societal issues in thinking about trust in science and scientists (Gluckman 2015b).

In New Zealand, the declining public confidence in science has been attributed to four causes (Gillespie 2017). Firstly, science had, on occasion, been manipulated for economic gain or to prevent new environmental rules. Secondly, there has been a lack of robust science responses to some public health concerns, for example in the debates about folic acid supplementation in bread or fluoride in public water supply. The remaining causes represent more insidious difficulties in environmental management processes that were exposed in a 2010 review of agencies engaged in the production of policy advice (conducted by a committee appointed by the Government to review expenditure on policy advice and supplementary reports by Sir Peter Gluckman; Gluckman 2011, 2013; Graham et al. 2011). These include a general theme of a “silo effect” in New Zealand, characterised by little to no communication across (and within) the public and private science providers, resulting in overlapping yet uncoordinated research priorities, little quality control on research, disconnects between evidence and policy formation, no standard processes for research purchase and a lack of best practice approaches to peer-review on both starting the research and reviewing its conclusions (Gluckman 2011). As the final and fourth cause of the declining public confidence in science, Gillespie (2017) identified instances of misuse of science for advocacy to avoid real debate on underlying values issues. On this aspect, Sir Peter Gluckman further described that:

There have been too many examples where appealing to apparently confused science masks what is in fact a policy or ideological debate (for example, exploiting scientific uncertainty to justify inaction on climate change). This has been termed the ‘misuse of science as a proxy for a values debate’. Such misalignment can only undermine confidence in both science and policy formation. (Gluckman 2013, p.10)

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3 See Gillespie (2017) page 5 for examples
The role of science in environmental management is uncertain

There is a lot of uncertainty and confusion among environmental managers on how to effectively integrate science into environmental management. While most agree that science plays an important role, it is common for environmental managers to either ask too much of science (Gregory et al. 2006a) or keep science in a subsidiary position (Gillespie 2017). Both overemphasising and relegating science diminishes the effectiveness of the science contribution and thus creates challenges for environmental management.

When faced with complex environmental management issues, some call for more and better science to develop acceptable management strategies (Gregory et al. 2006a). This approach reflects the science-based management of most of the 20th century, when environmental management issues were simple, and science-based solutions were easily found and generally accepted. In the context of complex environmental management issues, however, an over-reliance on science is not effective because it is asking more from science than it can deliver (Gregory et al. 2006a). Such issues require good decisions. Science informs and thus makes important contributions to environmental management. However, “science does not and fundamentally cannot decide” (Gregory et al. 2006a). Furthermore, calls for more science can be an attempt to divert from a reluctance to make tough decisions, which can have important consequences, including delaying decisions, avoiding public discussions of values-based decision factors and spending resources on more science instead of potentially more effective tasks (Gregory et al. 2006a; Montz and Dixon 1993).

Conversely, the role of science in environmental management decision-making processes is often relegated (Gillespie 2017). This can be a consequence of the distrust in science, exacerbated by often limited understanding by decision-makers of what science can and cannot deliver. For example, in a survey of 17 government agencies, Sir Peter Gluckman found that “some officials had limited understanding of the scientific process of knowledge production or were uncertain about it. In addition, they were not clear on how research to inform policy development without sufficient understanding of the role of science is often called for more and better science (Gregory et al. 2006a; Montz and Dixon 1993).

Further contributing to the uncertainty of the role of science is frequent miscommunication and misunderstanding between scientists and non-scientists. For example, during policy development, decision-makers may call for “the science” on a certain issue without elaborating on the wider context, articulating specific questions or explaining what it is they require or expect. This ambiguity creates difficulties for scientists in providing valuable information. On the other hand, scientists may conduct research to inform policy development without sufficient understanding of the environmental management processes or without understanding what science deliverables would be of value to policy staff. Both scenarios can lead to frustrations by both scientists and non-scientists, leading to increasingly ineffective communication and thus science contribution to environmental management.

There is limited awareness of what research can and cannot deliver for environmental management

When non-scientists request research or scientists embark on research to fill gaps in knowledge or understanding, they need to be aware of what research can and cannot deliver for environmental management. A lack of awareness or consideration of the capabilities and limitations of research can lead to a mismatch between the expectations placed on science and the relevance, value and robustness of scientific information that can be obtained. Both scientists and non-scientists contribute

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4 In this section the term research is used for consistency with the literature. In the context of this report, the term research is used interchangeably with the term science.
to such mismatches. This section describes three main types of research based on a classification presented by Donald Stokes who introduced the term “use-inspired basic research”. The aim of this section is to illustrate the core characteristics of and differences between these types of research, highlight what they can and cannot deliver and identify challenges related to research aimed at informing complex environmental management decision-making.

Donald Stokes divided research into three types and illustrated them in his quadrant model of scientific research based on the extent to which research is inspired by a quest for fundamental understanding and consideration of use (Figure 2; Stokes 1997). At the time Stokes developed his classification, research was generally classified as either “basic” research, referring to curiosity-driven research aimed at developing general knowledge, or “applied” research, goal-driven research aimed at meeting specific objectives. Stokes put forward that research projects can have both high basic and applied research potential and introduced a third category of “use-inspired” basic research. Use-inspired basic research has become increasingly popular and well-known in environmental management globally and in New Zealand. However, as outlined in this section, there are challenges associated with this approach that require attention to ensure existing and proposed research projects deliver the benefits that are expected of them.

Pure basic research (basic research) is guided by the quest for understanding without thought of practical use. Stokes calls this quadrant Bohr’s quadrant after Niels Bohr’s research of atomic structure that was purely driven by curiosity. A core characteristic of basic research is that it represents a “voyage of discovery” (Stokes 1997). Scientists undertaking basic research therefore cannot be constrained by expectations on the applicability or usefulness of their research. Basic research as described by Stokes has led to the discovery of fundamental knowledge that underpins environmental management, such as core knowledge of ecosystem function. Basic research is essential; however, it generally has no place in environmental management where research projects aim to develop solutions or derive targeted information.

Applied research is guided solely by an applied objective. This quadrant is also called Edison’s quadrant after Edison’s industrial research into commercially profitable electric lightning. Applied research can be extremely sophisticated but tends to be narrowly targeted and focussed on immediate goals. In the environmental management context, requests for applied research are the most common requests by non-scientists. For example, a request for research to inform setting maximum allowable nitrogen discharge limits from finfish aquaculture would require sophisticated research with a strong focus on the narrow objective of identifying a single value that can be used in policy formation or conditions of resource consents.

![Figure 2. Stokes’ quadrant model of scientific research. Reproduced from Stokes (1997, p.73).](image)
Stokes introduced the upper right-hand quadrant as use-inspired research. This is research that aims to extend our understanding and is also inspired by consideration of use. This quadrant is also known as Pasteur’s quadrant after Pasteur whose finding that fermentation was caused by bacteria led to discoveries about vaccinations. This area of research has become increasingly popular and diverse and includes numerous strategic and mission-led research projects, such as the National Science Challenges. This area of research is well suited to addressing complex environmental management challenges.

Stokes makes the important observation that “the sharper focus of working scientists on understanding and of their sponsors on use is a conspicuous element of a system that involves heavy government support” (Stokes 1997). While scientists are becoming increasingly confident and willing to conduct research targeted at a specific use, many are more motivated by enhancing general understanding in their field of research than by developing specific solutions to environmental management problems. This can lead to conscious or unconscious bias during their research. During a research project, constraints on time and resources require constant decision-making, reprioritisation and compromise. Conscious or unconscious bias thus creates the risk that the focus of research projects gradually shifts disproportionately towards enhancing general understanding, taking resources and focus away from tasks aimed at creating practical research outputs.

At the same time, funders and other beneficiaries of research projects, such as environmental managers, often place a disproportionate emphasis on practical research outputs. They may be unaware of or choose to overlook the inherent uncertainty of the research process and what science can and cannot deliver. They may not have the ability to or chose not to engage in the research process and thus may not be aware until it is too late that a research project does not deliver what they expected.

For use-inspired research to meet expectations of all involved requires considered communication, clarity and honesty. The often-diverging expectations on research projects that aim to address the complex environmental management challenges of today must be acknowledged and well managed. It is argued that there is room for improvement on these matters and that use-inspired research currently is the area of research most vulnerable to misunderstandings and conflicting expectations between scientists and non-scientists. Better mutual understanding of needs and constraints, meaningful involvement of environmental managers and more transparency on what can and cannot be achieved is essential.

While the Stokes model of scientific research is an over simplistic representation of the modern research context, it illustrates the core characteristics of and differences between the main types of research. Importantly, examining Stokes classifications provided for the identification of specific considerations that hinder effective research for environmental management purposes.

3.2.4 Scientists must choose their role in policy and politics

Scientists can play different roles in environmental management processes. Roger Pielke describes four idealised roles of science (or scientists) in policy and politics and introduces a framework for determining the most effective role for science in an environmental management issue based on the decision context (Pielke 2007). He reasons that the relevant decision context can be described by two factors; firstly, the diversity of values involved and, secondly, the level of uncertainty.

The four roles of scientists are Pure Scientist, Science Arbiter, Issue Advocate and Honest Broker of Policy Alternatives. Pielke emphasises that all four roles are important and necessary in a functioning democracy and that scientists can choose their role. However, he also stresses that scientists have to
choose a role and with it how they relate to the decision-making process. Knowing how to make appropriate choices and understanding the consequences of such choices is critical for scientists.

This section provides a summary of these idealised roles, their characteristics, Pielke’s framework and views presented by Sir Peter Gluckman on the place for science in societal decision-making and public policy making.

**The four idealised roles of science in policy and politics**

According to Pielke, the Pure Scientist focuses on generating knowledge without any consideration for its use of utility. Research findings add to a reservoir of knowledge that others can access and use to clarify and argue their interests. In its purest form the Pure Scientist has no direct connection with decision-makers and is removed from policy and political processes.

The Science Arbiter provides specific information to a decision-maker, typically in form of answers to factual questions that the decision-maker considers relevant. They serve as a resource to the decision-maker for information but do not attempt to influence the decision-maker on what he or she ought to prefer.

The Issues Advocate aligns himself or herself with a group that seeks to advance its interests through policy and politics and focuses on the use of research findings for a particular policy or political agenda. Issues Advocates consider it important that scientists engage with decision makers. They are willing to take sides on political issues and use their status as scientist to argue for their cause.

The Honest Broker of Policy Alternatives focuses on expanding (or at least clarifying) the scope of choice for decision-makers. They explicitly engage with decision alternatives and provide information that allows the decision-maker to reduce their choice based on his or her values and preferences. They are not concerned with a specific decision but serve as an information resource. In contrast to the Issues Advocate, the Honest Broker of Policy Alternatives presents information on a range of choices without indicating their own preference while the Issues Advocate selects information to support their own preferred choice.

Pielke makes some cautious remarks about the role of Issues Advocate. He comments that when scientists align themselves with political causes as Issues Advocate, they may be viewed as an instrument of politics. This may negatively affect their scientific credibility, which is problematic if scientific information is critical to making decisions on alternative causes of action. While this does not diminish the importance of the Issues Advocate, Pielke cautions that issue advocacy should always be complemented by scientists acting in the other roles. Difficulties arise when scientists who describe their role as Pure Scientist of Science Arbiter in reality use their scientific authority as a tool of advocacy. This threaten the scientific enterprise as a whole as it undermines scientific integrity.

**Framework for determining the most effective role of science**

Pielke’s framework provides criteria that can help determine what role scientists should play in different decision contexts in order to contribute productively to effective decision-making (Figure 3). He argues that there are two critical factors that scientists or organisations must consider when faced with a decision on how to engage with policy and politics.

The first factor is the level of values consensus on the issue up for decision. If there is broad consensus on values, science and scientists can play a positive role by providing scientific information without engaging with decision-makers, that is as in the role of Science Arbiter or Pure Scientist.

If issues are controversial with conflicting values, policy advocates tend to use scientific information as a support for arguing for their preferred decision outcome. In such situations, scientists acting as Pure
Scientists or Science Arbiter are less likely to contribute to effective decision-making. Even worse, contributing in these roles is likely to foster the politicisation of science because it allows decision-makers to cherry pick scientific information that supports their cause. For these reasons, if the decision context is characterised by values conflict, it is most effective for scientists to associate science information explicitly with choice by taking on the role of Issues Advocate or Honest Broker of Policy Alternatives. While the Issues Advocate presents the decision-maker with one choice, their preferred choice, The Honest Broker of Policy Alternatives provides a broader set of options that is independent of their personal preference.

The second factor to consider when deciding how scientists should engage with policy and politics is the level of uncertainty, both scientific and political, in the decision context. Pielke argues that the greater the uncertainty, the more science should focus on policy options (reducing the scope of choice) rather than just factual scientific information.

The concept of uncertainty in environmental management is complex and it is important to distinguish scientific uncertainty from uncertainty associated with the outcome of decisions. Scientific uncertainty is part of the scientific process. Improving knowledge through science is often interpreted as being synonymous to reducing uncertainty. Science cannot prove a negative, which means that scientists can never be “100% certain” that something is risk free or safe. Also, scientists are always open to the possibility that new research could change the current understanding. It is generally acknowledged that this flexibility of approach is one of science’s great strengths.

In policy or political decision-making, a different type of uncertainty is addressed. When decisions have to be made in a policy or political context, the most important uncertainty is that associated with the outcome of the decision. In some cases, reducing scientific uncertainty can reduce uncertainty with decision outcomes. For example, if a decision must be made on a nitrogen discharge limit for a fish farm, reducing scientific uncertainty on the carrying capacity of the receiving water body will assist in decision-making because it reduces the uncertainty of decision outcomes. However, if a decision must be made on whether or not removal of a small patch of mangroves adjacent to a coastal development should be allowed, reducing scientific uncertainty on the ecological effects of removing this patch of mangroves offers little contribution to the fundamental conflict over the values of mangrove removal at a specific location. In such situations, factors beyond science are likely to be the most important factors in decision-making.

![Figure 3](image_url). Flow chart illustrating the logic of roles for scientists in policy and politics. Reproduced from Pielke (2007, p.19).
Sir Peter Gluckman on the role of scientists in the public arena

Sir Peter Gluckman also commented on the two roles of scientists he refers to as the outward facing constructs: the Issue Advocate and the Honest Broker (Gluckman 2015b). His comments elaborate on the concepts discussed in this section and apply them to the specific New Zealand science context. The remainder of this section is a summary of Sir Peter Gluckman’s commentary titled “Trusting the scientist” (Gluckman 2015b).

Sir Peter Gluckman encourages scientists to play the role of Issue Advocate in the public arena to elevate issues in the public mind. However, he notes the difficulty this can create when the boundaries are blurred between presenting scientific consensus and actively advocating. Scientists allowing this distinction to be lost may compromise the integrity of their science and undermine its potential input into policy. Acknowledging the right of scientists to be active and engaged actors in issues about which they feel strongly, he identifies the challenge to manage the tension that may arise between their private and public faces.

When acting as science advisor, however, scientists are expected to take on the role of Honest Broker, whether in form of committees or individuals. In this role scientists can provide independent advice by trying to identify and overcome biases to present what is known, what is not known, the scientific consensus, the implications for policy and action and the trade-offs of various options.

Sir Peter Gluckman emphasises that these distinctions are not new but that they have become more important in the wider public discourse. He further illustrated his views by quoting from a cover story by Washington Post science writer Joel Achenbach in the National Geographic Magazine, that deals with public mistrust of science and highlights the thoughts of noted science communicators:

Some environmental activists want scientists to emerge from their ivory towers and get more involved in policy battles. Any scientist going that route needs to do so carefully. That line between science communication and advocacy is very hard to step back from. In the debate over climate change the central allegation of the skeptics is that the science saying it’s real and a serious threat is politically tinged, driven by environmental activism and not hard data. That is not true and it slanders honest scientists. But it becomes more likely to be seen as plausible if scientists go beyond their professional expertise and begin advocating specific policies.

Sir Peter Gluckman also reflects on how the professional roles of scientists affects their ability to follow their research preferences and speak out on scientific issues. He notes that for himself and government departmental science advisors, the roles and obligations as scientists are clear. In these roles, scientists must act as Honest Brokers. He further comments that scientists employed by government agencies are bound by the rules of State Services that usually require managerial approval to communicate their research outside of their workplace. While Sir Peter Gluckman does not refer to scientists in local government, it is important to point out that similar organisational rules apply to scientists employed in regional councils.

Sir Peter Gluckman contrasts this to university academics, who operate under the principle of academic freedom that is protected in New Zealand law. He remarks on the bounds of academic freedom created through the provisions of research ethics, scientific integrity and the function of peer review and comments positively on the value society places on academic freedom and that, in general, New Zealand university staff have neither abused it nor ignored it and therefore enjoy high profiles in the media. He does, however, point to growing evidence that university press offices over-emphasise research success stories and that this can undermine public confidence in the science and the scientist.
He also comments on the risk of distrust that can arise when university academics are engaged by the government in advisory roles but express inconsistent views as part of advisory processes compared to what they say in public. The greatest emergent issue for academics identified by Sir Peter Gluckman is real or perceived conflict of interest. This is common in small countries and can usually be handled through transparency. The most complex conflicts of interest tend to arise because of funding sources. This is a complex area and Sir Peter Gluckman states that the increasing dependence of academics on co-funding makes them an easy target for criticism.

Sir Peter Gluckman then refers to the half of New Zealand’s publicly funded scientists who work in government owned research institutes outside the university sector. Crown Research Institutes (CRIs) were set up as state owned companies with the multiple missions of conducting research needed by the government, public good research, supporting and assisting private sector research and making a return on investment. He observes that this diversity of roles can create tensions and angst. He comments that some CRI scientists would prefer the academic freedom university scientists have but that legally this is not provided for.

Sir Peter Gluckman raises that CRIs may have become too risk adverse in regard to their public role and that it might be time for them to encourage their staff to engage more in public communication, particularly in the role of Honest Broker. He notes that acting as Issue Advocate would not be appropriate given the mix of functions CRIs perform but stresses the benefits of enhancing the public sharing of expertise.

In summary, Sir Peter Gluckman argues that science ultimately depends on trust and integrity. Scientists want to be active and engaged members of society but when they use their position to speak to governments or to the public, they need to try and be Honest Brokers of knowledge. Those who want to take on an advocacy role, must clearly state their vested interests. Those who wish to advance a cause that extends beyond their limits of expertise have this right as citizens. As scientists, however, they have a responsibility to the public to position their comments appropriately.

### 3.2.5 Summary of premises and identified challenges

By looking at the role of and expectations on science in environmental management from a range of perspectives, the previous section provided insights into various roles science can play and factors that facilitate or create obstacles for effective environmental management. There have been many examples of successful integration of science in environmental management processes in New Zealand. However, it is clear that there remain challenges for scientists and non-scientists in ensuring that the role of science is better understood, trusted and more consistently and effectively implemented.

The first premise described in the previous section relates to the shifting role of science as environmental management issues have become increasingly complex, technically complicated, costly and involve strong emotional and ethical elements. This era of post-normal science has seen a decline of public confidence in science. It has created challenges for scientists and non-scientists in working with each other and with the public and has the potential to undermine confidence in both science and policy formation.

Secondly, the focus was placed on how science is taken into consideration in environmental management processes. It is apparent that there is uncertainty and confusion among environmental managers on how to effectively integrate science in environmental management with some asking too much of science and others relegating science. Both overemphasising or relegating science in environmental management create challenges and diminishes the effectiveness of science in environmental management. Scientists contribute to these issues if they conduct science with the aim
of supporting environmental management without adequate understanding of how to produce and deliver valuable scientific information.

The third premise raised that there is a limited awareness of what science can deliver for environmental management. A lack of awareness of the inherent differences between different types of research can lead to a mismatch between the expectations placed on science and the relevance, value and robustness of scientific information obtained. Emphasis was placed on the fact that both scientists and non-scientists contribute to such mismatches. An important conclusion was that, while use-inspired research is the area of research well suited to addressing complex environmental management challenges, it is also the one most vulnerable to misunderstandings and conflicting expectations between scientists and non-scientists.

Finally, Roger Pielke’s four idealised roles of science in policy and politics were introduced as well as his framework for determining the most effective role for a particular environmental management issue. The central theme of Pielke’s concept is that scientists have choices about if and how they engage in policy and politics and that the main factors determining which science role is most effective, are the level of values consensus and uncertainty in the decision context. He cautions that if scientists align themselves to a political cause and act as Issue Advocates, they are at risk of being viewed as an instrument of politics. This caution is echoed by Sir Peter Gluckman who emphasises that science ultimately depends on trust and integrity. Sir Peter Gluckman calls on scientists who use their position to speak to governments or to the public, they need to try and be Honest Brokers of knowledge.

3.3 Opportunities and recommendations for improving the effective integration of science in environmental management

Improving the effective integration of science in environmental management can take on many different forms. The approach recommended here focusses on three core goals:

1. Increase public confidence in science
2. Clarify the role of science in environmental management
3. Increase the mutual understanding between scientists and non-scientists

The remainder of this first part of the report describes these goals and supports them through practical recommendations. These recommendations are intended as stimuli for further explorations and discussions. It is hoped that some are picked up within organisations and used to inform improvements that ultimately lead to better environmental outcomes.

3.3.1 Goal 1: Increase public confidence in science

Regaining and strengthening public confidence in science is essential for building and reinforcing effective science contributions to environmental management. Efforts to increase public confidence in science have been made, primarily through the creation of institutional mechanisms that allow for the provision of (as much as possible) objective advice that can be relied upon by decision-makers and not dismissed as being “partisan, quack or relative” (Gillespie 2017). These efforts focused on making science an Honest Broker, taking on the role as outlined in section 3.2.4 and include the creation of codes of conduct, aimed at promoting the quality and integrity of science and scientific processes (Gillespie 2017).

What exact mechanisms are appropriate and effective for a specific institution depends on the institutional role, structure, culture, processes and willingness to enhance the effectiveness of science contribution to environmental management decision-making. Independent of such considerations, Gillespie (2017) presents four principles that need to be achieved for science to be trusted and for its
role to be lifted from a subsidiary position when dealing with policy problems: robustness of scientific work, preparation by leading experts, transparency and peer review. Furthermore, he calls for influential advocates, or guardians, to be created around decision-makers who ensure that these principles are built into scientific processes within institutions.

While Gillespie (2017) focuses primarily on the role of science in policy formation, the principles he introduces are generic and broadly applicable in the environmental management context. Here these principles are introduced and discussed. How they are best applied to a process or an environmental management issue needs to be determined on a case-by-case basis, but some general recommendations are made to overcome challenges and facilitate their uptake and thus to make them effective instruments for increasing public confidence in science.

First principle: all scientific work must be robust

The first principle is that all scientific work must be robust. For science to be robust it must be authentic and created with integrity and critical to achieving this is to remove conflicts of interest (Gillespie 2017). While these goals are generally accepted and agreed to, there is a lack of specific guidance for government entities on how to achieve these principles in the areas they govern (Gillespie 2017). Furthermore, many institutions, including central and local government and scientific organisations, are lacking clear procedures and safeguards that ensure adherence to this principle.

Second principle: scientific advice to decision-makers should be prepared by leading experts in their respective fields

The second principle is scientific advice to decision-makers should be prepared by leading experts in their respective fields. Gillespie (2017) emphasises that groups assembled to prepare such advice should not comprise only those who agree with each other. Instead, they should be inclusive, including, where possible, respectable dissenting views of other experts. The key criterion is the status of expert, which is associated with the scientist, not the institution they work for or are associated with. For this reason, Gillespie (2017) states that expertise should be sourced from wherever the right people can be found, including governmental, academic, non-government and/or commercial sources.

Adhering to this principle can create challenges for those seeking expertise. One challenge is the difficulty of accessing subject-matter experts. For many scientific areas the number of experts in New Zealand is limited and it would not be possible for them to be involved in all environmental management processes related to their field of expertise. For example, there are a very few scientists with expertise in coastal and marine water quality, however, the number and complexity of environmental management issues requiring such expertise, including marine aquaculture, is increasing. A second challenge arises when experts work in organisations that are not set up for them to support environmental management processes outside their organisation or region. This is typically the case for regional councils who employ a large proportion of New Zealand’s scientists with expertise and experience in both research and environmental management. While regional council scientists can support national environmental management initiatives, for example as members of technical advisory groups for central government agencies, their availability is typically limited. Furthermore, it is less common for them to provide input into environmental management initiatives in other regions or to support other agencies.

Finally, identifying what expertise is required for a specific environmental management issue is not trivial. It is relatively straightforward to identify technical experts; however, in environmental management, expertise often requires both technical expertise as well as understanding of the
regulatory context. The pool of experts who span these areas of expertise is small for many environmental management issues in New Zealand and this creates difficulties for achieving good environmental outcomes.

**Third principle: Peer review**

The third principle is peer review. Gillespie (2017) describes peer review of scientific work as “a rigorous review and critique of a study’s methods, results and findings by others in the field with the requisite training and expertise”. He claims that peer review processes within science policy in New Zealand are inconsistent and that practices range from poor to excellent. He further describes that peer review is often watered down by debates over whether it is required to be done externally of the organisation commissioning the work (for example a ministry) and whether it needs to apply to all scientific information or just aspects that are complex, novel and/or contentious. A further problem with peer review for quality assurance in New Zealand is the limited pool of people of calibre to do peer review and conflicts of interest. Gillespie (2017) states that “there is often a revolving door between those being awarded work and those doing peer review”. This is a relevant problem for many coastal and marine environment management issues, including aquaculture.

Gillespie (2017) concludes that New Zealand would benefit from improved standards of peer review across most sectors. The need for improved standardised peer review processes has recently also been identified in reviews of the use of models in environmental decision-making (Özkundakci et al. 2018; Parliamentary Commissioner for the Environment 2018). The Parliamentary Commissioner for the Environment reviewed the model Overseer and investigated the model’s fitness for purpose in a regulatory context. He identified that there has only been limited peer review of model components, which means that those using Overseer to inform their decision-making have limited reassurance that they are utilising the best available scientific information and that they are incorporating it appropriately. He also highlighted specific obstacles to conducting peer review of models, including that data used for model development and parameterisation are often not readily available for peer review and that the way data have been used can be unclear. Özkundakci et al. (2018) identified that the typical focus of scientific peer review on criteria related to novelty and originality creates additional limitation and that in instances where models are used to inform environmental decision-making, peer review should include factors such as model quality and suitability. They also pointed to the difficulty related to access to information for peer review, particularly when proprietary models instead of “open source” models are used.

**Fourth principle: Transparency**

The fourth principle is transparency. Gillespie (2017) states that scientific investigations should be undertaken as openly as possible and findings should be communicated fully and openly by the scientific and technological community. He observes that New Zealand understands the importance of transparency in the science and policy-making framework and is doing relatively well regarding the wider issues of transparency. Gillespie acknowledges that Sir Peter Gluckman called for greater transparency on the use of research-informed data (or its absence) in areas of complex and controversial decision-making where the public is directly or indirectly consulted (Gluckman 2013). Whether or not an organisation is genuine about transparency depends on their commitment to following through on declarations of intent by actually sharing data and relevant information. As Gillespie (2017) emphasises, transparency does not only require deliberations but also raw data to be available for review.
Recommendations

It is recommended that institutions review their internal procedures and protocols against these four principles and identify areas in which they, their scientists and their decision-makers, are acting (knowingly or unknowingly) in ways that are inconsistent or in breach with them. If no procedures or protocols exist, they may be vulnerable to inadvertently undermining public confidence in science. Ideally, this review should be conducted by an independent person with input from a diverse range of participants in environmental management processes. It should take a strong focus on identifying opportunities for practical solutions, best practice and implementation guidance.

New Zealand has several relevant and useful codes of conducts and guidelines that, even if not required to, organisations could use as starting points for developing fit-for-purpose protocols. Examples include:

- Environment Court of New Zealand Expert Witness Code of Conduct⁵
- Royal Society Te Apārangi Code of Professional Standards and Ethics in Science, Technology, and the Humanities⁶
- Code of conduct for the State Services - Standards of Integrity and Conduct⁷

3.3.2 Goal 2: Clarify the role of science in environmental management

Clarifying the role of science in environmental management processes within organisations is critical for improving the effectiveness of science in these processes. As stated by Gregory et al. (2006a):

> without closer attention to the requirements of an effective decision-making process, for which there are increasingly clear guidelines and best practices, it is simply not possible for science to do its job as part of environmental risk management debates (p. 733).

While this needs to be tailored for each organisation, there are some general aspects of decision-making processes that apply broadly and can be used as overarching frameworks for tailored institutional processes.

Gregory et al. (2006a) describe the core steps of decision-making as:

1. Define the context for the decision: the question or problem being addressed, why it is important, who needs to be involved, and relevant timelines and budgets.
2. Clarify the objectives or “ends” of the decision and the attributes or specific metrics used to measure progress toward them.
3. Identify a range of alternatives for achieving these objectives.
4. Examine consequences of the alternatives, including the associated uncertainties.
5. Explore trade-offs and make recommendations or choices that reflect the values and preferences of stakeholders.

They further summarise that making good decisions requires (at least) three things: good information about facts, good information about values and a process for integrating facts and values.

Good information about facts includes information about the current state and anticipated consequences of proposed actions. In this area science plays an important role and both Pielke’s framework for determining the most effective role of science and Pasteur’s quadrant model of

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scientific research can assist in making decisions on how to obtain the most appropriate and valuable scientific information.

Good information about values is about knowing what matters to us individually and as members of our families, local communities, regions or nations and what our priorities and preferences are for different outcomes of the decision-making process. In this process science has no special expertise and the only role scientists can play is the same as any other stakeholder. The values expressed by scientists are no more or less legitimate than those of other stakeholders and it is no easier or harder for scientists to understand and express their values than it is for any of the other stakeholders.

The critical third requirement of making good decisions is a process for integrating facts and values. Good decision-making is fostered through the interaction of these variables and there is a need to more carefully define the intersection of the facts- and values-based contributions to decision-making (Gregory et al. 2006a; Saner 2007). There is a plethora of literature on how this could be achieved but a review of decision-making concepts and methodologies is out of scope of this report. Most importantly, what works for one organisation may not work for another, especially when it comes to practical environmental management processes. The important principle to follow when reviewing existing or developing new decision-making processes in an organisation is to consider the relative emphasis placed on facts-based (i.e. scientific) and values-based considerations. Science should not be over-emphasised or relegated. Whether or not its contribution is appropriate should be determined by a diverse group of environmental management participants and tested in scenarios the organisation may encounter.

Once an organisation has developed good processes for integrating science in environmental management decision-making, these should be documented in standards, guidelines or protocols. For example, standard protocols could be developed on how requests for scientific information are made by those working on policy formation, how science is scoped, delivered and peer reviewed and how it is considered in decision-making alongside values-based contributions. Importantly, formal review of these processes by all involved would assist in identifying aspects that worked well and those that require improvement. This would create a culture of continuous improvement with increasingly effective environmental management decision-making processes.

3.3.3 Goal 3: Increase mutual understanding between scientists and non-scientists

In most instances, scientists and non-scientist do what they believe is best for environmental management outcomes. However, if they are not supported and developed in obtaining good awareness and understanding of relevant components of the environmental management process, including the capabilities and constraints of other participants, they cannot be expected to effectively contribute to decision-making. Understanding that good environmental management decision-making occurs at the borders between disciplines and therefore requires cross-disciplinary understanding of decision-makers and key participants is critical for individuals and organisations engaged in environmental management.

Increasing the mutual understanding between scientists and non-scientists to develop more knowledge of and empathy for their respective roles is a good place to start for organisations which are willing to address and improve the effectiveness of science in environmental decision-making. This is an area in which significant improvements can be made through practical initiatives, comprising both training and procedural elements.

One important aspect is communication. Both scientists and regulators have the tendency to use discipline-specific jargon and terminology or fail to identify clear goals for their communication, including what others need to know. Especially when working in the same organisation, both may
overestimate what other people know about a subject and may not provide appropriate opportunity for others to clarify information. Despite working on the same environmental management issue, scientists and regulators need to be aware that the methods they use to understand the world are different to each other’s and unlike the ways the public typically thinks about them. Scientific information is inherently insufficient, ambiguous and uncertain and conclusions can change over time as new information emerges. Scientists need to understand and acknowledge that this can unsettle non-scientists and create barriers to communication and understanding. Non-scientists need to ask appropriate and specific questions that allow scientists to provide targeted information and advice.

Effective communication will naturally lead to improved mutual understanding as people obtain meaningful information and feel comfortable asking for clarification. However, in addition, training and development on fundamental aspects of environmental management processes and scientific approaches are effective in reducing misunderstandings and improving effective information exchanges. For example, research scientists benefit from training on environmental management processes, including RMA requirements and how their scientific information is used in the decision-making process. Decision-makers benefit from training on relevant aspects of scientific methodologies to better understand what science can and cannot deliver. An important matter that frequently creates difficulties in policy development processes is insufficient allocation of time for science to be conducted and delivered so that it can meaningful contribute to policy development. Engaging in cross-technical (science-policy) conversations early in the policy development process benefits mutual understanding of objectives and requirements and thus creates opportunities for more robust and effective science contributions.

Within and across organisations it can be valuable to provide opportunities for people to work alongside people in other roles to experience projects and processes from their perspective. This would develop understanding and empathy and would be helpful in learning about how their own contributions are viewed and incorporated by others.

There are many more opportunities to improve mutual understanding between scientists and non-scientists and appropriate ones are best identified within organisations by those who affected. Involving scientists and non-scientists in the identification of initiatives will be critical to ensure they are meaningful, practical and supported.

To ensure such initiatives are not only one-offs that lose momentum over time, they should be embedded in organisations and individual’s position descriptions. They should not be considered a “nice to have” and thus be at risk of being neglected when times get busy but become engrained in the core aspects of the roles of those involved in environmental management decision-making.
4 Part 2: Scientific considerations, challenges and opportunities affecting the management of ecological effects of marine aquaculture

4.1 Introduction
This part of the report focuses on specific scientific considerations that influence the management of ecological effects of marine farming activities. The coastal marine area is a unique environment that requires different approaches to environmental management compared to land or freshwater environments. Within the coastal marine area, aquaculture is one of the more visible and well-known anthropogenic activities. Many challenges in and opportunities for more effective environmental management of aquaculture apply equally to other activities in the coastal marine area; thus, some of the findings of this part can be transferred to other activities or used to inform wider environmental management questions. Some ideas presented in this part relate to or build on the general concepts of integrating science in environmental management decision-making processes discussed in part one. In those instances, this part illustrates practical applications of these concepts. Most matters addressed in this part are interrelated. While they have been divided into sections to provide structure, several themes and ideas are relevant to multiples sections. Those interested in realising opportunities identified in this report are encouraged to think about related sections and aim for multiple benefits of improvement or change initiatives.

This part uses case studies to illustrate concepts and ideas discussed and to showcase projects or initiatives that represent novel or effective ways of supporting the management of ecological effects of marine farming activities. Case studies were selected based on the author’s awareness of projects or initiatives and participants’ willingness to share ideas and provide input. It is acknowledged that other projects or initiatives exist that also could have been chosen. By selecting or not selecting case studies, the author does not express any preference or opinion on the projects or initiatives.

4.2 Shared objective of high environmental quality
A unique feature of the environmental management of marine aquaculture is the shared objective of high environmental quality among marine farmers, regulators and other participants. Marine aquaculture is reliant on a healthy environment. For example, adequate dissolved oxygen levels are critical for the survival and high performance of farmed fish. New Zealand shellfish products must also meet or exceed the food safety requirements of markets worldwide. New Zealand Food Safety sets standards, regulations and specifications for human health acceptability for all commercial shellfish products for sale from New Zealand waters. New Zealand Food Safety can also classify areas as restricted or prohibited from harvesting shellfish due to the potential for human health impacts from waterborne contaminants. These classifications can be long term due to site conditions, or short term due to events (e.g. New Zealand Food Safety sets the site-specific restrictions on harvesting due to rainfall events). Furthermore, marine farmers value positive public perceptions of the environmental sustainability of their operations because this has positive impacts for coastal planning, may reduce objections in consent processes, and may help obtain a premium in the market for aquaculture products (Simpson and Co 2007).

Throughout the aquaculture industry there is a high level of awareness that poor environmental management can have adverse effects on the environment and thus the wider industry and this creates a climate highly conducive to industry self-regulation (Simpson and Co 2007). This is reflected
in the New Zealand Aquaculture Strategy and initiatives in this area include environmental codes of practice and frameworks, such as the recently developed A+ sustainable management framework.8

From a science perspective this provides opportunities for cross-sector collaborative projects and initiatives to address scientific challenges, including those identified in this report. A collaborative approach is essential for complex scientific projects as they require targeted scoping, often large investment, long timeframes and stakeholder involvement. It is also a more cost effective and likely more successful way of determining broader environmental effects than deriving conclusions from individual farm monitoring programmes or isolated research projects. Several successful scientific projects have been developed and conducted in a collaborative spirit. It would be helpful to reflect and share the learnings from these projects to enhance our national capabilities, allow for a broader participation of aquaculture industry members and regulators and address the environmental effects of aquaculture in a more broadscale, systematic and integrated manner. Case study 1 provides an example of a successful collaborative project between aquaculture industry members and a regional council that demonstrates how the value of a scientific survey was substantially increased through a collaborative approach while meeting environmental monitoring requirements under conditions of consents.

When it comes to addressing scientific challenges in specific environmental management processes, such as policy formation or resource consenting, it is common for participants to be hesitant about working collaboratively. A complex combination of factors is contributing to hesitation by all participants in these processes, including limited mutual understanding and trust and political, economic and logistical considerations. One key driver for marine farmers is the inflexibility way in which consent conditions are written. In order to effectively advance scientific contributions to environmental management of aquaculture, it is essential that a more collaborative approach is taken between aquaculture industry members and regulators. There is a need to move away from the “site specific–only” approach taken as a result of consent conditions and to think more broadly about environmental effects.

It would be insightful to explore the reasons for the hesitation displayed by both aquaculture industry members and regulators and identify opportunities for improved collaboration and more open communication. It is likely that improved collaboration on scientific matters would also reduce litigation and thus have economic benefits. To support implementation of collaborative initiatives in the environmental management context, it would be helpful to: (1) identify obstacles to working collaboratively; (2) identify benefits of more collaborative approaches for aquaculture industry members and regulators; (3) identify specific shared objectives and opportunities for improved collaboration, more open communication and innovative approaches; and (4) develop frameworks for collaborative approaches to resource consent applications (especially assessments of environmental effects), environmental monitoring and policy formation. Importantly, there is a need to identify a lead agency to drive such initiatives as the industry typically would not know how to.

8 http://www.aplusaquaculture.nz/
CASE STUDY 1: JOINT ENRICHMENT STAGE METHODOLOGY TRIAL IN THE WAIKATO REGION

The Enrichment Stage (ES) methodology had been successfully used for determining benthic effects of salmon farms in Marlborough Sounds. Waikato Regional Council (WRC) was interested in trialling the application of the ES methodology in the Firth of Thames and Hauraki Gulf in order to test the potential of this methodology to integrate monitoring and surveys of organic enrichment from land run-off, existing mussel farms and anticipated development of fish farming. Mussel farmers operating farms in the Wilson Bay Marine Farming Zone (WBMFZ), in the Firth of Thames, were due to conduct benthic monitoring surveys as part of their conditions of consent. They were interested in trialling the methodology as a potential replacement of existing benthic monitoring approaches.

Various challenges had to be overcome by both mussel farmers and Waikato Regional Council. Mussel farmers operated in consortia, which meant that the project champions had to communicate information about the project widely and seek agreement from many individuals. The project had inherent uncertainties and it was not known whether the methodology was fit for purpose for identifying ecological effects of mussel farms. Furthermore, mussel farmers had to seek a modification to their monitoring requirements from the consents team at WRC.

Waikato Regional Council had to manage a Request for Proposal process without knowing whether mussel farmers would collaborate as they reserved their final decision until the project costs were confirmed. This required substantial contingency planning from the science team and support from the finance and legal teams. The WRC consents team had to make decisions outside standard processes to allow for the variation of benthic monitoring surveys.

These challenges were overcome by open communication by all involved regarding benefits of the survey, actual or perceived impediments and needs. A shared solution-focussed and cost-effective approach helped overcome all obstacles and resulted in a successful shared survey.

The survey was a successful collaborative project and achieved all objectives. It helped assess the utility of the ES methodology for parts of the Waikato region and identified a range of limitations that would need to be overcome before the approach could be implemented. It was a cost-effective approach for all participants and, at the same time, met the requirements for benthic monitoring of mussel farms under existing conditions of consent.

Figure CS.1. Locations of sampling stations for the collaborative study.
4.3 Complexity of scientific issues and processes

Many challenges in the environmental management of marine aquaculture stem from the inherent complexity of scientific processes in the coastal marine environment. Coastal ecosystems are among the most complex ecosystems on Earth. They contain numerous organisms and materials that interact through physical, chemical, and biological processes. Many of these processes are not well understood, posing considerable difficulties in determining the state of the environment and predicting change in response to natural or anthropogenic factors, such as marine farming. This complexity creates challenges for making good decisions on operational aquaculture matters, including identifying suitable marine farm locations and predicting ecological effects.

Managing these challenges requires a strategic approach to improving our understanding of the coastal marine environment on a national scale. This is not a new problem by far and initiatives such as National Environmental Reporting by the Ministry of the Environment, and the National Science Challenge Sustainable Seas programme aim to address some of the general information gaps for our coastal and marine ecosystems. There are opportunities to build on these initiatives by improving usefulness of and access to information to better benefit environmental management.

An opportunity for those involved in aquaculture is to engage in these initiatives and advocate for information to be collated, presented and shared in a way that benefits their ability to make good decisions related to environmental management. For example, marine farmers could advocate for research aimed at improving understanding of offshore ecosystems and their response to organic enrichment as this would assist in the development of offshore aquaculture. Through ongoing participation in projects, for example through peer review of draft publication materials, they could ensure published information is meaningful and accessible for the public. Even more effective outcomes could be achieved if aquaculture industry representatives could participate in the development of research proposals.

An example of a project aiming at developing practical solutions for the mussel industry that builds on a large research project is presented in Case study 2. This case study demonstrates the importance of research projects focussing on developing new knowledge of complex scientific processes and environmental management issues (coastal acidification) and the ability to apply and extend the practicality of research findings through the creation of aligned applied research projects (mitigation strategies for the mussel industry). It further demonstrates the benefits of collaboration between aquaculture industry and scientists, community outreach and effective science communication in making research findings accessible and widely understood.
CASE STUDY 2: OCEAN ACIDIFICATION MITIGATION STRATEGIES FOR THE MUSSEL INDUSTRY

Ocean acidification (OA), is the “global-scale long-term decrease in seawater pH, that is currently primarily due to the human-driven increase in atmospheric CO₂” (Secretariat of the Convention on Biological Diversity 2014). The decrease in pH and associated changes in water chemistry has impacts on aquatic organisms (Law et al. 2018). Importantly, it reduces the availability of dissolved carbonate, which is critical for the survival of many organisms that build shells, including farmed shellfish.

CARIM (Coastal Acidification: Rate, Impacts & Management) is a four-year collaborative research project funded by the Ministry of Business Innovation and Employment (MBIE)⁹. It is led by the National Institute of Water and Atmospheric Research (NIWA) in collaboration with Cawthron Institute and the Universities of Otago and Auckland, iwi, national stakeholders (including the shellfish aquaculture industry, MPI, regional councils, DOC and the Hauraki Gulf Forum), as well as international scientists (US and Australia).

CARIM aims to provide new knowledge on ocean acidification (in coastal waters sometimes referred to as coastal acidification) to improve protection and management of New Zealand coastal ecosystems.

CARIM also has a significant outreach component through its website, monitoring data access, and an Oceans Guardian project for schools & local communities. Communication of scientific concepts and findings is further facilitated through the preparation of tailored information, for example infographics and factsheets (see Figure CS.2).

CARIM aims to develop models and tools for management of coastal acidification. Conversations with marine farming industry members and regulators identified the further opportunity to build on CARIM to explore and develop practical mitigation strategies for coastal acidification. This led to the development of a separate project that is now funded through the National Science Challenge Sustainable Seas Innovation Fund¹¹.

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⁹ http://www.carim.nz/
¹¹ https://sustainableseaschallenge.co.nz/programmes/valuable-seas/feasibility-of-coastal-acidification
This project, titled *A feasibility study of coastal acidification mitigation strategies for the mussel industry*, is assessing the potential of two practical remediation techniques, return of waste shell to the coastal marine area and aeration of water, to mitigate the impacts of low pH near mussel farms. The project includes laboratory experiments, models of two regions, the top of the South Island and the Firth of Thames, and field studies at a mussel farm to measure and test techniques. Results will be published in scientific journals and a synthesis report will be provided to the shellfish industry containing recommendations for follow-up field deployment and further refinements.

Related to these research projects is the New Zealand Ocean Acidification Observing Network (NZOA-ON). The NZOA-ON is a network of coastal sites around the country, a mix of pristine and urban sites, and sites which are of particular interest to regional councils, the aquaculture and fishing industries, and sites of scientific interest (Figure CS.3). Ocean acidification related data collected will be used to determine local conditions, and to provide a baseline against which to measure future change.

This is a NIWA led programme with sampling partners, including from the aquaculture industry, Department of Conservation and regional councils, who collect fortnightly water samples, liaise regarding shipment and logistics, and assist with deployment of the sensors.

The NZOA-ON monitors pH and associated variables at 15 sites around New Zealand. Results are quality-controlled and publicly available at: https://marinedata.niwa.co.nz/nzoa-on/

**Figure CS.3.** Map of the New Zealand Ocean Acidification Observing Network (NZOA-ON). Data can be downloaded for each site. Source: https://marinedata.niwa.co.nz/nzoa-on/
4.4 Dependence of ecological effects on environmental characteristics

Ecological effects of aquaculture are generally described as potential effects because actual effects depend on characteristics of the environment in which marine farms are located (Clay 2008). For example, releasing farm waste into an enclosed bay will have a greater (more adverse) impact than releasing the same quantity and type of farm waste into the open coastal zone.

It is well understood that the dependence on wider environmental characteristics provides opportunities for reducing actual effects through good selection of farm sites. For example, Price et al. (2015) refer to many studies that have been unable to detect a phytoplankton response to nutrient release from fish farms, especially in oligotrophic waters. They conclude that nutrient enrichment effects are inherently unlikely if the residence time of the water body is lower than the generation time of phytoplankton.

For the planning of new aquaculture developments these considerations highlight the importance of understanding relevant characteristics of the environment, including trophic status and other aspects that influence the assimilative capacity of the environment for marine farming.

An example where limited understanding of environmental characteristics is creating obstacles for advancing environmentally sustainable aquaculture development is offshore aquaculture. Moving aquaculture operations offshore is considered advantageous for farmed animals and the environment (Holmer 2010). However, the knowledge of environmental issues in offshore farming is limited (Holmer 2010) and there is little guidance in the scientific literature for spatial planning of sustainable development of offshore aquaculture (Gentry et al. 2017). The specific scientific challenges related to the development of offshore aquaculture are discussed in more detail in section 4.9.

The dependence of ecological effects on environmental characteristics also provides challenges for the effective monitoring of ecological effects of marine farms. Consent-related and SOE monitoring are typically disjointed activities, creating difficulties for the interpretation of consent-related effects in the context of its dynamic environment. This challenge can only be addressed by aligning different monitoring programmes. For example, Forrest and Cornelisen (2015) developed a monitoring framework for the Waikato coastal marine area that recognises that SOE monitoring can provide a direct context for understanding the effects of consented activities, including aquaculture. This monitoring framework is described in Case study 3.

4.5 Siting marine farms

Making good decisions on farm locations is one of the most important aspects in the environmental management of aquaculture. Optimal siting of marine farms in combination with technological innovations make it possible to achieve the joint objectives of economically and ecologically sustainable marine aquaculture (Price et al. 2010).

Identifying a good marine farms location is not trivial. The suitability of a location depends on a range of factors, including the complexity of scientific processes (see section 4.3), the difficulty in assessing and predicting cumulative effects (see section 4.6) and values-based considerations, such as conflicting interests in the coastal space.

New aquaculture locations are typically identified in regional council coastal plans. The planning process considers industry and regional development objectives and priorities, community interests and available scientific information. Under the current legislative regime, detailed ecological assessments are done as part of the resource consenting process. These assessments may reveal unexpected issues, including some that might render the location unsuitable for marine farming.
CASE STUDY 3: MONITORING FRAMEWORK FOR THE WAIKATO COASTAL MARINE AREA

Waikato Regional Council (WRC) commissioned Cawthron Institute to develop a monitoring framework that integrates consent-related and state of the environment (SOE) monitoring.

The regional framework advocates: (1) the definition of clear goals, (2) an understanding of the sources of risk to the CMA so that monitoring priorities can be determined based on actual or potential effects, and (3) identification of linkages between fine-scale consent-related environmental monitoring and broad-scale SOE monitoring (Figure CS.4).

Whereas consent monitoring is clearly targeted toward effects of discrete point source anthropogenic activities, Forrest and Cornelisen (2015) suggest that SOE monitoring should:

1. Align with, and provide a direct context for, understanding the effects of consented activities.
2. Capture trends in background conditions that may be influenced by diffuse-source pollution (e.g. from river discharge) and interact with consent-related sources.
3. Capture trends in background environmental conditions that may have no recognised or direct link with consented activities or other anthropogenic effects.

Forrest and Cornelisen (2015) demonstrated that for the effective environmental management of aquaculture the integration of fine-scale consent-related environmental monitoring and broad-scale SOE monitoring is essential or desirable for several categories of ecological effects (Table CS.1).

Table CS.1. Need for broad-scale SOE monitoring to effectively assess ecological effects of aquaculture as evaluated by expert judgment by Forrest and Cornelisen (2015).

<table>
<thead>
<tr>
<th>Ecological effects category</th>
<th>Water column</th>
<th>Seabed</th>
<th>Marine mammals &amp; seabirds</th>
<th>Wild fish interactions</th>
<th>Escapes &amp; genetic effects</th>
<th>Biosecurity: pests</th>
<th>Biosecurity: disease</th>
<th>Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for broad-scale SOE monitoring</td>
<td>Essential</td>
<td>Desirable</td>
<td>Desirable</td>
<td>Unnecessary</td>
<td>Unnecessary (research desirable)</td>
<td>Desirable</td>
<td>Unnecessary (research desirable)</td>
<td>Unnecessary</td>
</tr>
</tbody>
</table>
Processes such as spatial planning, as part of coastal plan development or as non-statutory initiatives, can assist in ensuring that aquaculture is considered in the context of other activities and that relevant information, including scientific information, is used to inform decision-making on aquaculture sites. **Case study 4** describes how the collaborative, stakeholder-led, co-governance process followed in Sea Change – Tai Timu Tai Pari identified new candidate sites for aquaculture in the Hauraki Gulf. As noted in the Hauraki Gulf Spatial Plan, the indicative areas will be considered through RMA processes:

> These indicative sites do not override the regional coastal planning and resource consent application processes, and it is these which will ultimately decide the zoning for and authorisation of a marine farm. It is through these processes that the candidate areas will be subject to more detailed site investigation and assessment of environmental effects and more precise boundaries will be determined. These processes will also enable greater iwi, public and industry involvement in the decision-making process through the Resource Management Act 2001 consultation, submission and appeal rights. (Stakeholder Working Group, Sea Change – Tai Timu Tai Pari, 2017, p. 93)

Planning for new aquaculture locations could be improved through the development of science-based frameworks for the placement of marine farms. Lessons learned from previous developments can be used to inform a framework for siting and operating fish farms that maximises production while minimising environmental effects (Price et al. 2015). It is possible to identify environmental characteristics that facilitate mitigation of ecological effects of marine farms and these could be used to develop criteria for good marine farm siting. While sites would always require more detailed assessments, such frameworks would improve consistency and robustness of scientific considerations in marine farm siting. Furthermore, frameworks could systematically consider both adverse and positive effects. This would lead to more integrative assessments compared to the current approaches, which focus prominently on adverse effects and make it difficult to adequately account for positive effects (also see section 4.8). Within these frameworks, it would be possible to develop criteria for identifying aquaculture locations and operational conditions that, on ecological grounds, could be developed with reduced regulatory scrutiny. For example, this could include low intensity mussel farming over non-sensitive habitats or experimental aquaculture.

The ultimate success of such frameworks would depend on their recognition in legislative processes and implementation guidance. If science-based outcomes of applying these frameworks could be ignored or easily over-ruled in legislative processes, they would likely (and understandably) be considered an additional financial burden. If no implementation guidance is provided, differences in opinion on scientific requirements and uncertainty will likely result in disputes and calls for more scientific information on aspects that were deemed settled would flare up again and effectively restart the scientific assessment process.

There is an opportunity to build on the progress made in Sea Change – Tai Timu Tai Pari and similar overseas examples by developing a science-based framework for identifying new aquaculture locations in New Zealand. This would allow scientific considerations to be dealt with in an appropriate, robust and consistent manner. The development should involve a review of the process followed to identify the indicative aquaculture areas in Sea Change – Tai Timu Tai Pari, including scientific criteria used to inform these locations, learnings from that process, challenges that may be encountered under the current legislative regime and opportunities for strengthening the robustness of and public trust in scientific information used in the process. Clearly, the associated matter of allocation of space would need to be considered, however this is outside the scope of this report.
The Hauraki Gulf Marine Spatial Plan prepared by Sea Change – Tai Timu Tai Pari includes aquaculture as one of 16 themes with the aim to provide a prosperous aquaculture industry which positively contributes to the health and wellbeing of the people and the environment of the Hauraki Gulf (Stakeholder Working Group, Sea Change – Tai Timu Tai Pari, 2017). To achieve this aim, the plan proposed a number of actions, including further investigating potential new aquaculture areas identified within the Hauraki Gulf Marine Park.

Based on a detailed assessment, 13 areas were identified that are considered likely to be appropriate for future aquaculture development (Figure CS.5). Attention has been paid to biophysical factors, environmental factors, minimising adverse effects on sites of significance to mana whenua, natural character and landscape, and minimising exclusion of other users of coastal space. Locations have been identified with the expectation that further investigation will be undertaken on a place-by-place basis to identify potential benefits and effects and to further define the boundaries.

The plan emphasises that the spatial element of managing aquaculture is not simply about avoiding areas with environmental constraints, but also about identifying the water space that is well-suited to farming and areas where the benefits of aquaculture will be maximised.

Sea Change – Tai Timu Tai Pari highlights that the identification of preferred locations and inappropriate locations need to be supported by a consistent and robust regulatory framework and monitoring regime that supports mana whenua, industry and local communities. Policies, rules and other methods must provide industry with the clarity and certainty it needs to make large scale investment decisions and to deliver on mana whenua and local community expectations regarding protection of the environment and engagement with councils and industry.

For more information see https://www.seachange.org.nz/
4.6 Cumulative effects

The environmental effects of aquaculture on the aquatic environment need to be assessed in the context of other stressors. This is commonly described as cumulative effects. Here cumulative effects include the combined effects of multiple marine farms and the combined effects of marine farms with effects of other stressors (anthropogenic activities or natural stressors).

Located in the receiving environment of effects from land-based activities, in proximity to other marine activities and reliant on high environmental quality, aquaculture is vulnerable to cumulative effects and is dependent on good environmental management of other activities as well as non-anthropogenic stressors. The intensification of agriculture (especially animal agriculture), deforestation, coastal development, urbanisation, freshwater quality inflowing into the coastal marine area, overfishing and habitat modification are some contributors to degradation of coastal environments. Climate change and ocean acidification pose further threats to coastal ecosystems. Effective environmental management of cumulative effects requires a good understanding of how the various stressors interact and lead to environmental change. Natural stressors, such as sedimentation associated with flood events or weather-induced shifts in water temperature can be exacerbated by anthropogenic activities. For example, changes in land use can enhance streambank erosion and thus sediment delivery to coastal waters. As a consequence, many ecological impacts observed in the coastal marine area have multiple causes, of which aquaculture may be one possible contributor.

In addition to the scientific challenges created by this complexity, managing ecological effects in such circumstances is further complicated by the typical regulatory need to establish cause and effect before actions aimed at reducing ecological effects are implemented, requested or enforced. For many ecologically critical parameters, for example dissolved nutrients in coastal waters, it is difficult, and often impossible, to link effects to a specific activity or stressor, including aquaculture.

These are by no means new challenges. While they have been discussed extensively over the past decades, our ability to address cumulative effects in environmental management has progressed very little since the introduction of the RMA. In 1993, Montz and Dixon raised questions about how to evaluate cumulative effects under the RMA, including uncertainties about the meaning of cumulative effects in the context of approving resource consents. They raised that:

"At issue in discussion of cumulative effects, as presented in the RMA, is whether or not the intent is to look at the cumulative effects of a given application or at the cumulative effects of a given application combined with other activities in the area. If the emphasis on sustainable management is to be upheld, then it seems that the cumulative effects of all activities must be considered. This raises the question: does effects mean "effects from" (an activity) or "effects on" (an environment or a site)? The Fourth Schedule uses the term "effects on," thus suggesting that the site is of concern and not specific activities. This is in keeping with the theme of the RMA on environmental outcomes. One might therefore assume that evaluating cumulative impacts will move EIA in New Zealand away from project-oriented evaluations to environment-oriented evaluations. However, the application process suggests otherwise. This, then, leaves planners with the task of filling in the gaps, or moving from the project-specific effects presented in an EIA to environment-specific effects required to evaluate cumulative impacts. How this will be accomplished is unknown. (Montz and Dixon 1993, p.94)"

It is argued here that the questions raised by Montz an Dixon in 1993 are still valid today.

Further complicating the management of cumulative effects, particularly in the coastal marine area, are regional boundaries and divided regulatory responsibilities. As some stressors lie outside the direct control of councils or other regulators (either spatially, for example activities in adjacent regions or districts, or in terms of regulatory responsibilities, for example weather-induced events), regulators...
tend to accept a narrow interpretation of the need to address cumulative effects in environmental management processes. In many specific situations, assessing and managing cumulative effects is simply too hard and thus avoided.

In his article “When is enough, enough? Dealing with cumulative effects under the Resource Management Act”, Philip Milne concludes that the inadequate management of some types of cumulative effects is not caused by problems with the RMA itself but with its implementation at national, regional and district level (Milne 2008). He acknowledges difficulties faced by resource managers in this area as a result of practical, policy and political barriers to dealing with cumulative effects. While some frameworks have been developed in the ten years since the report by Philip Milne that provide for improved assessments of cumulative effects in an environmental management context (e.g. Forrest and Cornelisen 2015), successful implementation to support day-to-day environmental management has not yet been achieved. To the author’s knowledge, no practical implementation support is available to resource managers in New Zealand for addressing cumulative effects in key processes, such as resource consenting or policy formation.

The anticipated increase in pressure on the coastal marine area, including through the planned growth of aquaculture, anticipated effects of ocean acidification and ongoing coastal developments, creates an urgency for improving our ability to assess and manage cumulative effects on coastal and marine ecosystems. While there is a need for targeted research, it is critical that operational solutions for the effective management of cumulative effects are developed and supported with practical implementation tools. Solutions need to be designed so that they can be implemented now and improved with time as our understanding of cumulative effects improves.

One project that aims to improve our ability to manage cumulative effects is the Sustainable Seas National Science Challenge Innovation Fund funded project “Enabling inter-agency collaboration on cumulative effects” (Case study 5). The project aims to develop recommendations that will assist managers in making more informed decisions within existing legislative and institutional constraints. A critical aspect of this projects is that it brings together many of the agencies and institutions involved in managing cumulative effects to address this challenge.
CASE STUDY 5: ENABLING INTER-AGENCY COLLABORATION ON CUMULATIVE EFFECTS

Enabling inter-agency collaboration on cumulative effects is a project funded through the Innovation Fund of the Sustainable Seas National Science Challenge.

This project recognises that managing the cumulative effects that arise from human activities and natural events is one of the most urgent and complex problems facing marine resource use decision makers today. It is based on the premise that cumulative effects management in New Zealand is fragmented and inconsistent and emphasises the need for a consistent, ki uta ki tai (mountains-to-sea) strategy because human and natural stressors cross political, jurisdictional, cultural and geographic boundaries. The project aims to develop recommendations that will let managers make more informed decisions within existing legislative and institutional constraints. A core value of this projects is that it brings together many of the agencies and institutions interested in cumulative effects management to address this challenge.

Scenario planning to bridge institutional and behavioural disconnects

The research team used scenario planning techniques. This approach provided an opportunity for resource managers, planners, iwi/Māori, and other key stakeholders and representatives to share their experiences of managing cumulative effects and explore possibilities for future improvements to the system. It enabled the research team to explore core themes and some of the barriers that must be addressed to facilitate bold action on the topic of cumulative effects.

Figure CS.5. Images that accompanied six scenario descriptions. Reproduced from Davies et al. (2018).

The project is led by Kate Davies (NIWA) and the research team represents a range of organisations including Aquaculture NZ, Bay of Plenty Regional Council, Department of Conservation, Environmental Protection Authority, HH & R Mikaere Ltd, Marlborough District Council, Ministry for the Environment, Ministry for Primary Industries, Ministry of Foreign Affairs and Trade, NIWA, Te Ohu Ka moana, Tūtaiao, University of Auckland and Victoria University.

For more information on this project and a list of publications see https://sustainableseaschallenge.co.nz/programmes/our-seas/navigating-implementation-impasse
4.7 Far-field effects

Ecological effects of aquaculture, especially those on water quality, are often categorised into near-field and far-field effects. Near-field effects occur near the marine farm, whereas far-field are observed at a distance or over a larger area. Often these are measured in relation to a body of water, such as a bay. Near-field effects include localised organic enrichment of sediments or reduced dissolved oxygen in bottom waters under a farm. Far-field effects of aquaculture include increased (for fish farms) or decreased (for shellfish farms) phytoplankton production, introduction of non-native species and pathogen exchange between captive and wild populations.

Near-field effects of aquaculture have been studied more extensively and are better understood, primarily because they are more amenable to evaluation (Clay 2008, Grant 2010). For example, monitoring the seafloor under finfish cages allows a robust assessment of organic enrichment under the farm and estimates of the spatial extent of effects (Keeley et al. 2015b).

In contrast, far-field effects are less well understood, primarily because they cumulate with other effects. There is large uncertainty associated with far-field ecological effects of aquaculture (Clay 2008); however, communities are often most concerned about far-field effects, especially if they relate to livelihoods such as local fisheries or tourism (Grant 2010).

Regulatory bodies traditionally focus on near-field effects, such as comparing sites under a fish cage with control sites. In some locations, this focus may be mismatched with the perspective of coastal communities who inherently focus on a larger spatial scale (Grant 2010). This focus reflects and is, to a large extent, caused by the state of science, which dwells on localised spatial scales, rather than by a lack of diligence by regulators (Grant 2010).

Achieving more effective management of ecological effects and better matching the expectations of communities requires a change in focus by regulators and industry as well as targeted research. For example, regulators and industry could substantially improve the knowledge of far-field effects by substituting the traditional notion of environmental monitoring as a stand-alone, compliance-focussed activity, with an integrated regional environmental monitoring programme or framework that combines different monitoring and information gathering programmes. An example of such a framework is provided by Forrest and Cornelisen (2015; see Case study 3).

Research needs that have been identified include research into far-field and regional processes, especially in intensively farmed areas and over longer time scales (Grant 2010, Price et al. 2015). Selecting a suitable research approach is critical for ensuring that research findings are of benefit for environmental management. Ecosystem-based management (EBM), which is the focus of the National Science Challenge Sustainable Seas, could be an appropriate approach and the experience gained by New Zealand scientists from the project might provide opportunities for leveraging research into the scientific information gaps identified in this report. When conducting research on complex environmental issues such as far-field effects of aquaculture, it is important that researchers don’t lose sight of the need for relevant, practical and easy-to-understand information and the development of practical tools for regulators and industry to ensure the newfound knowledge can be implemented and thus contribute to more effective environmental management.

4.8 Secondary effects

Further complicating the detection of ecological effects is the fact that direct effects may not be measurable because the parameter potentially indicating a direct effect transforms through chemical, physical or biological processes. This is particularly relevant for water column effects. For example,
dissolved nitrogen discharge from fish farms is often not measurable in the waters surrounding the farm because nitrogen is taken up by phytoplankton. Increased phytoplankton production then represents a secondary effect of fish farming. Secondary effects can be of greater concern than direct effects, especially when they are visible, such as algal blooms, or affect broader biodiversity values, such as changes in trophic structures. The potential for adverse secondary effects on marine biodiversity is often identified as a primary concern by scientists and regulators (Price et al. 2015).

Research findings on secondary effects to primary production resulting from increased nutrient discharge from fish farms are highly variable (Price et al. 2015). In some locations, increased nutrient discharge has little or no trophic impacts, while in other locations primary productivity increases as a result of assimilation of nutrients by primary producers (Price et al. 2015). This is partially a consequence of the dependence of ecological effects on environmental characteristics (see section 0). However, there is a need for more research on the ecological mechanisms causing such variability in trophic transfer of energy from fish farms to the marine food web (Price et al. 2015). This knowledge gap presents challenges for predicting potential effects of finfish farms, for example as part of assessments of ecological effects for resource consent applications.

Another complicating factor for assessing the severity of ecological effects is that it is not always clear what indicates an adverse effect. For example, some researchers may consider an increase in primary production harmful and indicative of a shift to eutrophic conditions while others view the ecological effects of the farm as positive because it provides a net benefit by enhancing production in a nutrient-limited system (Price et al. 2015).

There are strong overlaps between the concepts of direct/secondary effects, near-field/far-field effects and cumulative effects. For example, nutrients are typically flushed away from a fish farm area faster than they can be assimilated into the food web and this makes it difficult to measure direct impacts of the farm on phytoplankton production (Price et al. 2015). If an increase in phytoplankton production can be measured at some distance from the fish farm (far-field), this is a secondary effect (the primary effect was nitrogen discharge) and likely a cumulative effect of one or several fish farms and other anthropogenic and/or natural stressors, such as land-derived organic matter or upwelling of nutrient-rich waters. Instead of focussing regulatory regimes and research projects on the inevitably impossible task of establishing specific cause-and-effect relationships for such effects, a more effective approach would be to establish regional environmental objectives and identify the possible contributions that each participant in the regional regulatory or development/use sectors can make towards achieving these objectives.

4.9 Opportunities for offshore aquaculture

Offshore aquaculture typically refers to aquaculture operations located on the continental shelf more than 3 km offshore where they are not visible from shore and in water depths of more than 50 m (Holmer 2010). Offshore aquaculture is predicted to increase substantially in the near future globally and in New Zealand. Concerns about environmental effects and conflict with other users of the coastal marine area have long created a desire for offshore aquaculture. Recent cage and farm structure technology advances have made it feasible to establish economically viable aquaculture in the harsher conditions of offshore waters.

Moving aquaculture operations offshore is considered advantageous for farmed animals and the environment (Holmer 2010). Offshore aquaculture locations receive less influence from terrestrial run-off and coastal activities and waste material from farms are rapidly diluted. This is expected to reduce environmental effects of aquaculture and increase the carrying capacity of the farming sites (Holmer 2010). While there are many intuitive advantages, the knowledge of environmental issues in offshore
farming is limited (Holmer 2010) and there is little guidance in the scientific literature for spatial planning of sustainable development of offshore aquaculture (Gentry et al. 2017). Holmer (2010) cautioned that experience from coastal zones cannot be directly transferred to offshore conditions and that attempts to do so creates risks. This section summarises information provided by Holmer (2010), followed by recommendations related to the development of offshore aquaculture in New Zealand.

The main reason for the limited information on ecological effects of offshore aquaculture is the limited number of full-scale offshore farms in operation. Furthermore, general scientific knowledge of these offshore environments is limited. This creates additional difficulties for predicting ecological effects and may hamper development and expansion of offshore farming, especially because of the high costs of baseline surveys of biological, chemical and physical environmental characteristics at potential offshore farm locations.

This is particularly relevant for benthic habitats. While locating aquaculture offshore will enhance dispersal of organic enrichment and thus reduce the intensity of organic deposition under farms, the response of offshore benthic communities and subsequently the assimilative capacity of benthic offshore ecosystems for organic enrichment is largely unknown. These ecosystems will have some capacity to consume (by benthic fauna) and decompose (by benthic microbes) organic matter but it is important to consider that organic matter released from fish farms is enriched in proteins and lipids and thus of higher quality and more easily broken down than organic material naturally occurring in these areas. In comparison to benthic fauna communities in coastal sediments that are diverse and typically tolerant to organic pollution and reduced oxygen, benthic fauna communities in offshore sediments are adapted to low food conditions and oxidised sediments and therefore are most likely less tolerant to organic enrichment.

In order to support development of environmentally sustainable offshore aquaculture in New Zealand, there is a critical need for research into benthic fauna community structure and functionality and its response to deposition of high-quality organic material. Research should focus on determining the assimilative capacity of offshore benthic environments and identifying favourable environmental characteristics, such as water depth, current speeds and benthic community structure, that could be used to inform planning for potential offshore aquaculture locations. Research should also focus on recovery from organic enrichment to provide for evidence based fallowing plans if fallowing is identified as an effective mitigation strategy.

This current lack of information poses obstacles and delays for the aquaculture industry in developing offshore aquaculture. Current initiatives to improve our knowledge of the carrying capacity of potential offshore aquaculture locations are primarily led by industry. The lack of a strategic national approach for addressing information gaps results in ad-hoc and isolated initiatives that likely will slow down progress and lead to sub-optimal outcomes. While it could be argued that an industry-led and financed approach is appropriate because the industry stands to gain economic benefits from such developments, realising the environmental benefits of moving aquaculture offshore is of wider interest for New Zealand. It could therefore also be argued that a more collaborative approach between industry and national and local government would be of greatest overall benefit. Working collaboratively to make offshore farming space available and co-investing in targeted research projects to address the current knowledge gaps could expedite the transition of some marine farming operations offshore and thus reduce the pressure on near-shore environments.
4.10 Acceptable levels of effects

Agreement on expected environmental outcomes, including determination of the type and level of effects that are deemed acceptable, is a fundamental requirement for the environmental management of any anthropogenic activity or natural stressor (Forrest and Cornelisen 2015). However, at times insufficient focus is placed on identifying clear and meaningful expected environmental outcomes and calls for “action on the ground”, monitoring, research, development of strategies or other activities are responded to without obtaining clarity and agreement of what type of effects are of primary concern, what levels are acceptable and what management responses are appropriate for potential exceedances of acceptable levels.

As described in part 1 of this report, making decisions on what effects are acceptable requires facts- and values-based contributions. This section focusses primarily on facts-based (scientific) contributions and related environmental management processes. There are numerous concepts used to identify the threshold between acceptable and unacceptable effects, including carrying capacity, trigger levels and trigger points. Exploring these concepts in detail is not helpful for the purpose of this report. Instead, this section describes some considerations related to determining and managing acceptable ecological effects of aquaculture and uses a case study to illustrate some challenges in setting limits, designing and conducting monitoring to assess actual effects against these limits and keeping limits relevant over time.

While conceptually intuitive, determining what effects are acceptable is far from trivial. While there is often a strongly stated commitment to ensuring that aquaculture grows within acceptable environmental limits, progress on our ability to determine such limits has been patchy. Substantial progress has been made on identifying limits related to seabed effects of salmon farming in the Marlborough Sounds, particularly as a result of scientific research and consent related environmental monitoring conducted in relation to the New Zealand King Salmon finfish farm developments in the Marlborough Sounds (for example, see Keeley et al. 2015b). An important factor in achieving this progress was the strong commitment by industry, scientists and regulators as well as the timely and open publication of scientific information that enabled new knowledge to be shared and used to inform subsequent scientific and industry projects. However, our knowledge on how transferrable these limits are to other locations and species is limited (for example, see Morrisey et al. 2016). Moreover, our understanding of how to identify acceptable limits for water column effects, such as nitrogen release from finfish farms, is far less advanced even though progress has been made on revising best practice for finfish farm management in the Marlborough Sounds and the management of finfish farms in Big Glory Bay.

Some of the challenges in identifying acceptable levels of effects in complex environments and under conditions of uncertain information is described in Case study 6. This case study describes the process followed to develop and implement acceptable levels of effects for mussel farming in the Firth of Thames using the Limits of Acceptable Change (LAC) management framework. The process commenced in an era where information on the effects of mussel farming on phytoplankton was limited and the approach taken represented an appropriate cautionary approach that was considered

12 For example, the government’s aquaculture strategy and five-year action plan to support aquaculture 2012 states that the government “supports well-planned and sustainable aquaculture growth in New Zealand and is committed to enabling industry to achieve its goal of $1 billion in annual sales by 2025. An essential part of this commitment is to ensure aquaculture growth takes place within acceptable environmental limits and respects other uses and values of our waterways and marine environment”. Source: https://www.fisheries.govt.nz/dmsdocument/15895/send
to be appropriate for the over 3,000 ha Wilson Bay Marine Farming Zone (WBMFZ) in the Firth of Thames. It supported staged development of the WBMFZ with subsequent stages being allocated if it could be demonstrated that there were no significant adverse environmental effects.

A collaborative process was followed and in 2003 indicative water column trigger points for the WBMFZ were developed that would trigger a management response that would be jointly determined between scientists, marine farmers and council. These trigger points are used for managing water column effects of mussel farms in the WBMFZ. Substantial scientific work and research has since been conducted on phytoplankton dynamics in the Firth of Thames, which has improved our understanding of mussel farm effects on phytoplankton dynamics in the Firth of Thames and helped inform resource management processes. However, despite it being envisaged that the initial trigger points and associated management responses would be reviewed and improved over time as more information became available, this was never formally done. As a result, there is some uncertainty on whether the indicative trigger points and the level of depletion they represent are still appropriate in the current environmental context, 16 years after they were developed. While addressing this uncertainty requires targeted research that is outside the scope of a consenting process, it is imperative that such research is conducted with practical resource management objectives and implementation in mind.

In addition to knowing, or being able to estimate, the threshold between acceptable and unacceptable effects, the management of ecological effects requires knowledge of the trajectory to such thresholds. Environmental monitoring requirements under resource consents typically require monitoring of a range of parameters aimed at identifying whether thresholds have been exceeded or whether there is evidence of environmental change towards such thresholds that can be attributed to the consented activity. Identifying the trajectory to a certain environmental condition that represents the threshold to unacceptable ecological effects within the complexity of environmental conditions is highly complicated, scientifically uncertain and requires very careful development of monitoring programmes and conditions of consents. A lot of New Zealand research effort has gone into trying to address the question of how much is too much, but for many activities and effects we are still a long way from finding solutions that are sufficiently practical to be used in resource consent processes. Questions that need to be answered in this context are:

1. What level of change (for example, increase in contaminants, decrease in phytoplankton or oxygen) is known to have adverse effects to aquatic animals?
2. At what point will change become irreversible or push the system over the edge from an ecosystem health perspective?
3. What is the trajectory of change and how can we detect that the ecosystem is approaching the point described in point 2, i.e. what early warning signs can we identify and measure?

These matters are particularly important for resource consents that provide for a staged approach to development where progress between stages depends on meeting certain environmental conditions.

Only if we have agreed on what the most important ecological effects are, what levels of effects are acceptable and if we understand the trajectory of change from the current conditions to the limits set by thresholds from acceptable to unacceptable effects, are we able to strategically take a management approach to alter farming practices if required, for example through reduction in lines or stocking densities, the development of best management practices (BMPs) or staged development, all of which would need to be supported by relevant environmental monitoring. An important first step would be the collation and analysis of all available information. Unfortunately, this is partially hampered by a reluctance to share information, cumbersome data storage or technical obstacles by all parties holding data, including industry, research agencies and councils.
CASE STUDY 6: THE LIMITS OF ACCEPTABLE CHANGE FRAMEWORK FOR MANAGEMENT OF AQUACULTURE IN THE WILSON BAY MARINE FARMING ZONE (FIRTH OF THAMES)

In 2001 Waikato Regional Council (WRC) granted the first resource consents for mussel farming in the over 3,000 ha Wilson Bay Marine Farming Zone (WBMFZ), Firth of Thames. The provisions of the then proposed Waikato Regional Coastal Plan provided for staged development of the WBMFZ with subsequent stages being allocated if it could be demonstrated that there were no significant adverse environmental effects. In order to develop an environmental management approach for the WBMFZ, WRC started a collaborative process to identify key environmental variables and the levels at which they may indicate that significant adverse effects are occurring as a result of mussel farming in the WBMFZ (Turner and Felsing 2005).

The Limits of Acceptable Change (LAC) management framework was identified as a suitable approach. The main characteristics of an LAC process have been described as “transparent and collaborative; an on-going iterative process; criteria are flexible and based on current knowledge; and decisions are based on monitoring results” (Turner and Felsing 2005).

A series of reports and workshops led to the implementation of two water column trigger points for the WBMFZ that would trigger management response (Figure CS6). Waikato Regional Council did not envisage that the initial trigger points were definite and emphasised the need to improve them and associated management responses over time as more information becomes available (Turner and Felsing 2005). In 2006, WRC intended to implement a 3-yearly review of the trigger points and the management framework to ensure the process remains relevant and collaborative (Turner and Felsing 2005).

The LAC approach was a novel approach for environmental management in the early 2000s and a lot of effort and investment went into the development of the trigger points. Marine farmers conducted extensive monitoring, including fortnightly (later reduced to monthly) water column sampling and periodic synoptic surveys. While this consent-related water column monitoring programme provided useful information about phytoplankton depletion as well as other changes in water column

<table>
<thead>
<tr>
<th>Marine Farming Zone trigger point</th>
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<tbody>
<tr>
<td>Spatially and temporally averaged chlorophyll a depletion resulting from marine farming activities, and relative to un-impacted waters, should not exceed 25% over an area twice that of the Wilson’s Bay Marine Farming Zone.</td>
</tr>
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<th>Firth of Thames wide trigger point</th>
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<tr>
<td>Spatially and temporally averaged chlorophyll a depletion resulting from marine farming activities, and relative to un-impacted waters, should not exceed 20% over 10% of the area of the Firth of Thames.</td>
</tr>
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Figure CS6. Water column trigger points for the Wilson Bay Marine Farming Zone recommended in Turner and Felsing (2005) and subsequently implemented. Graph sourced from Zeldis et al. (2006).
Substantial scientific work and research has been conducted to improve the understanding of phytoplankton dynamics in the Firth of Thames, evaluate effects of mussel farming, explore the use of satellite imagery and assess the carrying capacity of the Firth of Thames for finfish farming\textsuperscript{13}. This work allowed for somewhat informal assessments of the Firth of Thames wide trigger point and helped inform resource management processes as well as contributing to Sea Change – Tai Timu Tai Pari, a marine spatial plan for the Hauraki Gulf. Despite this additional knowledge, from a consent perspective, the review of the trigger points and associated management responses was never implemented. As a result, the effectiveness of the LAC approach as initially implemented was never strategically assessed and the water quality monitoring programme has not been reviewed in a long time to ensure that it is still fit for purpose and effective for industry and regulators.

In 2015, Keeley et al. (2015) expressed their view that the LAC approach “cannot work based on the current level and spatial coverage of monitoring since changes in indicators such as chl-a will be driven by a number of natural and anthropogenic factors other than the aquaculture activity itself” and suggested that water column monitoring for individual aquaculture consents should be integrated with other consent and regional state of the environment monitoring programmes in order to adequately capture reference conditions and wider, cumulative environmental changes that may be occurring. It is important to emphasise, though, that the water column monitoring has generated valuable data that has enabled robust comparisons of phytoplankton levels inside and outside the WBMFZ. The approach also allowed for joint monitoring of the individual consent holders and thus was reasonably cost-effective. Furthermore, the trigger points provided useful reference point for assessing monitoring results. Even though precise assessments have not been possible, the assessments undertaken provided assurance that effects were well within the trigger points.

A more recent challenge for the current LAC approach in the WBMFZ is the upcoming development of finfish farming in the Coromandel Marine Farming Zone north of the WBMFZ. The ecological effect managed through the LAC approach is phytoplankton depletion due to mussel filtration, whereas finfish farming can lead to increased phytoplankton production in response to nutrient release. In such close proximity, the cumulative effect of mussel and finfish farming will make it even more difficult, if

not impossible, to meaningfully assess monitoring results against the trigger points. It could also be argued that the phytoplankton removal by mussels offsets some of the ecological effects of finfish farming. This is typically considered a positive effect in the context of multi-trophic aquaculture.

There also is the overarching question of whether removing phytoplankton via mussel filtration in an environment known to be (semi)eutrophic is, in fact, an adverse effect that requires monitoring. For non-fed aquaculture, Keeley et al. (2015) also recommend that “consent monitoring of water column effects be required only in certain situations; for instance, when a significantly-sized mussel farm is being developed in an undeveloped area where no data or knowledge on water column conditions exist”. It might thus be time to consider whether further phytoplankton monitoring of farms in the WBMFZ is necessary because:

- The WBMFZ is approaching full development, effects are relatively well known and stable; and
- Phytoplankton depletion may no longer be a relevant environmental concern in the Firth of Thames that warrants the current level of investment in monitoring and regulatory oversight.

The challenges experienced with the LAC approach in the WBMFZ are not inherent issues with the LAC approach or the initial stages of the process but were created through its implementation and particularly the lack of review that was originally intended. Furthermore, the approach was possibly too complex to be implemented for resource consents in isolation of related regional environmental management initiatives. Regular review, assessment of implementation processes and a willingness to go back to the drawing board if issues are identified are critical for any environmental management approach. Unfortunately, it is not uncommon in environmental management that after an initial set up phase, effort and investment drop off rapidly, resulting in ineffective implementation. This case study demonstrates the importance of regular reviews and assessments of environmental management approaches to ensure they remain relevant, especially in the context of dynamic environments and cumulative effects.
4.11 Public perceptions of aquaculture

Past marine aquaculture practices were less developed and, in some parts of the world, resulted in significant environmental degradation. These environmental performance problems have contributed to a poor reputation of the aquaculture industry that lingers today (Grant 2010).

Like many industries, aquaculture has learnt from mistakes and has made improvements that reduced environmental impact per unit production, especially through improved feeds and better siting of farms (Price et al 2015). Overall, the risk from aquaculture to coastal environments is reduced (Grant 2010).

In a summary of current knowledge on dissolved nutrient loading from marine fish farms around the world, Price et al (2015) found that modern operating conditions have minimised the effects of marine finfish farms on water quality. They demonstrated that the effects on dissolved oxygen and turbidity are largely eliminated and that water column nutrient enrichment is not detectable beyond 100 m of a farm when formulated feeds are used and feed waste is minimised.

Despite these improvements, a lot of information about the environmental effects of aquaculture in the public domain and even in peer-reviewed articles are of questionable robustness (Clay 2008). This is partially due to a lack of comprehensive analyses of how fish farms, as currently operated with modern management practices, have developed over the years and achieved to reduce potential negative environmental effects (Price et al 2015). Similarly, we don’t have a clear overview of what issues remain problematic or need more research and development.

In New Zealand, a lot of scientific information on the environmental effects of aquaculture has been gathered as part of research projects, central and local government policy development, resource consent applications and monitoring and other initiatives. Despite these efforts, no attempt has been made to collate this information in a way that it can be used to practically inform environmental management processes or provide clear information to the public. There have been valuable literature reviews (for example, Ministry for Primary Industries 2013); however, their contribution to effective environmental management is limited because they represent factual scientific information in form of the “Pure Scientist”, which has been demonstrated to be of reduced value for the management of issues that are controversial with conflicting values and high uncertainty (see section 3.2.4). The value of these types of information summaries for informing the public and alleviating their potential concerns about environmental issues related to aquaculture is equally limited because of the great level of uncertainty it generates for non-scientists.

Instead, environmental decision-making would benefit from scientific information that focusses on specific policy options to assist decision-makers in reducing the scope of choice. The public perception of aquaculture in New Zealand would benefit from relevant information that clearly identifies and separates aspects that are of no or minimal concern and those that have been shown to require robust management or more scientific research. A fundamental requirement and current obstacle for these objectives is that it requires science-based consensus. This is an area that needs careful thought and new ways of thinking.

The need for good information to address public perception issues has also been demonstrated by Froehlich et al. (2017) who examined the development of public perceptions of aquaculture over time by evaluating sentiments and opinions from people around the world (see Case study 7). The project took a broad approach, including different types (nearshore vs. offshore) and contexts (policy vs. development) of aquaculture and assessed how they influenced public opinion.
Froehlich et al. (2017) explain that especially in the food sector, media acts as an intermediary for scientific information reaching the public. They further state that, even though the extent of influence on public perception is complex, media sources, such as news articles, are frequently used as a proxy for public perception in many contexts, including aquaculture.

In evaluating newspaper headlines from developed and developing nations, ranging over periods of 1984 to 2015, they found a positive trend in perception over time of general “aquaculture” coverage, however, the perception of “marine” and “offshore” aquaculture appeared more negative. The authors concluded that negative perceptions of offshore aquaculture development were driven by misunderstanding of differing types of risks associated with the various forms of aquaculture. More detailed information on how New Zealand perceptions compare to other countries is provided in Case study 7.

In a case study focussing on public comments from the United States of America and New Zealand, Froehlich et al. (2017) also found that public perception may be influenced by local environmental disasters not directly related to aquaculture, such as oil spills. In both countries, people expressed concern over environmental impacts, but concerns were primarily of general nature, rather than targeted issues.

Froehlich et al. (2017) identified that informed discussion and decisions about offshore aquaculture might be hindered by a lack of applicable knowledge about aquaculture and a lack of knowledge about actual local development issues. This is an important consideration for New Zealand where offshore aquaculture is still in conceptual and research stages.

Froehlich et al. (2017) concluded that better communication of the real versus perceived effects of aquaculture could assist in clarifying the debate about aquaculture and thus help support future sustainable growth.

There are many opportunities to improve the public perception of the environmental performance of New Zealand aquaculture through better information. For example, marine farmers could be more transparent about the environmental effects of their farms by making monitoring information publicly available. Scientists could publish their work in more accessibly ways, for example in industry publications. Regulators could set requirements for transparency and facilitate collation and sharing of information through regional or national information repositories. Importantly, information must be presented in a way that tells a story and provides meaningful and clear information about the environmental performance of New Zealand aquaculture.
CASE STUDY 7: PUBLIC PERCEPTION OF AQUACULTURE IN NEW ZEALAND COMPARED TO OTHER COUNTRIES

This case study presents the results of an analysis of newspaper headlines from developed and developing nations, ranging over periods of 1984 to 2015, including a comparison of results among countries (Froehlich et al 2017).

Like almost all countries, New Zealand media have published more positive than negative “aquaculture” headlines (Figure CS.7). However, the authors explain that when they evaluated a subset of the global data that also included “salmon” in the title, the perceptions were largely negative. It is therefore likely that positive public perception in New Zealand is predominantly directed at mussel aquaculture.

Only one media publication containing the term “offshore aquaculture” it its heading was found in New Zealand and it was positive. Froehlich et al (2017) found that the misunderstanding of risks associated with offshore aquaculture creates negative perceptions of offshore aquaculture. This has contributed to the surprisingly high proportion of negative sentiments in countries with more publications on offshore aquaculture. To maintain a positive public perception of offshore aquaculture in New Zealand, it is therefore important that during the development of offshore aquaculture good information on this type of marine farming is produced and made accessible to the public.

Figure CS.7. Newspaper (a) “aquaculture” and (b) “offshore aquaculture” media sentiment. Sentiment over time based on the frequency of newspaper headlines with negative (red), positive (blue), and neutral (grey) titles. Reproduced from Froehlich et al. (2017).
5 Part 3: Assessing and managing the effects of activities

This part explores challenges and opportunities for improvement in the way that effects of activities are assessed and managed through assessments of environmental effects (AEEs), environmental monitoring and adaptive management. Furthermore, the relevant considerations discussed in this report are combined into a proposed structure that could be used as a first step in developing a new framework for assessing and managing ecological effects of marine aquaculture.

5.1 Assessments of environmental effects (AEEs)

Since the New Zealand aquaculture industry began in the mid-1960s and became more established in the 1980s, there has been significant change in legislation and regulation of marine aquaculture. Furthermore, regional councils have taken different approaches to coastal planning and marine farm resource consenting, leading to a patchwork of coastal plan provisions, resource consent conditions and environmental management requirements throughout New Zealand.

The resulting inconsistencies in decision-making processes and requirements for scientific information have created difficulties for the aquaculture industry, planners and scientists and exacerbated the difficulties in integrating science in environmental management identified in part 1 of this report. This section explores some of these difficulties by focusing on assessments of environmental effects (AEEs) for resource consent applications.

Of particular importance for the environmental management of activities, including aquaculture, was the introduction of the RMA, which made it mandatory for local authorities to assess the environmental effects of applications for resource consents (Montz and Dixon 1993). Schedule 4 of the RMA details what should be included in an assessment of environmental effects (AEE) and is therefore the heart of the assessment requirement (Montz and Dixon 1993). The information requirements for AEEs and mandatory matters to be addressed by AEEs are very broad. In theory, any resource consent application must include an AEE that assesses all actual or potential effects on the environment, including cumulative effects. The level of detail required in an AEE must “corresponds with the scale and significance of the effects that the activity may have on the environment” (RMA Schedule 4 2(3)(c)). This means that the first, and arguably most important, decision that must be made relates to the scale and significance of anticipated environmental effects (Montz and Dixon 1993). In addition to specifying the scope of the AEE, this also serves to define notification requirements.

From the beginning, difficulties with implementing the AEE requirements had been anticipated. Montz and Dixon (1993) described three groups of difficulties. The first relates to the need to determine the scale and significance of anticipated effects from an activity in order to determine the level of detail required in the AEE and whether the application is notified or non-notified. However, an assessment of scale and significance of effects cannot be made until an AEE has been received, illustrating the circular nature of this RMA requirements. Montz and Dixon (1993) pointed out that planners need to provide specific guidelines to applicants so that they are aware of the standards they must meet. Applying this to aquaculture consents, this means that regional coastal plans need to provide clarity for applicants on standards and conditions they must meet, and councils need to provide guidance material for how these should be implemented. In regions where such requirements were specified in first generation plans, they have not remained robust over time and most second-generation plans are now not detailing such requirements.

The second group of difficulties deals with the incorporation of cumulative effects in AEEs, including the question of how to assess cumulative effects but also what the meaning of cumulative effects is in the context of a resource consent application. Issues related to managing cumulative effects are
described in section 4.6. Planning practice has not developed much in this arena, and this continues to be an arbitrary matter in any consents case.

The third and final group of difficulties with implementing the AEE requirements focusses on operational aspects. Issues anticipated under this group include problems associated with defining “minor” and “significant”, the need for planners to be familiar with plans and policies of neighbouring districts so that they can notify them when appropriate, when to commission an independent report of an AEE instead of requesting additional information from the applicant, and issues related to monitoring requirements. At the time it was expected that some of the anticipated issues in these three groups would likely be resolved with time and experience or with case law (Montz and Dixon 1993).

To assess the success of councils in developing appropriate and practicable procedures for implementing the RMA requirements related to AEEs, Morgan (1995) surveyed key personnel in regional and district councils, government departments, planning consultancies and law firms. He concluded that:

> Overall, the task of implementing the EIA requirements has been tackled positively by councils, but there are signs of major differences emerging in the EIA procedures they are developing. Key issues that need to be considered by councils include: the need for explanatory documentation for, and verbal advice to, resource consents applicants at the earliest stage possible; the lack of public involvement in the EIA activities and the need for council staff to encourage and facilitate such participation; and problems with ensuring the adequacy of EIA information in such a devolved and comprehensive EIA system. (p.333)

With the changes introduced through the RMA came a stronger emphasis on the use and integration of scientific information; however, much of the baseline information on biophysical characteristics of regions and districts needed for RMA processes had not been collected or collated in an easily accessible way (Montz and Dixon 1993). Concerns were raised in the early 1990s that there was a need to achieve greater scientific certainty but that the costs involved may be prohibitive at the time when there was considerable political pressure for local government to reduce costs (Montz and Dixon 1993). While making AEEs routinely part of decision-making processes elevated the importance of environmental effects in development decisions, concern was expressed that council planners now had to do more without adequate resources or tools (Montz and Dixon 1993).

In his master’s thesis, Leo Fietje reviewed challenges faced by environmental impact practitioners in New Zealand (Fietje 2001). He summarised the criticisms in relation to environmental impact assessment (EIA) directed at the Resource Management Act as:

1. Uncertainty by proponents about what subjects to include in an EIA and to what level of detail;
2. Unreasonable and repeated demands for information by consent authorities;
3. Consent authorities making decisions without adequate information;
4. Consent authorities taking an overly cautious deterministic approach when evaluating effects; and
5. Consent authorities inconsistent in their requirements for information and decisions made - over time, between staff and between authorities.

A consistent theme that runs through all challenges described in this section is the lack of specificity, guidance and tools for both the preparation and the assessment of AEEs. The RMA relies on regional

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14 In the context of this report, the terms Environmental impact assessment (EIA) and assessment of environmental effects (AEE) are interchangeable.
and district plans to specify what detail an AEE should contain; however, these typically only contain lists of topics that need to be addressed. Furthermore, the RMA does not define critical terms, such as “scale” or “significance”. Fietje (2001) describes the limited use of these terms in determining the content of AEEs as follows:

At one end of the spectrum an effect may be significant enough to warrant mention in an EIA, but only so that explanation can be given as to why it is of no concern. At the other end an effect may be so significant that it cannot possibly be consistent with the sustainable management of natural and physical resources. ‘Significance’ is not a fixed benchmark against which an adverse effect can be placed to determine its acceptability. The RMA also uses the word ‘minor’ to denote an adverse effect on the environment small enough not to require notification of an application; and as a threshold for determining jurisdiction to consider an application for a non-complying activity (RMA s105). It does not define the term ‘minor’. (p.28)

These assessments and critiques will strike a chord with practitioners working on AEEs for activities in the coastal marine area. An important consequence of the difficulties described in this section is that the quality of AEEs prepared is highly variable. Equally, the expectation on quality by different councils, in different disciplines and even for different activities differs considerably. This inconsistency presents substantial challenges when trying to obtain a more comprehensive overview of environmental conditions or compare the effects of different activities. Furthermore, this inconsistency is creating an uneven playing field among those conducting or seeking consented activities.

An area that has received recent attention is the use of models in environmental management. This is relevant because predictions of environmental effects and environmental decision-making frequently relies on predictive mathematical modelling as an evidence base. Publications by Freeman (2010), Özkundakci et al. (2018) and the Parliamentary Commissioner for the Environment (2018) highlight problems resulting from a lack of standards, development and application guidance, adherence to best modelling practice and transparency. Özkundakci et al. (2018) conclude that:

If models are to be of substantial help in environmental decision-making then modellers and decision-makers will need to ensure that there is a clear understanding of the purpose of a model, the modelling process is transparent, limitations are acknowledged and considered, and that best practice guidelines are followed. (p.52)

A key recommendation of the Parliamentary Commissioner for the Environment (2018) is that:

...the Minister for the Environment task his officials to develop guidance on the development, evaluation and application of environmental models in a regulatory setting. Overseer is by no means the only model being used by regulators. Models are essential tools and it is vital that when they are used, the wider community can be confident that development, maintenance and use meet appropriate standards. (p.10)

The general standard of AEEs could be improved by setting clear and specific standards, guidance and tools for both the preparation of AEEs and for the assessment of AEEs by regulators. These should include requirements on qualifications and experience for those preparing AEEs and standards for preparation and presentation of scientific information. A useful starting point could be the evidence requirements for expert witnesses in the Environment Court of New Zealand Practice Note 2014 (Box 1). This would have the added advantage of standardising requirements and expectations for different phases of environmental management projects that are challenged in the Environment Court. It would be advantageous if these issues would be addressed on a national level to avoid the continuation of inconsistent development of processes and requirements throughout the country. It would also be helpful if they sat outside the regulatory system of plans so that they could be readily reviewed and updated as required.
**Box 1: Environment Court of New Zealand Practice Note 2014**

**7.3 Evidence of an expert witness**

(a) In any evidence given by an expert witness, that person must, in the witness’s statement or affidavit (if the evidence is in writing) or orally (if the evidence is being given orally):

(i) acknowledge that he or she has read this Code of Conduct and agrees to comply with it;

(ii) state the witness’s qualifications as an expert;

(iii) describe the ambit of the evidence given and state either that the evidence is within her or his area of expertise, or that the witness is relying on some other (identified) evidence;

(iv) identify the data, information, facts, and assumptions considered in forming the witness’s opinions;

(v) state the reasons for the opinions expressed;

(vi) state that he or she has not omitted to consider material facts known to the witness that might alter or detract from the opinions expressed;

(vii) specify any literature or other material used or relied upon in support of the opinions expressed;

(viii) describe any examinations, tests, or other investigations on which she or he has relied, and identify, and give details of, the qualifications of any person who carried them out; and

(ix) if quoting from statutory instruments (including policy statements and plans), do so sparingly. A schedule of relevant quotations may be attached to the statement of evidence, or a folder containing relevant excerpts may be produced. If the statutory instrument is included in a common bundle of documents, a cross-reference to the bundle will suffice.

(b) If an expert witness believes that his or her evidence, or any part of it, may be incomplete or inaccurate without some qualification, that qualification must be stated in the evidence.

(c) If an expert witness believes that her or his opinions are not firm or concluded because of insufficient research or data, or for any other reason, that must be stated in the evidence.

(d) If after the exchange of a brief of evidence has occurred, an expert witness changes any of his or her opinions or conclusions, that must be communicated without delay to all parties to the proceeding.
5.2 Environmental monitoring

Environmental monitoring can be described as a suite of activities that aim to characterise baseline conditions, track changes and establish trends in parameters used to describe environmental quality (Forrest and Cornelisen 2015). Consent related environmental monitoring\(^{15}\) is an essential part of managing the effects of activities. Monitoring of activities is embedded in the Fourth Schedule of the RMA and is recognised as an integral component of the consent process. While predicting environmental effects in AEEs is important, only through monitoring the actual effects of an activity can we measure the validity of predictions (Montz and Dixon 1993). A critical, yet surprisingly often overlooked, requirement of monitoring is that, in order to be useful, monitoring requires a clear purpose and objectives that it will satisfy (Forrest and Cornelisen 2015).

The type and scope of environmental monitoring depends on the potential environmental effects and the scale of the activity. Environmental monitoring is usually prescribed as part of conditions of consent, typically via environmental monitoring plans. The cost of monitoring is usually borne by the consent applicant/holder. If uncertainty on effects is high and there are concerns about adverse effects, environmental monitoring may be embedded in an adaptive management framework (see section 5.3).

For monitoring to fulfil an effective role in the environmental management of activities, it is important that it is linked to clearly specified actions that are taken in response to monitoring results. If monitoring reveals adverse effects that require intervention, clear pre-defined actions should be triggered. These could include changes in operational practices, targeted investigations or other mitigation measures. Similarly, if monitoring reveals that effects are low and well understood, there should be actions to provide for a reduction in monitoring effort. Unfortunately, this is often not easily provided for in conditions of consents. This can lead to ongoing monitoring efforts that do not add knowledge or other value but are of significant cost to the consent holder. Developing better processes for addressing such instance of “monitoring for the sake of it” could assist both the aquaculture industry and regulators in obtaining a clearer focus on environmentally important aspects of aquaculture activity management and better allocate resources to high priority matters.

Despite the importance of monitoring, it is important to consider that it is one component of a wider toolbox for managing the environment. As Forrest and Cornelisen (2015) describe:

> For some activities or locations, suitable indicators and associated standards may be unavailable (or impractical to implement), or cause-effect links between an activity and its effects may be confounded by multiple sources or a spatio-temporal disconnect between a stressor and the expression of its effects, or effects may simply be poorly understood. In essence, monitoring may not always be feasible or helpful, and situations may arise where further research is needed to better understand effects. It is therefore important that a broader framework should include management practices (often termed ‘best management practices’ or ‘BMPs’) that aim to minimise actual or potential environmental effects to the extent feasible and practical, irrespective of known actual or potential risks or uncertainties. (p.8)

Developing and implementing effective environmental monitoring is not a trivial exercise. It is outside the scope of this report to review the range of difficulties associated with these tasks. Instead, the remainder of this section discusses a few core challenges and presents some suggestions for improvements.

\(^{15}\) Unless specified otherwise, in this section environmental monitoring refers to consent related environmental monitoring, not to other types of monitoring such as State of the Environment (SOE) monitoring.
A common problem related to environmental monitoring plans is a lack of objectives, standards or environmental limits. Answering questions, such as, what are we monitoring and why, is often missing from imposed consent conditions. Setting limits is difficult and often impossible, however, this does not hinder the development of clear monitoring objectives and, where appropriate, a defined pathway towards developing standards or environmental limits over time as more information becomes available through environmental monitoring. A lack of monitoring objectives often leads to difficulties when monitoring results are interpreted and contextualised differently, including by different scientists and over the lifetime of the consent. This is not helpful for effective environmental management of aquaculture activities and the wider coastal marine area.

The links between environmental monitoring, reporting requirements and best management practices are often not well described or developed. This creates difficulties for regulators and consent holders to obtain a good understanding about the various measures in place to manage environmental effects. Consequently, regulators may take an overly risk adverse approach or require a level of monitoring that the consent holder may consider unwarranted. Under the present regulatory regime, it is suggested that consent applicants could improve the situation by more clearly articulating how best management practices, management interventions, environmental monitoring and other mitigation measures are aligned to form a comprehensive environmental management framework. Under a potentially revised resource management system, it would be valuable to have requirements for those conducting activities to provide such an integrated framework and for regulators to appropriately consider the various aspects of the framework and thus be more flexible to accept appropriate management measures instead of defaulting to extensive monitoring, even if its meaningfulness is doubtful.

Another issue related to environmental monitoring is that consent-related environmental monitoring is usually limited to monitoring of effects that can be directly linked to specific activities. For this reason, it tends to be restricted to local scale surveys, such as seabed monitoring in the immediate environs of a marine farm. The difficulties of this approach and suggestions for embedding consent-related environmental monitoring in other monitoring activities, such as state of the environment monitoring are described in detail in part 2 of this report. As discussed above, it is therefore recommended that the traditional notion of environmental consent monitoring as a stand-alone, compliance-focussed activity is replaced by integrated regional environmental monitoring programmes or framework that combine different monitoring and information gathering programmes.

Related to the current focus on specific activities, is the limited wider use of information collected through environmental monitoring. Results are often not made available for wider assessments of the environment. The reasons for this are complex but one important obstacle is an inconsistency in data collection and a lack of data repositories. These issues could be addressed by developing a standard set of tools to consistently deal with monitoring data. Grant (2010) suggests an approach in which existing technology such as GIS, decision support, and mapping tools could be integrated into monitoring processes. Even though specific effects of activities might be different, common denominators, i.e. parameters, of environmental effects can be found (Grant 2010). These parameters could be collated, analysed and presented in integrated assessments and maps. This would also support the provision of integrated information to the public. To illustrate this approach, Figure 4 shows a hypothetical example of a bay in which finfish farms, dredging and storm events affect surface sediment organic matter in different ways. By including monitoring of surface sediment organic matter into consent-related monitoring of finfish farming and dredging (anthropogenic activities) as well as in state of the environment monitoring that aims to assess the effects of storm
events, it is possible to create integrated regional maps of surface sediment organic matter. These provide information in a regional context and could assist in setting regional environmental objectives that could subsequently inform the management of consented activities.

New Zealand is currently in a position where monitoring requirements for marine farms are inconsistent. This is a legacy of complex factors, including interregional inconsistencies, changes in legislation over time, inconsistent requirements stipulated by the Courts and inconsistent interpretations by individuals (including scientists working for consent holders or councils, and consent staff) involved in developing or approving monitoring plans.

We must accept that there will always be inconsistency in the way marine farms are monitored. Allowing for site and farm specific variations in monitoring is critical for enabling relevant and appropriate assessments of effects in the complex coastal marine area. However, the current situation is creating a number of problems. For example, regulators may take an overly risk adverse approach to setting monitoring requirements because they do not have the knowledge, confidence, authority or community support to make decisions that are fit-for-purpose for a particular location and activity but instead follow precedents where monitoring requirements were very comprehensive. This approach by individuals can lead to a “creep” in expectations and monitoring requirements. Equally, it makes it increasingly difficult for monitoring requirements to be reduced where it is warranted.

![Figure 4](image.png)

**Figure 4.** Illustration of a hypothetical example of a bay for which integrated regional maps of surface sediment organic matter were created based on combined results of consent-related (fish farming and dredging) and state of the environment (storm events) monitoring results of surface sediment organic matter.
Similar issues arise when attempts are made to standardise and streamline requirements at a national scale. For example, some provisions in the proposed NES for Aquaculture rely heavily on existing information collected at the time when coastal permits were first granted or through monitoring. This means that requirements under the NES will automatically be different among farms with different levels of existing farm-specific information. While this makes intuitive sense and cannot be avoided, it somewhat undermines the intent of the NES. This inherent problem creates an urgent need for a strategic approach to improving consistency over time. If we accept that achieving consistency will take time, under the current regime likely to be in the order of at least one cycle of resource consent renewals, we have an opportunity to develop a focussed and practical framework that sets requirements for environmental monitoring that are fit-for-purpose for individual farms but provide for appropriate consistency. Large improvements could be made, for example, by specifying consistent methodologies and sampling strategies. It is often these details that preclude datasets being combined and analysed on a wider scale.

In relation to reconsenting, the proposed NES does not include such information. Instead, the proposed NES states that “[a]dministrative matters such as [...] information and monitoring requirements [...] are also proposed to be matters that councils could consider when processing applications to replace consents for existing marine farms” (p.28). It is unfortunate that information and monitoring are categorised as “administrative matters”, when environmental management conflicts and difficulties often relate to information on the environmental effects of marine farms.

It is acknowledged that the proposed NES refers to other elements being actively progressed, including the understanding and monitoring of the environmental effects of aquaculture. The proposed NES also states that MPI would continue to develop and implement guidance material to assist regional councils, the community and the aquaculture industry to implement the NES. However, there is a risk that the planned improvements and guidance come too late to effectively support the objectives of the NES related to consistency in environmental management. This is because under the proposed NES it is intended that the regulation would come into force immediately after being publicly notified in the New Zealand Gazette. This means that regulators would be required to implement the NES in the absence of implementation guidance, which would likely lead to a continuation of, and possibly increase in, inconsistent monitoring practices as individual councils would remain responsible for interpreting the NES.

5.3 Adaptive management

One approach commonly used to support the management of activities that require resource consent under the RMA and that have uncertain, complex and potentially significant environmental effects, is adaptive management. Adaptive management is based on the premise that, although there is uncertainty as a result of incomplete knowledge, decision-makers must act (Walters 1986).

The concept of adaptive management is intuitive and resonates well with resource management practitioners and scientists (Allen 2011). Adaptive management is a flexible approach, which has resulted in multiple interpretations and confusion and thus limited the ability of resource management organisations to develop successful implementation processes (Allen 2011, Gregory et al. 2006b). Furthermore, adaptive management is often misunderstood because of a belief that it is akin to traditional “trial and error” or “learning by doing” (Allen 2011). Some believe that management approaches underpinned by expert advice or that the requirement of environmental monitoring are

sufficient to make a project “adaptive” (Williams and Brown 2014). As expressed by Gregory et al (2006b), “[f]ew concepts in environmental management are both as widely promoted and as widely misunderstood as adaptive management” (p.2411).

Adaptive management is a structured, iterative and goal-oriented process that builds knowledge, improves management and reduces uncertainty. Adaptive management comprises two phases (Williams 2011; Figure 5; Table 2). Firstly, a set-up phase during which five structural elements are set up, and, secondly, an iterative phase, in which these elements are incorporated into an iterative decision-making process. Iteration through the elements of the iterative phase creates technical learning about the resource system.

As outlined in part 1 of this report, uncertainty about environmental management processes creates challenges for effective contribution of science to environmental management. Part 2 of this report describes a range of scientific challenges for the environmental management of aquaculture. When trying to develop and implement adaptive management approaches for aquaculture developments, these challenges combine and create significant difficulties for all participants involved. There is an urgent need to improve the understanding of adaptive management among regulators and others participating in environmental management in New Zealand and to develop practical guidelines for developing and implementing adaptive management approaches, particularly within the context of resource consent conditions. While some guidance has been developed overseas, this predominantly applies to large conservation projects (see, for example, Williams et al. 2009). No practical guidelines exist for implementing adaptive management for projects at the scale of consented activities.

Giles and Barton (submitted) examined the implementation of adaptive management under the RMA and identified a range of opportunities for improving the understanding and implementation of the adaptive management approach for the management of consented activities. A summary of this work has also been published by Giles (2019) and the key findings are shown in Box 2.

**Figure 5.** The two phases and elements of adaptive management. Source: Giles and Barton (submitted).
Table 2. Descriptions of the elements of the adaptive management process. Source: Giles and Barton (submitted).

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set-up phase</strong></td>
<td></td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>Engage the appropriate stakeholders and ensure their involvement in the entire process.</td>
</tr>
<tr>
<td>Objectives</td>
<td>Identify clear, measurable, and agreed-upon management objectives to guide decision making and evaluate management effectiveness over time.</td>
</tr>
<tr>
<td>Management options</td>
<td>Identify a set of potential management options at each decision point, given the status of the resources being managed at that time.</td>
</tr>
<tr>
<td>Predictive models</td>
<td>Create models to predict how the resource system responds to the potential management options. Note: A model may be a deterministic model, quantitative conceptual model, statistical model or another appropriate predictive tool.</td>
</tr>
<tr>
<td>Monitoring plan</td>
<td>Design and implement a monitoring plan to:</td>
</tr>
<tr>
<td></td>
<td>i. evaluate progress toward achieving objectives;</td>
</tr>
<tr>
<td></td>
<td>ii. determine resource status;</td>
</tr>
<tr>
<td></td>
<td>iii. increase understanding of resource dynamics via the comparison of predictions against survey data; and</td>
</tr>
<tr>
<td></td>
<td>iv. develop and refine models.</td>
</tr>
<tr>
<td><strong>Iterative phase</strong></td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>At each decision point, select from initially identified management options, based on management objectives and current state of understanding obtained from predictions and assessments.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Use ongoing monitoring to track resource change in response to management options.</td>
</tr>
<tr>
<td>Assessment</td>
<td>Assess predicted against actual outcomes to:</td>
</tr>
<tr>
<td></td>
<td>i. improve understanding of resource dynamics (= learning);</td>
</tr>
<tr>
<td></td>
<td>ii. increase confidence for models that accurately predict change and decrease confidence for models that are poor predictors of change; and</td>
</tr>
<tr>
<td></td>
<td>iii. evaluate effectiveness of management and measure its success in attaining management objectives.</td>
</tr>
<tr>
<td>Iteration</td>
<td>Cycle through the iterative phase and, less frequently, back to the set-up phase.</td>
</tr>
<tr>
<td></td>
<td>Cycling through the set-up phase allows for continuing involvement of stakeholders and re-assessment of objectives and management options to maintain overall relevance.</td>
</tr>
</tbody>
</table>

Importantly, adaptive management is useful for the management of many but certainly not all activities. Uncertainty and risk of potential adverse effects may be too high to allow for the experimentation inherent in adaptive management. Under these conditions adaptive management is not suitable and other management approaches are required. Adaptive management can be detrimental if it risks a delay in making “hard” management decisions that allow degradation to progress beyond sustainable limits. For example, if a decision-making has the potential to adversely affect a critically endangered species, the potential impact on the species may make it unacceptable to conduct the experimentation inherent in adaptive management.
In New Zealand, most activities that have potential adverse effects require a resource consent under the RMA. Once the outcome of the resource consent process has been communicated as final, the administrative decision is effective and final, cannot be revoked and the decision-maker becomes “functus officio.” The tension between the need to allow flexibility to “adapt” management actions during the lifetime of the resource consent and the finality of decision-making under the RMA is a likely source of legal problems for consented activities utilising adaptive management.

Problems of this nature have been the subject of several disputes in New Zealand courts. The Supreme Court of New Zealand case Sustain Our Sounds Inc v New Zealand King Salmon Company Ltd ([2014] 1 NZLR 673 [Sustain our Sounds]) provides guidance for complex cases subject to the NZCPS.

The conditions of consent proposed by New Zealand King Salmon and finalised by the Board of Inquiry contained a comprehensive framework for marine environmental monitoring, adaptive management and reporting comprising environmental quality standards (EQS) and environmental objectives specified in the conditions of consent, baseline plans and reports to be completed before farms could be developed or fish could be stocked, and ongoing requirements for annual Marine Environmental Monitoring and Adaptive Management Plan (MEM-AMP), annual reports and review of all plans and reports by a peer review panel.

Sustain our Sounds confirmed that this comprehensive adaptive management approach was lawful. However, the decision does not provide a rigid formula for adaptive management and there remains uncertainty how the courts would decide if presented with a framework of conditions of consent and EMPs that are set up differently to that proposed by New Zealand King Salmon and finalised by the Board of Inquiry.

Giles and Barton (submitted) added to the guidance of the Supreme Court by taking a broader view of legal issues that may arise under different frameworks of conditions of consent and EMPs, which are more common for resource consent applications that utilise adaptive management. These applications are typically for activities that are less complex and propose less detailed conditions of consent. Importantly, they tend to place more emphasis on environmental management plans (EMPs) as the place for detailed provisions, sometimes to be provided after consent has been granted.

Giles and Barton (submitted) conclude that the RMA provides legal mechanisms for all steps of the adaptive management process. While some mechanisms available under the RMA to support the adjustments of decisions after consent has been granted have been used effectively, there is opportunity to further explore how certification, change and review of consent conditions and shortened duration of consent could be used more effectively and in a manner that is not perceived punitive or regarded as a tool of last resort by consent holders and regulators.

Depending on the specific circumstances, there may also be legal difficulties. There are legal limitations on adjusting decisions after granting consent. As explored through the case law analysis, the legal options available at a time after consent has been granted, depend on the specific nature of conditions of consent and EMPs. This indicates that there likely is a strong negative correlation between the effort made during the set-up phase of adaptive management and the potential for legal disputes related to adjustments in decision-making after consent has been granted. This can result in a restricted ability to implement adaptive management successfully, particularly if little effort was put into the set-up phase. For this reason, meeting RMA requirements alone may not be enough for

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**Box 2. Adaptive Management Under the RMA**

In New Zealand, most activities that have potential adverse effects require a resource consent under the RMA. Once the outcome of the resource consent process has been communicated as final, the administrative decision is effective and final, cannot be revoked and the decision-maker becomes “functus officio.” The tension between the need to allow flexibility to “adapt” management actions during the lifetime of the resource consent and the finality of decision-making under the RMA is a likely source of legal problems for consented activities utilising adaptive management.

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17 The Latin term “functus officio” can be translated as “having performed his or her office”
successful adaptive management. Developing guidance to clarify the requirements of the set-up phase is, i.e. the resource consent application and decision stage, is possibly the most important step for improving the implementation of adaptive management under the RMA.

This research has revealed a range of opportunities for improving the implementation of adaptive management under the RMA, including:

- Develop guidance and best practice guidelines for all parties involved in the consenting process to help make directions given by the courts more accessible and support the effective implementation of adaptive management
- Further explore legal mechanisms that have the potential to be used more effectively in support of adaptive management, for example certification and review of consent
- Improve the understanding of adaptive management of all parties involved in resource consent processes to:
  - Strengthen the focus on co-operation and the opportunities of adaptive management rather than viewing it primarily as a tool within an adversarial process
  - Highlight the benefits of voluntarily undertaking more work than legally required in the early stages of the process to reduce the risk of legal obstacles to effectively adjusting management options over time

A summary of the work by Giles and Barton (submitted) has also been published by Giles (2019).
5.4 A structure for improved assessment and management of ecological effects

5.4.1 Towards a framework for assessing and managing ecological effects of marine farms

Combining the relevant considerations discussed in this report, this section presents a structure that could be used as a first stage of developing a framework for assessing and managing ecological effects of marine aquaculture (Box 3).

Based on the findings of this report, good assessment and management of ecological effects requires a sequence of five steps. The first is the determination of “baseline” environmental information on the current state of the environment and anticipated changes over time as a result of non-aquaculture related factors).

The second step addresses the ecological effects of aquaculture. In addition to general effects of the aquaculture species and culture method, this information must be combined with local environmental information to determine the potential ecological effects of the development. Steps one and two are predominantly facts-based and informed by scientific information.

The third step focusses on identifying the assimilative capacity of the environment for the aquaculture activity. Because it includes determining what effects are acceptable, it has strong values-based contributions. Once acceptable levels of effects, or environmental limits, have been identified, the trajectories of scientific parameters to these limits need to be described to inform monitoring approaches.

The fourth step comprises what is most commonly considered the “environmental management process”. It includes identifying and assessing mitigation options to minimise environmental effects, developing an adaptive management approach (where appropriate) and conditions of consent.

Finally, the fifth step is the ongoing evaluation of effects and adjustment of practices and methodologies through monitoring and review.

While focussed on an individual activity, this structure would lead to a successful decision-making framework, if it was integrated in a wider, typically regional, framework for environmental management that includes critical aspects, such as the specification of clear environmental objectives and triggers for dealing with cumulative effects. Furthermore, the framework is designed to incorporate the lessons and knowledge gained from the past to avoid each new activity assessment starting from a clean slate. The latter is a critical requirement for consistent, effective and efficient assessment and management of ecological effects of marine aquaculture.

5.4.2 Considerations for reconsenting

Approximately 64% of marine farm consents will expire before 2025.¹⁸ Reconsenting marine farms is a challenge for New Zealand. From a scientific perspective, the primary challenges are that information about environmental effects of farms due for reconsenting is often limited and that some farms are located at sites that may not be considered environmentally suitable. Addressing these challenges requires a careful balancing of the desire and need for certainty and the need to ensure reconsented marine farms are sustainable into the future.

Under the RMA, the reconsenting process focusses on individual farms. Where environmental monitoring information exists (and environmental effects have been shown to be acceptable), the scientific aspects of the reconsenting process might be relatively uncomplicated because potential

environmental effects of the reconsented farms can be predicted from the existing information. However, for farms that have not been subject to environmental monitoring requirements, the reconsenting process may require the same level of effort (and cost) as the application for a new resource consent. Importantly, from a scientific perspective, the reconsenting process for these farms may be highly uncertain.

Efforts have been made to ease the reconsenting process. For example, the proposed National Environmental Standard (NES) for Marine Aquaculture seeks to make the replacement consenting pathway more consistent and efficient while still allowing local decision makers to have discretion for some matters. While this goes some way towards addressing the challenges of reconsenting, it does not address the challenges related to differing levels of existing information and potential gaps in scientific information.

Furthermore, the list of assumptions about the relevance of those effects for consideration of applications for replacement consents provided in Appendix G of the proposed NES for Marine Aquaculture provides only limited bounds on the assessments of effects for reconsenting. Phrases like “[m]ussel and oyster farms do not typically cause significant water quality issues” and “[f]ed aquaculture can [cause significant water quality issues], although benthic effects are typically the more limiting factor” used in Appendix G are unlikely to ease the process for reconsenting.

Concerns about potential environmental effects of reconsented marine farms are valid and the assessment process must be robust. However, attempting to address the scientific challenges of reconsenting under an approach that focusses on farms-specific information only and, for some farms, effectively starts from a clean slate would be subject to many of the scientific challenges outlined in part 2, resulting in complex and costly reconsenting processes. It is therefore suggested that, in order to ease the reconsenting process for the marine farming industry and regulators, we require a different way of thinking about how we approach the task of assessing environmental effects. Unless we find alternatives to the current approach of addressing reconsenting on an individual farm basis, it is difficult to see how the reconsenting process can be improved.

The structure shown in Box 3 could be used to assist in developing an alternative approach. We do have a good level of understanding about several of the proposed steps for sub-sets of locations and species. It would be possible to compile existing information on a national level and create a “catalogue” of scientific information and associated criteria for the application of this information to specific reconsenting circumstances. For example, based on existing knowledge from mussel farms, we may be able to conclude that mussel farms of certain maximum sizes in certain environments do not require any assessments of water quality effects. Benthic effects assessments could possibly be restricted to assessing whether sensitive habitats are present under or near the farmed area. This approach would provide for different levels of assessment effort based on the likelihood of adverse effects rather than based on the somewhat arbitrary criterion of past resource management regimes.

While this proposed alternative approach is in line with that of the proposed NES for Marine Aquaculture, it extends the approach by proposing a robust and practical framework for reducing the need for comprehensive scientific investigations for marine farms where scientific information is limited but we can make informed assessments on environmental effects from our national knowledge.

In addition to reducing the overall scientific effort required, the proposed approach would also provide for more consistent and targeted investigations and an opportunity to continue growing our national catalogue of scientific information on aquaculture effects by setting up procedures to add new information. Over time, the use of increasingly consistent and robust methodologies would
emerge as best practice because of our ability to directly compare results and assess effectiveness of different approaches. New information would build on existing knowledge and strengthen our ability to assess and manage the ecological effects of aquaculture for reconsented and new marine farms.

A starting point for an alternative approach for assessing ecological effects for reconsenting would be to categorise marine farm effects information by location, species and other relevant factors, compile information on effects and develop criteria that could be used to develop decision trees for assessments of effects for marine farms that require reconsenting.

As explained in part 1 of this report, it will be important that the compilation of scientific information will be done for the purpose of informing specific options or approaches for reconsenting (akin to the Honest Broker of Policy Alternatives as discussed in part 1), rather than for the purpose of providing a general summary of existing information.

This proposed approach does ensure that marine farms with potentially significant adverse effects will be assessed thoroughly and it does not pre-empt the outcome of the reconsenting process. What it could achieve, though, is to make reconsenting for the large proportion of well-managed marine farms in environments suitable for marine farming much less complicated and challenging for all participants.
**Box 3. Structure for Assessing and Managing Ecological Effects of Marine Aquaculture**

1. Determine “baseline” information
   - Current state of the environment
   - Anticipated changes over time (because of non-aquaculture related factors)

2. Determine potential effects of aquaculture development
   - Generic for aquaculture species and culture method
   - Specific to local environment and management practices

3. Assimilative capacity of environment for specific aquaculture activity
   - Identifying acceptable levels of effects (environmental limits)
   - Trajectory to limits

4. Management of effects
   - Mitigation options
   - Adaptive management (where appropriate)
   - Conditions of consent

5. Monitoring and review
   - Evaluation of effects over time
   - Area-wide monitoring within collaborative networks
   - Adjustment of practices and methodologies
6 Implications for resource management reforms

The Government is currently proposing changes to our resource management system to make the RMA less complex, give people more certainty on RMA issues and to increase public participation and ultimately support a more productive, sustainable and inclusive economy\(^\text{19}\). This section provides some thoughts on scientific considerations for such reforms based on the findings of this report.

The underlying philosophy of the RMA is to focus on managing the effects of activities (effects-based approach) rather than regulating the activities themselves. This is seen as a more enabling approach, which aims to only intervene where activities are likely to result in unacceptable environmental impacts\(^\text{20}\). However, with the development of second-generation plans, there is an increasing focus on managing activities, and addressing the effects holistically.

As discussed extensively in this report, there are numerous challenges in identifying (and agreeing on) what environmental impacts are acceptable and whether (perceived) acceptable levels have been exceeded for specific aquaculture activities. This substantially limits the effectiveness of environmental management of aquaculture under the RMA.

While these challenges are relevant and often particularly visible for aquaculture developments, it is important to emphasise that they are not unique to this activity. Instead, they reflect the difficulties in dealing with complex environmental issues and conflicting interests and values in public coastal space.

From the science perspective, there are two important matters to consider for potential resource management reform related to activities in the coastal marine area:

1. Science will always be about assessing ecological effects of activities. This is independent of whether the resource management legislation takes an effects-based, activity-based or different approach.
2. The core scientific challenges in environmental management derive from underlying conflicts related to the allocation of public space and associated conflicting interests and values.

To provide for more effective environmental management, new or amended legislation should improve the processes for integrating the scientific assessment of effects in the values-based components of environmental management. This could be achieved by introducing a requirement to focus on allocating space for activities and specifying what ecological effects are acceptable within allocated zones. The primary focus for science would then be on a spatial area (zone) rather than on individual activities.

Legislation could require each zone to have defined environmental quality objectives that must be developed in a collaborative process involving regulators, scientists, industry and other stakeholders. Regulatory processes could be stipulated for allocating space within each zone to different activities or to preserve and exclude it from specific uses. Allocation of space for activities should include articulation of clear activity-specific environmental objectives and limits where possible. Critical to the success of such an approach would be the development of integrated, robust and consistent zone-focused monitoring frameworks to ensure environmental quality objectives are being met.

Zones would need to be sufficiently large to ensure they receive appropriate regulatory dedication and resourcing. On the other hand, the would need to be sufficiently small to provide for meaningful

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community input and allow for targeted management of local issues. It would be possible to develop criteria that could assist in identifying suitable zones.

To support the implementation of such an approach, a standard set of tools would be required to consistently deal with and report on the various activities. This would involve combining existing technology such as GIS, decision support, and mapping tools and integrating them in space allocation and monitoring processes. Even though the specific effects of activities would be different, common denominators of ecological impact assessment could be identified. For example, aquaculture might require assessment of benthic organic enrichment, while marinas might require assessment of sediment contaminants. Both assessments are based on sedimentary parameters and could be collated, analysed and presented in integrated assessments and maps. This would combine SOE and environmental consent monitoring and contribute consistent information aligned with zone objectives. This would also provide for the provision of integrated information to the public and would assist greatly with cumulative effects assessments.

Under the RMA, decision-making has been decentralised to local and regional levels. From a scientific perspective, this has contributed to national inconsistencies and lost opportunities for improving our national understanding of ecological effects and developing capabilities and tools for effectively contributing to environmental management.

Building on the effects-based approach of the RMA with a more encompassing zone approach focussed on allocating space for activities within the context of a zone, would have the benefit of strengthening our monitoring resources and could lead to developing solutions that are consistent and transferable on a national scale. It might provide incentives for pooling our national scientific capability into developing practical approaches and tools and thus allow us to become more effective in dealing with the increasing complex environmental management issues we are facing.

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21 http://www.environmentguide.org.nz/rma/
References


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