Ministry for Primary Industries
Manatū Ahu Matua

LITERATURE REVIEW OF ECOLOGICAL EFFECTS OF AQUACULTURE






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Preamble

Aquaculture planning must be supported and underpinned by science-based information on ecological effects. This information is critical in making appropriate decisions to support future aquaculture development. As the Government's principal adviser on aquaculture, the Aquaculture Unit is committed to fostering sustainable aquaculture that is within ecological limits. It is important that the effects both positive and negative of aquaculture are understood and considered, particularly as variables that are important to aquaculture such as clean water quality, are also important for a variety of other uses like recreation.

The Aquaculture Unit has recognised that there is a need to compile ecological guidance on aquaculture at a national level to assist local authorities, the aquaculture industry and other stakeholders with their planning for aquaculture. To accomplish this, the Aquaculture Unit contracted two of New Zealand's main science providers in aquaculture – the National Institute of Water and Atmospheric Research (NIWA) and the Cawthron Institute – to develop a document that brings together existing scientific and technical knowledge about the main ecological effects of aquaculture, ranging from benthic effects to its impacts on marine mammals.

This document addresses the ecological effects of aquaculture through a literature compilation that also identifies knowledge gaps and potential management options. This technical information will assist in developing a risk assessment tool to help understand the scale, likelihood and magnitude of the potential ecological effects of aquaculture activities.

Our scientific understanding of the ecological effects of aquaculture continues to grow. For this reason, this document will only be available online and will be updated on a regular basis so that it continues to reflect current thinking and research.

This document is a collaborative output from a number of authors that attempts to provide the best available information across the broad subject area. There has been some standardisation between chapters but variance in writing style, information available and, to a lesser extent, depth of analysis is to be expected between chapters.

Ministry for Primary Industries
Manatū Ahu Matua

LITERATURE REVIEW OF ECOLOGICAL EFFECTS OF AQUACULTURE

Introduction

Photo courtesy of Phil Kirk

CAWTHRON INSTITUTE

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Introduction

1

1.1 Purpose

This scientific document is intended to assist the public, regional councils, industry and science providers in understanding and assessing the current and future potential ecological effects of marine aquaculture in New Zealand.

Planning for aquaculture development in the coastal marine area needs to be supported by good quality information on ecological effects in order to enable appropriate decision making. This document aims to bring together existing knowledge on the ecological effects of aquaculture, to consider the state of current understanding and to identify uncertainties and knowledge gaps. Consolidation of this information will underpin the development of guidelines and approved methodologies to assess the ecological impacts of aquaculture in New Zealand. This information should be particularly useful for research prioritisation and for informing the consenting processes for proposed new aquaculture sites or site re-consenting.

This document is intended to be updated as required to incorporate new information or information about new aquaculture species. This document reflects the understanding of the best available information, rather than Ministry for Primary Industries (MPI) policy.

1.2 Scope

This document focuses on the ecological effects of aquaculture activities in the marine environment. The environment is defined as:

> the combined external conditions affecting the life, development and survival of an organism or an ecosystem' (Choudhury & Jansen 1999).

The definition of environment in the Resource Management Act 1991 (RMA) considers factors outside of the scope of this report, including people and communities, amenity values and social, economic and cultural conditions.[1] For the purposes of this report aquaculture activities are considered, but not limited to those described under the RMA as:

> the breeding, hatching, cultivating, rearing, or ongrowing of fish, aquatic life, or seaweed for harvest if the breeding, hatching, cultivating, rearing, or ongrowing involves the occupation of a coastal marine area and includes the taking of harvestable spat if the taking involves the occupation of a coastal marine area ...[2]

The terms "adaptive management" and "environmental impact assessment" are also defined in Appendix 1.1 for consistency of use in the following chapters.

The species to be considered are listed below in Table 1.1 and include currently commercially farmed species and species with short-term potential to be commercially farmed. Short-term potential in this context is defined as those species that could possibly be farmed commercially within the next 5 to 10 years as determined by consensus from the authors of this document. Other species were considered for inclusion in this report, including butterfish, trout, flat oyster, sponges, deep sea clams (geoducks), seahorses, paua and some other seaweed but, due to their experimental nature of their farming and/or current legislative constraints and barriers, they were not deemed by the authors to be commercially viable in the short term. In any case, it is expected that some of the ecological effects of these species will be similar to species that are considered in Table 1.1 as they would be farmed using similar method. More research may be needed to gain information on species-specific effects for those species not listed in Table 1.1. This report will be updated as required in the future to encompass new aquaculture species as they become commercially viable at a scale that justifies inclusion.

The species are grouped in the report by feeding type, as feed-added species, filter feeders and lower trophic levels species. Many ecological effects that arise from aquaculture are common to organisms that share feeding strategies (e.g. filter-feeding bivalves), some of which also share similar farming structures (e.g. all feed-added species are likely to be enclosed in nets). This is because most of the effects stem from either feeding and waste products or the physical presence of the structures themselves (Keeley et al. 2009).

[1] Part 1, section 2(1), Resource Management Act 1991 No 69 (as at 1 April 2011).

[2] Part 1, section 2(1), Resource Management Act 1991 No 69 (as at 1 April 2011).

Table 1.1: Marine aquaculture species in New Zealand with their farming status and trophic level (feeding type)

Species	Farming status	Trophic Level
Green-lipped mussels (*Perna canaliculus*)	Current	Filter feeders
Pacific oysters (*Crassostrea gigas*)	Current	Filter feeders
Chinook salmon (*Oncorhynchus tshawytscha*)	Current	Feed-added species
Yellowtail kingfish (*Seriola lalandi*)	Short-term potential	Feed-added species
Hapuku (*Polyprion oxygeneios*)	Short-term potential	Feed-added species
Sea cucumber (*Australstichopus mollis*)	Short-term potential	Lower trophic levels
Undaria seaweed (*Undaria pinnatifida*)	Short-term potential	Lower trophic levels

Table 1.2: Standardised inputs to the scale row of the summary tables

Spatial	Temporal
Local scale (< 100 metres from farm structures)	Short term (abates within < 1 year)
Bay-wide (100 metres – 1 km from farm structures)	Medium term (continues for 1 to 5 years)
Regional (> 1 km from structures)	Long term (continues for > 5 years and may be permanent)
National	
International	

1.3 Structure

This report addresses ecological effects (known and potential) relating to aquaculture in the marine environment. It is structured so as to consider key issues a chapter-by-chapter basis. These chapters include the following:

- Pelagic effects – Effects of aquaculture on the water column (excluding those explicitly dealt with by other chapters) at approximately the scale of the farm.
- Benthic effects – Effects of aquaculture on the seafloor.
- Marine mammal interactions – Effects of aquaculture on marine mammals.
- Wild fish interactions – Effects of aquaculture on non-farmed marine populations.
- Effects on seabirds – Effects of aquaculture on birds.
- Biosecurity – How aquaculture may influence risks associated with pests and diseases.
- Escapee effects – The effects of escaped farmed species upon the environment.
- Effects from genetic modification and polyploidy in farmed species – Potential effects of genetic modification[3] and polyploidy[4] on the environment.
- Effects from additives – The effect of chemicals used in aquaculture upon the environment.
- Hydrodynamic alteration of flows – Effects of aquaculture on the water column (excluding those explicitly dealt with by other chapters) at scales greater than the farm scale.
- Cumulative effects – The cumulative effects of aquaculture at scales greater than the farm.

Within each chapter the effects on each of the key species groupings (feed-added, filter feeders and lower trophic levels) are discussed. For ease of use, the more detailed reviews contained within each chapter are prefaced by a summary table outlining the key effect by species grouping or species. The level of effect within these tables is summarised in terms of spatial and temporal extent according to the definitions provided in Table 1.2. Knowledge gaps and management options to address these ecological effects are also summarised.

[3]Genetic modification refers to the process of organisms having foreign DNA artificially inserted into their own genomes.

[4]Ployploidy here refers to individuals with induced extra sets of chromosomes through the manipulation of embryos.

1.4 Background

1.4.1 The global context

In 2010, the Food and Agriculture Organization (FAO) produced a State of the World Fisheries and Aquaculture Report, which provides a comprehensive overview of both these sectors. Aquaculture is the world's fastest growing primary industry and currently supplies almost half of the supply of seafood globally, with marine aquaculture responsible for approximately 17 percent of seafood consumed globally (FAO 2010). Fish convert a greater proportion of the food they eat into body mass than livestock and therefore the environmental demands per unit biomass or protein produced are lower (Hall et al. 2011). The production of 1 kilogram of finfish protein requires less than 14 kilograms of grain compared to 62 kilograms of grain for beef protein and 38 kilograms for pork protein. However, although farmed fish may convert food more efficiently than livestock the farming of carnivorous fish species can place heavy demands on the use of capture fisheries for animal feeds.

The international drive for sustainable development of aquaculture is being addressed through significant investment in research that seeks to refine aquaculture technologies and better understand the interactions between aquaculture and the environment. Technical innovation within the industry aims not only to improve production efficiency but also to lower environmental impacts in response to consumer demand and tighter regulatory control. Governments have strengthened their capability to monitor and manage the environmental effects of aquaculture. They have made conscious efforts to address these in a transparent manner, backed by scientific evidence. However, the FAO cautions that one of the main difficulties has been not to overreact at the expense of aquaculture producers, particularly small-scale farmers, for example, by framing legislation that would be costly, time consuming and difficult to implement.

The balance between production and environmental protection is difficult, but there are ways to bring clarity to this decision-making process, such as summarising known aquaculture effects and creating of environmental standards for aquaculture activities based on scientific evidence.

1.4.2 New Zealand's aquaculture within the global context

Global aquaculture is concentrated in the world's tropical and subtropical regions. Significant aquaculture activities occur in Asia's inland freshwaters and the delta areas of major rivers (FAO 2010). However, New Zealand's environment is quite different from the majority of global aquaculture, so we must look to temperate countries with analogous farming conditions, species farmed, legislative environment and level of economic development for reference points for our aquaculture. A selection of environmental standards that are potentially applicable to the New Zealand industry is listed in Appendix 1.2.

Environmental Quality Standards (EQS) are defined by the FAO "as standards set in relation to specific planning objectives and targets and relating to specific natural resource systems"[5]. The key considerations when analysing these standards are their development, structure, goals, whether the standards are qualitative or quantitative and their stage of development. Standards can be grouped by the type of organisation responsible for their formation; government, farming associations or private organisations, such as environmental non-governmental organisations (ENGOs).

It is known that the environmental effects of aquaculture vary by country, region, production system and species (Hall et al. 2011). As a result, a general overview of the international standards (Appendix 1.2) highlights a lack of consistency among EQS, which makes comparisons difficult. Emphasis is placed on different areas in different countries as factors such as public pressure or disease prevalence dictate. All standards focus on ensuring environmental sustainability, however, there are marked differences in the progress towards this objective. For example, Norway's goals form a good basis for future development of quantitative standards while Scotland's wide-ranging review of effects provides a valuable resource for decision makers but will not result in clear standards. New Zealand can look to these and the relevant standards produced by the Aquaculture Stewardship Council (ASC), but must aim to produce environmental objectives that reflect the marine farming environment in New Zealand.

In 2008 New Zealand produced approximately 0.2 percent of the worlds aquaculture production (112 358t); globally over 52 million tonnes were produced (Hall et al. 2011). The value of New Zealand's aquaculture production is dominated by green-lipped mussels ($239 million), salmon ($68 million) and Pacific oysters ($28 million) (Aquaculture New Zealand 2012[6]). In New Zealand, the majority of aquaculture activities

[5]http://www.fao.org/fi/glossary/aquaculture/spec-term-n.asp?id_glo=16152&id_lang=TERMS_E&lang=en

[6]These values may include some wild fisheries captures, but are expected to be mainly from aquaculture.

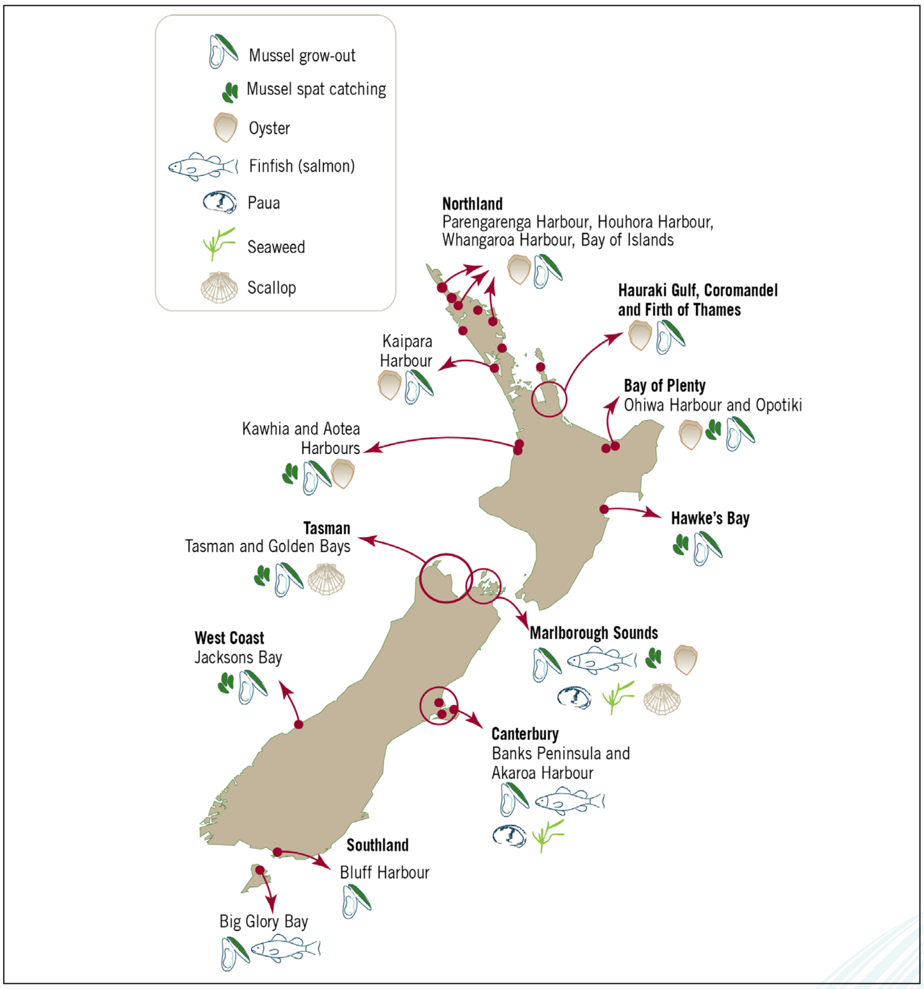
are located in the coastal marine environment, and the main aquaculture locations are shown in Figure 1.1. This places aquaculture within the downstream footprint of multiple land uses and in close proximity to other marine activities. Therefore, the ecological effects of aquaculture should be considered within the context of cumulative effects from multiple stressor sources (agricultural land use, climate change, fishing, urban development and so on) and incorporated into consideration of impacts at bay-wide or regional scales (Forrest et al. 2007b).

1.4.3 Feed-added species

Species to be considered in this section are farmed with the addition of feed. Feed-added aquaculture in New Zealand is based primarily around sea-cage farming of Chinook salmon and is currently small in comparison with the international market (Forrest et al. 2007b). For example, in 2009, Norway produced 862 000 tonnes of Atlantic salmon while New Zealand produced 12 000 tonnes of Chinook salmon. This industry is mainly based in the Marlborough Sounds, Canterbury and Southland (Figure 1.1).

Ongoing regulatory monitoring of salmon farms in New Zealand for at least the past 10 years has led to the conclusion that benthic effects are highly localised and can be reduced with mitigation methods (Forrest et al. 2007b). In the drive to boost the aquaculture industry (see the New Zealand Aquaculture Strategy and Action Plan) MPI has engaged in studies into the potential of growing the finfish farming sector in New Zealand. These studies focused on predictive modelling of the local and regional impacts of fish waste on the environment using different finfish stocking scenarios (Zeldis et al. 2010, 2011a, 2011b). However, research on the wider ecological effects of feed added aquaculture in New Zealand, in relation to such things as seabird interactions, emerging diseases and habitat creation by farms is, at present, limited. Therefore, research gaps need to be prioritised so that research can be funded in a logical order when funding becomes available.

Figure 1.1: Geographic locations of main marine farming activities in New Zealand



Note: not all species shown here are considered in this document.

Source: Keeley et al. 2009.

1.4.4 Filter-feeding species

The current intensity of aquaculture of marine filter feeders (mussels and oysters) in New Zealand is still considered low to moderate by international standards (Keeley et al. 2009). In the 12 months to March 2010, the industry produced 90 588 tonnes of mussels and 2820 tonnes of oysters (Barratt 2010). Global aquaculture production of molluscs in 2008 was 13.1 million tonnes so even if this had not increased by 2010 (which it is likely to have) then New Zealand production would only have been 0.7 percent of the global mollusc aquaculture production (FAO 2010). Mussel culture is broadly distributed around New Zealand but oyster culture is limited to the north of the North Island and the Marlborough Sounds (Figure 1.1).

Mussels are suspended on rope droppers usually at water depths of greater than 20 metres, whereas, typically, oysters are laid out on sticks, in mesh bags or trays across racks (0.3–1 metres high) that are fixed in the intertidal zone in estuaries and exposed during low tide (Forrest et al. 2007a).

There is a large body of international literature that indicates that the main environmental impact from farming filter-feeding species is increased sedimentation through biodeposition. This is also the case in New Zealand where the severity of effects on the seabed from farming filter feeders has been assessed as low to moderate compared to other sites internationally (Keeley et al. 2009).

1.4.5 New Zealand's ecological status in the coastal zone

New Zealand was ranked the best in an international review of marine living resource management (Alder et al. 2010). This review used 14 indicators in three categories related to biodiversity, value and jobs. Whilst it ranks New Zealand very favourably, more specific information is needed to assess our status relating to ecological impacts in the coastal zone, where aquaculture impacts are mainly to be expected.

A review of land-based effects on coastal fisheries and biodiversity concluded that sedimentation is arguably New Zealand's most widespread and damaging pollutant (Morrison et al. 2009). Annual sediment discharge into the oceans of 1856 ± 261 tonnes km^{-2} $year^{-1}$ for the South Island and 916 ± 82 tonnes km^{-2} $year^{-1}$ for the North Island have been calculated (Griffiths & Glasby 1985). This makes the average erosion rate of the South Island amongst the highest known in the world. This is largely because New Zealand is geologically young, has high rates of tectonic uplift and rainfall and has had much land-use change from forested catchments. This review also highlighted eutrophication as an internationally important threat to marine coastal zones, although the potential effects of this may be modest in New Zealand relative to the rest of the world. Two contrasting situations with relevance to aquaculture were discussed: Tasman and Golden Bays, where nutrient inputs come predominantly from the ocean (Zeldis 2008) and the Firth of Thames where nutrients are mainly sourced from rivers (Broekhuizen & Zeldis 2006). Other pollutants associated with urbanisation (such as heavy metals) were stated as being generally more localised and at relatively low, although sometimes still ecologically influential, concentrations in New Zealand compared to other industrialised countries. This last conclusion is reinforced by more specific ecotoxicity studies (Hickey 1995, Kelly 2007).

1.4.6 Threat assessment

A 2009 survey of experts assessed the relative importance of 62 threats on 65 New Zealand marine habitats (MacDiarmid et al. 2012). Threat scores were categorised as extreme if the score was 3 or more, major if the score was 2–2.9, moderate if the score was 1–1.9, minor if the score was 0.5–1.0, and trivial if the score was less than 0.5. The top three threats identified were ocean acidification, increased sea temperatures from climate change and bottom trawling which scored as a mean impacts across all habitats of 2.6 (major), 1.6 (moderate) and 1.5 (moderate) respectively. Three threats posed by aquaculture activities were considered; benthic accumulation of debris (shells, faeces, food material), a decrease in the availability of primary production downstream of the marine farm (particularly mussel farms) and an increase in habitat complexity that may be detrimental to some species. The benthic accumulation of shells, food and faeces from aquaculture ranked 19th equal with a score of 0.7 (minor). The two other impacts of aquaculture were ranked 36th equal with a score of only 0.4 (trivial).

The actual and potential effects of mussel, feed added and elevated intertidal oyster culture are shown diagrammatically in Figures 1.2 to 1.4..

Figure 1.2. Schematic of actual and potential ecological effects from Mussel farming (Keeley et al. 2009).

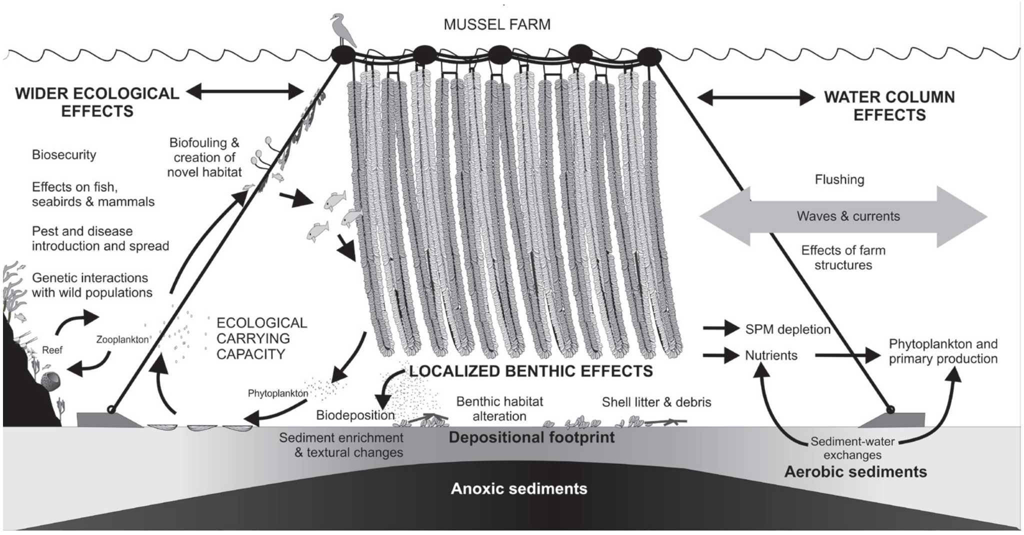


Figure 1.3. Schematic of actual and potential ecological effects from feed-added farming (Forrest et al. 2007).

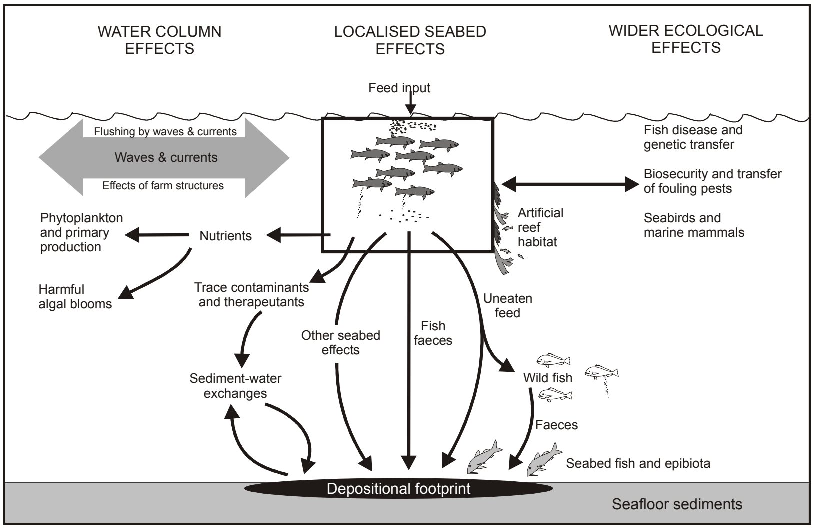
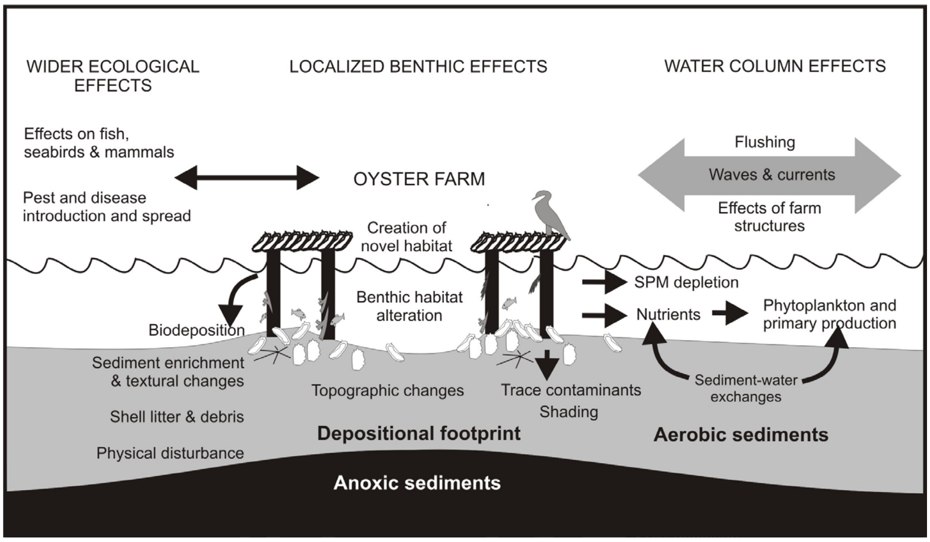


Figure 1.4. Schematic of actual and potential ecological effects from elevated intertidal oyster cultivation. (Forrest et al. 2009).



An expert panel (aided by a draft of most of this review) was used to, amongst other things, trial a method for prioritising the ecological threats from aquaculture as subdivided in this document (Stoklosa et al. 2012). This process brought together 17 knowledgeable participants from across the range of interested parties (central and local government, aquaculture industry and scientists), to attempt to gain consensus on the relative importance of a range of ecological threats from aquaculture. The results of this process are preliminary but for both feed-added and filter-feeding species the same three issues were identified as most important, these were (in decreasing order of importance): biosecurity threats, pelagic effects and marine mammal interactions (Table 1.3).

Table 1.3: Trial prioritisation of potential after effects decreasing in importance for the feed-added species.

	Feed-added species		Filter-feeder species	
Potential ecological effects	**RIW**	**Rank**	**RIW**	**Rank**
Biosecurity	0.360	1	0.373	1
Pelagic effects	0.236	2	0.143	2
Marine mammal interactions	0.118	3	0.135	3
Benthic effects	0.090	4	0.088	5
Seabird interactions	0.079	5	0.092	4
Additive effects	0.042	6	0.019	9
Escapee effects	0.029	7	0.088	5
Wild fish interactions	0.026	8	0.021	8
Hydrodynamic alteration of flows	0.019	9	0.041	7

Note: Results of pair-wise comparisons using the Analytical Hierarchy Process (Saaty 1987) from the phase two workshop of the Aquaculture Ecological Guidance Project. RIW is relative importance weight. Order is decreasing in importance for the feed-added species.

1.4.7 Lower trophic level species

Lower trophic level species are not currently commercially farmed in New Zealand but are being considered both in their own right (for sea cucumbers) but also for use in Integrated Multi-Trophic Aquaculture (IMTA) for seaweeds. IMTA is the co-culture of species from different trophic levels, each filling a niche to extract the dissolved inorganic nutrients and suspended particulates emanating from the feed-in culture of finfish (Zeldis et al. 2010). Both sea cucumbers and *Undaria* have had research conducted on their life cycle in New Zealand and an international market exists that has stimulated interest in commercially farming these species. There is a wild fishery for sea cucumber, and sea ranching of this species is currently being reviewed by MPI. *Undaria* is an introduced species and recent changes to its biosecurity classification allow its culture in certain areas that are considered to be heavily infested already. Due to the ability of sea cucumbers to assimilate detritus and *Undaria* to absorb nutrients, both species, when used as part of IMTA, have the potential to mitigate the effects of other aquaculture activities.

1.4.8 Existing New Zealand industry codes of practice

In 2007, Aquaculture New Zealand produced the Codes of Practice (CoP)[7] for mussels and oysters, and the New Zealand Salmon Farmers Association Inc produced the salmon CoP. All of these codes contain practical guidance to establish systems that both ensure farm productivity and minimise environmental impacts. For example, the mussel CoP sets procedures for the storage, transfer and use of hazardous substances. A wide definition of environment (as discussed earlier in the introduction) is implied in the CoPs and thus effects other than ecological impacts are considered. For example, all three codes set the requirement for the use of navigational lights on boats and farms for public safety. While the CoPs form a valuable practical resource for farmers, they would not be directly useful for the creation of ecological standards due to their operational nature. However, they offer valuable insight into current farming approaches.

A review of the ecological effects of marine finfish aquaculture suggested that consideration should be given to the development of a more comprehensive environmental CoP for the industry as a whole (Forrest et al. 2007b).

1.4.9 Future management Strategies

The management of the ecological effects of aquaculture in the future is discussed by Forrest et al. (2007b). Recommendations from this report have been applied to situations where multiple farms in close proximity to each other have been proposed, for example, in Waikato and Tasman/Golden Bay. At the scales of development proposed (up to 300 hectares in the Waikato), it was recommended that development proceed in a staged manner, especially when cumulative effects are recognised

[7]New Zealand aquaculture industry CoP are the property of Aquaculture New Zealand

but not well understood, within an adaptive management and monitoring framework. For example, an approach involving Limits of Acceptable Change has been implemented since 2001 to manage the environmental performance of the Firth of Thames Aquaculture Management Area by Waikato Regional Council (Turner & Felsing 2005; Zeldis et al. 2010).

The potential use of IMTA has also been suggested as a possible mitigation strategy in these areas (Zeldis et al. 2010). For example, in Canada, IMTA systems typically combine finfish, mussels and seaweeds with caged deposit feeders (e.g. sea cucumbers, scallops, sea urchins) on the seabed or suspended under the finfish farm (Chopin et al. 2008).

1.4.10 Legislation

Aquaculture planning and consenting processes are managed by regional councils and unitary authorities under the RMA. MPI is responsible under the Fisheries Act 1996 for making aquaculture decisions on the undue adverse effects on fishing as a result of aquaculture activities.

The changes to the aquaculture planning and consenting processes introduced by the 2011 aquaculture reforms aim to reduce regulatory costs, delays and uncertainty, encourage investment in aquaculture and integrate decision making.

The RMA is the key piece of legislation responsible for the sustainable management of resources in New Zealand. Sustainable management requires avoiding, remedying or mitigating any adverse effects of aquaculture activities on the environment.

Other key legislation that governs marine aquaculture includes the following:

- Biosecurity Act 1993 – Provides a legal basis for excluding, eradicating and effectively managing pests and other unwanted organisms, including those causing diseases in aquaculture.
- Hazardous Substances and New Organisms Act 1996 – Created by the ERMA, the Environmental Risk Management Authority (subsequently restructured into the EPA, the Environmental Protection Authority) which decides on applications to introduce hazardous substances or new organisms into New Zealand. The applications may include genetic modification of plants, animals and other living things within New Zealand.
- Marine Mammals Protection Act 1978 – Dictates interactions between aquaculture farmers and marine mammals.
- Maritime Transport Act 1994 – Protects the maritime environment within New Zealand and maintains safety and security through safe boating and navigation lighting on boats and farms.
- Animal Products (Regulated Control Scheme – Bivalve Molluscan Shellfish (BMS)) Regulations 2006 – The prime purpose of the scheme is to identify, monitor, evaluate and manage the risks associated with the commercial growing, harvesting, sorting and transporting of BMS intended for human consumption. Management measures stemming from water and shellfish flesh testing to verify levels of microbiological and chemical contaminants include closure after rainfall, to deal with microbiological contamination from runoff.
- Animal Welfare Act 1999 – Must be complied with when rearing all animals including fish.

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Appendix 1.1: Definitions

Adaptive management – Adaptive management was defined in New Zealand in the Environment Court in the case of *Crest Energy Kaipara Limited v Northland Regional Council* (Decision A. 130/09).[10] The five features are:

- that stages of development are set out;
- the existing environment is established by robust baseline monitoring;
- there are clear and strong monitoring, reporting and checking mechanisms so that steps can be taken before significant adverse effects eventuate;
- these mechanisms must be supported by enforceable resource consent conditions that require certain criteria to be met before the next stage can proceed; and
- there is a real ability to remove all or some of the development that has occurred at the time if the monitoring results warrant it.

Monitoring – Systematic recording and periodic analysis of information over time.[11]

Environmental impact assessment (EIA) – A set of activities designed to identify and predict the impacts of a proposed action on the biogeophysical environment, and to interpret and communicate information about the impacts, including mitigation measures that are likely to eliminate the risks.[12]

[10]Crest Energy Kaipara Limited, Environs Holdings Limited, A & C Mcgillivray & Director General of Conservation V Northland Regional Council & Crest Energy Kaipara Limited. Court reference: [2011] NZEnvC 26.

[11]http://www.fao.org/fi/glossary/aquaculture/spec-term-n.asp?id_gio=17013&id_lang=TERMS_E&lang=en

[12]http://www.fao.org/fi/glossary/aquaculture/spec-term-n.asp?id_gio=16151&id_lang=TERMS_E&lang=en

Appendix 1.2: International standards and further discussion

The table below lists coverage of an effect for a species grouping but the depth of coverage and its applicability to New Zealand will differ between standards. The list below may not be comprehensive and should be added to over time where necessary. The letters indicate species group effects covered: A = feed added, F = filter feeders, and L = lower trophic level species.

	Type of effect							
International standards	Hydrodynamic	Pelagic	Biosecurity	Benthic/ecosystem	Marine mammal, fish and seabird	Additions	Escapee	Growth hormones or genetic modifications
Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry.		A	A	A		A	A	
Environmental Regulation for Aquaculture. Republic of Chile.		A	A	A	A		A	
ASC Salmon Dialogue 2nd Draft Standards for Responsible Salmon Aquaculture.		A	A	A	A	A	A	A
ASC *Bivalve Aquaculture Dialogue Standards.*		F	F	F	F	F		F
Guidelines for the Promotion of Environmental Management of Coastal Aquaculture Development, Section 6. FAO Fisheries Technical paper 328.		AFL	AFL	AFL		AFL		
Aquaculture Development 4: Ecosystem approach to aquaculture. FAO Technical Guidelines for Responsible Fisheries.		AFL	AFL	AFL	AFL	AFL	AFL	
Guide for the Sustainable Development of Mediterranean Aquaculture.	AFL	AFL	AFL	AFL	AFL	AFL	A	AFL
A Code of Conduct for Responsible Aquaculture Development in the U.S. Exclusive Economic Zone.	AFL	AFL	AFL	AFL	AFL		A	AFL
Review and Synthesis of the Environmental Impacts of Aquaculture. Scottish Association for Marine Science and Napier University.		AFL	AFL	AFL	AFL	AFL	A	
Australian Aquaculture Code of Conduct.		AFL	AFL	AFL	AFL	AFL		
BCSFA Code of Practice. BC Salmon Farmers Association.		A	A	A	A	A	A	
Environmental Management System Code of Practice. British Columbia Shellfish Growers Association.			F		F	F		

Discussion of international standards

To date, no government has legislated aquaculture environmental standards; these are rather implemented by regulations developed by regional or local authorities. Many countries are developing documents relating to the establishment of ecological best practice for aquaculture. These vary in extent from codes such as the Norwegian Government Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry (2009), which sets goals based on their five main areas of concern and the National Marine Fisheries Service (NMFS) Code of Conduct for Responsible Aquaculture Development in the US Exclusive Economic Zone (2002), which focuses on seven objectives. In contrast, in 2001, the Republic of Chile established Environmental Rules and Regulations for Aquaculture (RAMA), which established specific requirements for the environmentally sustainable development of aquaculture projects, allowing for the prevention, mitigation and remedy of associated impacts. In the United Kingdom, the Scottish Association for Marine Science published the Review and Synthesis of the Environmental Impacts of Aquaculture (2002). This document highlights the known environmental effects of aquaculture, but was not intended for the creation of standards.

In some countries, such as Canada, Ireland, Australia and New Zealand, industry organisations have produced their own code of practice in place of clear public environmental standards. These usually consist of mandatory practices with the aim of maintaining and protecting environmental quality while improving production efficiencies. Each issue is often broken down into background, environmental objectives, legislation and recommended practices. These documents do not usually include quantitative standards to meet but do reflect areas of environmental concern, with instructions to farmers of practices to avoid detrimental effects in these areas.

In addition to government and industry-led standards that seek to directly protect local environments, consumer pressure for reassurance that cultured foods meet high food safety, environmental and social standards has led to a recent proliferation of private standards or certification schemes for aquaculture (Washington & Ababouch 2011). ENGO's, such as the World Wildlife Fund for Nature, have conducted reviews of standards and certification schemes used in aquaculture, which highlighted areas for improvement (WWF 2007). In New Zealand, the Aquaculture Stewardship Council has currently completed 8 standards for 12 species including standards for bivalves and salmon.

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